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Predicting the Home Location of Serial Offenders: A Preliminary Comparison of the Accuracy of Human Judges with a Geographic Profiling System

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The accuracy with which human judges, before and after 'training', could predict the likely home location of serial offenders was compared with predictions produced by a geographic profiling system known as Dragnet. All predictions were derived from ten spatial displays, one for each of ten different U.S. serial murderers, indicating five crime locations. In all conditions participants were asked to place an 'X' on each spatial display corresponding to where they thought the offender lived. In the control condition, a comparison was made between the accuracy of these predictions for 21 participants on two separate occasions a few minutes apart. In the experimental condition, between their first and second predictions the 21 participants were given two heuristics to follow—distance-decay and circle hypothesis. Results showed that participants with no previous knowledge of geographic profiling were able to use the two heuristics to improve the accuracy of their predictions. The overall accuracy of the second set of predictions for the experimental group was also not significantly different from the accuracy of predictions generated by Dragnet. Copyright © 2002 John Wiley & Sons, Ltd.

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INTRODUCTION

In recent years, a variety of algorithms have been used to predict the home location of unknown serial offenders on the basis of crime locations that have been linked to one offender (Canter & Larkin, 1993; Rossmo, 1993). These have evolved from spatial typologies such as the marauder/commuter distinction (Canter & Gregory, 1994) to software packages that can provide direct support to investigations, often known as *geographic profiling systems* (Canter, Coffey, Huntley, & Missen, 2000; Levine & Associates, 2000; Rossmo, 1993, 2000). Until very recently, however, the predictive accuracy of these geographic profiling systems had not been compared to other predictive methods.

Levine and Associates (2000) compared a variety of predictive methods, such as those used in geographic profiling systems, to identify those methods that were most accurate. In a task that involved using crime site locations to predict the home location of 50 serial offenders they compared the accuracy of spatial distribution methods (e.g., spatial, geometric, and harmonic means) with the accuracy of journey-to-crime methods (e.g., mathematical and kernel density functions). The distance (in miles) between the predicted home base and the actual home location produced similar results for each method. So, although no statistical tests were reported, Levine and his associates concluded that all methods were of equal utility. As a consequence, they suggested that crime analysts should continue to look at the distribution of crime locations and make predictions about where the offender may be residing without needing the support of software packages or other computer based geographic profiling systems.

If the various procedures tested by Levine and his associates give similar results this raises the possibility that the essential principles of geographic profiling are relatively straightforward and could therefore be utilized by crime analysts with minimal training without the need for a geographic profiling system. In other words, it is hypothesized that if individuals are informed of some clear principles that may underlie offender spatial behavior they will make predictions that are as accurate as those produced by geographic profiling systems.

This is an important hypothesis to test because, if supported, it would question Rossmo's (2000) suggestion that in order for individuals to be qualified to use a geographic profiling system to make geographic predictions they should have three years experience investigating interpersonal crimes and a superior level of investigative skill. Support of the hypothesis would also question the need for police forces with limited resources and technological capabilities to invest in geographic profiling systems.

Therefore, as a preliminary examination of these issues, the current study tested the extent to which human judges could accurately predict the home location of serial offenders before and after training. This study also compared the accuracy of these predictions to those produced using a geographic profiling system.

Study Design

Defining Predictive Accuracy

At the most basic level, a geographic profile is a prediction of the most likely location at which the search for a serial offender's home should commence. A geographic profile may also include consideration of temporal and behavioral information, and a search strategy beyond the most likely home location. For the current study, however, the consideration of accuracy was limited to the prediction of the most likely home location. This accuracy was measured from the distance between the predicted and actual home location on the spatial displays used (henceforth referred to as *error distance*, measured in millimeters).

Two Heuristics for Predicting Home Locations

Part one of the study investigated the extent to which participants could improve in their predictive accuracy if provided with two heuristics frequently mentioned in the geographic profiling literature: 'distance-decay' and 'the circle hypothesis.'

