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Space Time Dynamics of Insurgent Activity in Iraq

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This paper describes analyses to determine whether there is a space-time dependency for insurgent activity. The data used for the research were 3 months of terrorist incidents attributed to the insurgency in Iraq during U.S. occupation and the methods used are based on a body of work well established using police recorded crime data. It was found that events clustered in space and time more than would be expected if the events were unrelated, suggesting communication of risk in space and time and potentially informing next event prediction. The analysis represents a first but important step and suggestions for further analysis addressing prevention or suppression of future incidents are briefly discussed.
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Introduction

Prior to September 11, 2001 many private and public organisations viewed security in the same light as many police organisations perceive crime prevention: an ancillary function which takes away from operational capacity and is tangentially related to core business. This view, of course, has changed in the last 7 years and is unlikely to return to the halcyon days of the late 20th century for some time. Now, security functions of the state and private enterprises are seen as the primary delivery mechanisms of deterrence, prevention and resilience to terrorist attacks or natural disasters.

The authors have, for some time, been conducting research which considers how crime patterns vary in space and also how they vary in time (Johnson *et al.*, 1997; Bowers *et al.*, 1998; Ratcliffe and McCullagh, 1998a, b; Ratcliffe, 2000, 2002, 2004; Townsley *et al.*, 2000; Townsley and Pease, 2002). More recently, they have explored how the distribution of crime varies simultaneously in both space *and* time (Johnson *et al.*, 2007; Ratcliffe and Rengert, 2008; Townsley *et al.*, 2003; Bowers *et al.*, 2004; Johnson and Bowers, 2004a, b; Bowers and Johnson, 2005; Ratcliffe, 2005). In particular, we have explored whether patterns of crime exhibit the characteristics of an infectious process. That is, does the occurrence of a crime at one location and time affect the risk of crime nearby (as well as at the same location) and if so, for how long does this influence endure? Specifically, the original work of Townsley *et al.* (2003) and Johnson and Bowers (2004a, b) identified that after a burglary, there was an elevated risk to nearby properties for a finite time (a few weeks). Subsequently, Ratcliffe and Rengert (2008) identified similar spatio-temporal patterns for shootings in Philadelphia.

The following research paper outlines our attempts to study the spatial and temporal patterns of insurgent attacks in Iraq during U.S. military occupation. We attempted to identify patterns that would be operationally relevant from a security point of view. There are a number of novel aspects to the current study. To the best of our knowledge, this research is the first examination of space-time patterns of crime conducted outside of a Western country. As such, it provides an opportunity to determine if spatio-temporal behaviours common in Australia, the U.K. and U.S., which may be due to the urban landscape and socio-demographic patterns in those countries, are the same in a non-Western situation (specifically Baghdad). Secondly, the (unfortunately) high volume of insurgent activity provides an opportunity to establish if research approaches originally developed for property crime can be used to effectively model an emerging and evolving security challenge. Finally, it provides an opportunity to make a modest contribution to better understanding a problem currently facing coalition troops and Iraqi security forces.

The theoretical underpinning of the work presented here is rational choice theory (Cornish and Clarke, 1986), although the most germane perspective is Clarke and Newman's recent monograph *Outsmarting the Terrorists* (2006). They claim that we should consider terrorism as a type of crime and that the decision-making processes of criminals and terrorists are broadly similar. Terrorists have certain goals (both short and long term), and are constantly evaluating opportunities to achieve these in terms of a risk and reward calculus. Like offenders, terrorists have limited resources (money, time and personnel) and attempt to evade the attention of organisations dedicated to preventing their activity. In short, attacks are carried when the perceived reward exceeds the perceived risk. In concrete terms:

(1) not all targets are equally attractive to terrorists; and
(2) terrorists are unlikely to be able to strike at will because they are constrained by finite resources or excessive risk.

To the casual reader having watched on television the devastating result of roadside bombs in Iraq, it might seem incongruous to consider suicide bombings and other forms of insurgent activity to be theoretically related to rational choice perspectives used to explain vehicle crime and burglary. There seems little that is rational about the targeting of improvised explosive devices (IEDs); however, to the perpetrator these acts are entirely rational. It is probably more realistic to suggest that these acts display what is more commonly termed "limited" or "bounded" rationality (Cornish and Clarke, 1986). As Sandler and Arce explain (citing some of Sandler's earlier work), "empirical support for terrorists' rationality is given credence by their predictable responses to changes in their constraints" (2003, p. 320).[1]

[1] Interestingly, much of the empirical work on terrorist attacks supports a rational actor thesis but implicitly suggests that displacement of attacks is inevitable. Clarke and Newman (2006, Chapter 4) argue that displacement is far from certain and the data sources used in such studies are not suited to shedding light on this issue.

In the current analysis, we explored the time-space distribution of insurgent incidents in Iraq. Two patterns seemed plausible: (i) attacks would cluster in space but not time; or (ii) that attacks would cluster in space and time in the same way as a disease (and crime). Clarke and Newman would predict that the latter more likely not least because this would be an efficient way of operating. On the basis of the least effort principle (Zipf, 1949), attacks would need to occur near enough to each other to minimise the effort expended by operatives in travelling to new locations, but not so close as to make the risk of capture more than trivial.

We considered the former a possibility in case insurgent resources were not constrained (e.g. operatives were easily replaced) or the military were not perceived as a credible threat and therefore did not curtail terrorists' movement. A recent Brookings Institution Iraqi Index certainly suggests that the rate of capture is low; the number of insurgents in Iraq is consistently estimated at more than 15,000, yet only about 2,000 of these are detained or killed every month. The number of insurgent attacks per day shows a virtual monotonic increase (O'Hanlon and Kamp, 2006).[2,3] However, there is also the possibility of the latter if insurgents respond to security force activity. Clusters of actions in both time and space may suggest that insurgents identify a location near a weapons cache and then conduct a number of quick attacks that allow them to strike and move on before a concerted response can be organised. Like property offenders who do not travel farther than necessary to steal property (the least effort principle), insurgents are unlikely to stray too far from a weapon haul due to the increased risk of interdiction prior to an attack. They may only travel far enough to minimise the chance of identifying an explosives cache should they be intercepted (essentially an unusual twist on the least effort principle).

The research question posed in this paper is different in scope to those dealt with previously in the academic research. Our reading of the conflict prediction literature suggests that the units of analysis are often large in size (two nation states resolving a dispute), the data are qualitative (troop build up, trade sanctions, political posturing, etc.) and often have a long time horizon. In contrast, the aim of our approach is to identify patterns in the actions of distinct cells of operatives (even if they cannot be individually identified) using quantitative data at fine levels of resolution in space and time. The purpose of so doing is