The first heuristic emanated from the consistent finding that offenders do not travel far from home to offend and that the frequency of offending decreases with increased distance from an offender's home location; a concept known as 'distance-decay' (Capone & Nichols, 1976; Turner, 1969). The second heuristic originated from tests of the 'circle hypothesis' first proposed by Canter and Larkin (1993). They found that the majority of serial rapists did not typically commit crimes outside a circle with its diameter defined by the distance between the offender's two furthermost offences. Subsequent research by Kocsis and Irwin (1997) and Tamura and Suzuki (1997), using different types of crime, has also found support for this hypothesis.

A significant reduction in error distance after being provided with the two heuristics would indicate that participants are able to use the heuristics to improve and structure their geographic predictions.

Predicting Home Locations Using Dragnet

The second part of the study examined the possibility that participants told about these heuristics could make predictions that are as accurate as those produced by a geographic profiling system. The geographic profiling system used in the current study was Dragnet, described in detail by Canter *et al.* (2000). In essence, it uses a distance-decay function selected by the user from the negative exponential family. The function identified as optimal by Canter and his associates for a sample of U.S. serial murderers was used in the current study. This function is converted into probabilities around each crime location, indicating the likelihood that any location around an offence contains the home/base of the offender. These probabilities are then combined at each point in the total search area. In the current study, the point on each map where the average probability was highest is taken as the predicted home and was used to measure error distance.

If error distances when using Dragnet were found to be significantly smaller than error distances for the trained human judges this would suggest that the participants were unable to make predictions that were as accurate as Dragnet, even when using appropriate heuristics.

METHOD

Participants

Participants in the control group consisted of 21 students (four undergraduates, 17 postgraduates), without any knowledge of geographic profiling, studying a variety of disciplines at the University of Liverpool. The 21 students included ten males and 11 females from a variety of nationalities. The age of the students ranged from 19 years to 40 years with an average age of 25.90 years (SD = 5.23).

The experimental group consisted of 21 students (eight undergraduate, 13 postgraduate), without any knowledge of geographic profiling, studying a variety of disciplines. The 21 students included 13 males and eight females from a variety of nationalities. The age of the students ranged from 21 years to 61 years with an average age of 27.67 years (SD = 8.75).

Procedure

In phase 1 of the experiment each of the 21 participants in the control and experimental groups were given ten different spatial displays. Each display represented the locations of five offences for an American serial murderer as points on an otherwise blank sheet of paper. These points were drawn from actual maps but were all adjusted to fit comfortably onto a sheet of A4 paper (21 × 29.7 cm). These spatial displays were used because current geographic profiling systems do not take account of land use or other topographical features. The heuristics and algorithms built into these systems are purely geometric. Participants in both groups were asked to indicate, by marking an 'X' somewhere on each display, where they thought the home of each of the serial murderers was likely to be found. Participants were also given the opportunity to indicate the heuristics they used to reach their conclusions.

Control Group

After the spatial displays given out in phase 1 were collected, participants in the control group were again given the same displays as those used in phase 1. They were asked to indicate a second time where they thought the home location of each of the serial murderers was likely to be located and how they came to their conclusions. They were not given any feedback between the two phases, which were just a few minutes apart.

Experimental Group

For the experimental group, phase 1 was identical to the control group, but after phase 1 they were told

(1) the majority of offenders commit offences close to home and
(2) the majority of offenders' homes can be located within a circle with its diameter defined by the distance between the offenders two furthermost crimes.

Participants were therefore being provided with the essential information that is utilized by geographic profiling systems. They were then given the same displays again and were asked to indicate where they thought the home of each of the ten serial murderers was likely to be located. They were also asked to indicate the heuristics used to make their predictions.

Dragnet Calculations

Dragnet produces a series of probabilities for each location on the display. By searching through these probabilities the highest value was identified and this was taken as the computer prediction of the home location. A display was then produced the same size as that given to participants and the distance on this display between the computer predicted home location and the actual home location was calculated in millimeters. This distance was taken as Dragnet's error distance for comparison with participants' predictions across the two phases.

RESULTS

Control Group

The mean error distance across all ten displays for the control group in phase 1 was 35.30 mm (SD = 22.66) and that in phase 2 was 34.22 mm (SD = 21.65; two spatial displays in phase 2 were not filled out). Figure 1 illustrates the minimal change in the mean error distance across the two phases for the control group. A related-samples

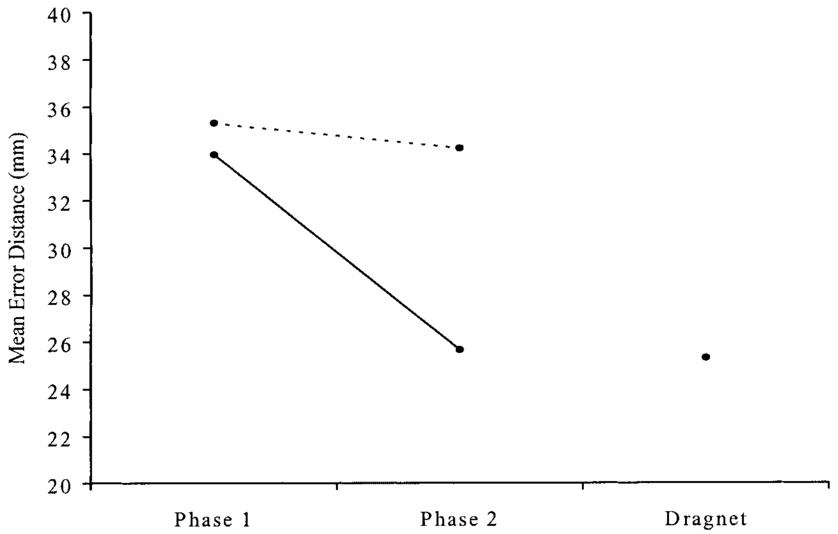

Figure 1. Mean error distances for the control group (Dotted Line) and experimental group (Solid Line) across the two phases and Dragnet.

t-test confirmed that no significant difference existed between the two phases ($t_{207} = 1.63$, n.s.).

Experimental Group

The mean error distances before and after the participants were given the heuristics are also shown in Figure 1. The mean error distance in phase 1 was 33.94 mm (SD = 23.45), and it was 25.65 mm (SD = 15.17) after the participants were informed about the heuristics. A related-samples t-test established that these error distances were significantly different ($t_{209} = 5.45$, $p < 0.05$). That is, participants made more accurate predictions when they were provided with the two heuristics.

Control Group, Experimental Group, and Dragnet

The mean error distances for the control group, experimental group, and the average Dragnet value are also shown in Figure 1. The figure illustrates the existence of similar baseline results in phase 1 for both the control and experimental groups. An independent t-test did not reveal any significant difference in the mean error distance between the control group and the experimental group in phase 1 of the experiment ($t_{418} = -0.61$, n.s.). The difference in the mean error distance between the control group and the experimental group in phase 2 of the experiment was significant ($t_{416} = -4.70$, $p < 0.05$). This difference can be explained by the fact that participants in phase 2 of the experimental group were provided with and used the two heuristics.

The average distance from the point of highest probability, as indicated by Dragnet, to the actual home was 25.30 mm (SD = 14.83). A one-sample t-test revealed that the error distances for the participants in phase 1 of the control group were significantly larger than those produced by Dragnet ($t_{20} = 3.14$, $p < 0.01$), as were the error distances for participants in phase 2 of the control group ($t_{20} = 2.94$, $p < 0.01$). That is, Dragnet was more accurate than the participants in both phases of the control group.

A one-sample t-test revealed that the error distances for the participants in phase 1 of the experimental group were also significantly larger than those produced by Dragnet ($t_{20} = 2.31$, $p < 0.05$). However, a one-sample t-test revealed that the error distances for the participants in phase 2 of the experimental group were not significantly different from those produced by Dragnet ($t_{20} = 0.40$, n.s.). Thus, participants who received a small amount of training on some basic geographic profiling principles were, on average, as accurate as Dragnet.

Offender Spatial Behavior and the Predictions

While there was a general trend for some of the participants provided with heuristics to improve in their predictions, and to make predictions as accurate as Dragnet, there were a number of spatial displays where reductions in error distance were not found, even after participants were provided with the heuristics. Table 1 contains

Table 1. Mean error distances and standard deviations for each spatial display for the control group and experimental group across the two phases and Dragnet

Spatial display	Control group		Experimental group		Dragnet
	Phase 1 ($n=21$)	Phase 2 ($n=21$)	Phase 1 ($n=21$)	Phase 2 ($n=21$)	
1	23.86 (20.17)*	26.10 (25.86)	21.30 (20.88)	15.76 (8.87)	19.00
2	37.33 (21.72)	35.07 (21.07)	35.76 (20.75)	26.00 (7.27)**	21.00
3	43.24 (17.99)	41.38 (17.55)	39.38 (17.89)	39.67 (13.52)	51.00
4	23.62 (17.00)	22.81 (16.19)	25.38 (20.38)	13.85 (7.07)**	20.00
5	37.57 (28.50)	35.05 (26.54)	33.48 (27.67)	19.24 (11.60)**	14.00
6	27.52 (22.12)	25.67 (15.70)	28.29 (19.75)	20.43 (6.11)	23.00
7	29.67 (25.88)	27.57 (25.89)	30.43 (32.64)	13.24 (14.88)**	2.000
8	32.05 (25.56)	33.00 (24.23)	33.43 (25.30)	19.95 (8.39)**	17.00
9	46.05 (12.75)	42.67 (9.23)	41.05 (17.15)	42.67 (8.77)	49.00
10	52.10 (14.31)	52.10 (12.32)	50.86 (17.61)	45.62 (7.31)	37.00
Mean	35.30	34.22	33.94	25.65	25.30

*Numbers in brackets are standard deviations.
**Denotes a significant difference ($p < 0.05$) between the error distance in phase 1 and phase 2 for that group in relation to that spatial display.

the mean error distances for the control group and experimental group in relation to the ten serial murderers across the two phases of the experiment. Results in the table reveal that there are no significant reductions in error distance between phase 1 and phase 2 for the control group. In the experimental group, however, significant reductions in error distance are found between phase 1 and phase 2 for half of the serial offenders.

Inspection of the spatial displays indicated that in each case where there was no error reduction in the experimental group this was because the offenders were commuters (i.e., these offenders lived some distance away from their crime sites). In the case of these offenders it is difficult to accurately identify the likely location of their homes (Canter *et al.*, 2000; Rossmo, 2000).

To examine this issue further, Spearman's rank-order correlations were calculated between the mean error distances for every condition in Table 1. The only correlation that reached significance was between the phase 2 experimental group error distances and the error distances resulting from Dragnet ($r_s = 0.83$, $p < 0.01$). This indicates that when the heuristics provided to participants were less appropriate (i.e., less accurate) for a particular offender the Dragnet results were also less accurate.

Enhancing Agreement Amongst Participants

An examination of the standard deviations for the predictions made in each phase indicates the extent to which participants agreed upon the most likely home location of each serial murderer. Table 2 contains the mean standard deviations for the control and experimental groups in the two phases. A paired samples *t*-test revealed that there was no significant difference in the standard deviations between phase 1 and phase 2 for the control group ($t_9 = 1.18$, n.s.). This suggests that the participants, across the two phases, generally disagreed about the area likely to contain the home of each offender. For the experimental group, however, a statistically

Table 2. Mean standard deviations for the control group and experimental group across the two phases

Group	Condition	
	Phase 1	Phase 2
Control	20.60	19.46
Experimental	22.00	9.38

significant decrease in the standard deviations existed between phase 1 and phase 2 ($t_9 = 9.75$, $p < 0.001$), suggesting that the level of agreement amongst the participants in phase 2 was modified by providing them with the heuristics, such that they tended to carry out the decision task in a more similar way.

What Heuristics Were Used?

The use of inappropriate heuristics by some of the participants in phase 1 of the control and experimental groups was likely to have contributed to the larger error distances. For example, some participants in phase 1 said that 'I guess the perpetrator lives away from the average position of the victims'. In phase 2, participants in the control group reported similar inappropriate heuristics, which explains their consistent performance across the phases. Conversely, participants in the experimental group reported that they were able to adopt the appropriate heuristics provided to them in phase 2 in order to make more structured and accurate predictions.

DISCUSSION

This study indicates that some of the most frequently cited results in the research literature on offender spatial behavior can be summarized as simple heuristics that can be quickly understood and utilized by people without any special training in criminal behavior or experience of criminal investigations. They can understand these well enough to improve their accuracy in predicting the likely home location of serial murderers and can utilize them so effectively that, at least for the sample of serial killers used here, their judgments are, on average, as accurate as a geographic profiling system. These results therefore provide support both for the power of the two heuristics identified—distance decay and circle hypothesis—and for the possibility of summarizing those heuristics in ways that make sense to people otherwise uninformed about criminal behavior. It therefore raises the possibility of identifying other aspects of criminal behavior that could be similarly distilled for general application.

The power of the heuristics appears to be that they focus the decision processes of participants, demonstrated by the fact that agreement amongst the participants increased once provided with the heuristics. For these participants, error distance variability was reduced and the strategies they reported became less idiosyncratic and variable. This illustrates a potential problem of those aspects of investigative decision-making often referred to as 'gut feeling', 'intuition', or even 'experience.'

The variability in the strategies used for these personal judgments may be so great that no two people will use the same decision rules. This reduces the possibility of general improvement and increases the risk that some individuals will use completely inappropriate procedures.

The second major finding, that participants on average were able to make as accurate predictions as a geographic profiling system, also raises questions about the specific benefits of using specialized geographic profilers and computer based geographic profiling systems. The results of this study indicate that if the basic processes underlying offender spatial behavior are understood, prerequisite qualifications may not be required to make accurate geographic predictions. Moreover, the results from the present study suggest that, on average, individuals with some knowledge of criminals' spatial behavior can make these accurate predictions relatively quickly. Indeed, the experimental respondents here may be less prone to seek novel interpretations or draw on their 'experience' than police officers. They may therefore be able to use the provided heuristics in a more objective manner than experienced investigators. Future research needs to be conducted to test this possibility. Of course, experienced criminal investigators bring other knowledge to their work when preparing geographic profiles. They will have an understanding of the legal context in which an investigation is being carried out as well as the operational possibilities available to those they are advising.

These findings have potential positive implications for police organizations. For example, they indicate that police organizations may be able to correct any use of inappropriate heuristics by providing officers with more appropriate ones, thereby increasing the ability of these officers to make more effective decisions about offenders' residential locations. The significance of these results increases for police agencies that have limited resources and technological capabilities, making low-cost, easy-to-implement alternatives to geographic profiling systems desirable.

The consistent rank ordering of the error distances between the experimental group participants in phase 2 and Dragnet indicates that at the present time when heuristics were ineffective for the participants, Dragnet was also ineffective. This does support the central assumption of the present study that the two heuristics used are the cornerstone of the Dragnet algorithm. It also demonstrates that there is a need for other heuristics that will aid effective spatial decision making in those cases for which the current algorithms are not very effective. For example, there may be some heuristics that are useful for commuting offenders, who are particularly difficult to locate with existing geographic profiling systems. Once appropriate heuristics have been discovered for commuting offenders they may be employed to increase the overall accuracy of both human and computer procedures.

It is also worth noting that geographic profiling systems provide more than a single location as tested in this study. They provide graded areas of differing priorities for investigative searches. These priorities do not fan out evenly from the highest probability but are influenced by the distribution of the crimes. The basis on which these various priorities are calculated can be summarized as a heuristic. Such heuristics could therefore be used as the basis for future studies that are rather more subtle in the comparisons that can be made between human judges and geographic profiling systems. For example, search cost functions (Canter *et al.*, 2000) generated by individuals could be compared with those generated by geographic profiling systems.

Lastly, it is important to point out that the present results are very dependent on the particular spatial distributions selected. The current sample was drawn at random from a larger database, but without full knowledge of the spatial distribution of the population of American serial murderers it is impossible to know how representative this sample is. The results could certainly have been biased against the heuristics used in the current study if a sample had been drawn for which those heuristics were inappropriate, such as a sample of offenders 'commuting' some distance into an area to commit their crimes. It might also be the case that samples could be biased in favor of Dragnet by choosing complex geometries that the computer algorithm could manage but which would be very puzzling for a person, such as uneven distributions and varied sizes of clusters of crime locations. Future research could explore these issues by developing more refined classifications of the geometries of crime locations and determining the roles and effectiveness of different heuristics in relation to those different geometries. Only after such research will it become clear whether the decision rules needed to deal with the complexities of these matters can be readily understood and used by people with little training or whether they require computer support.

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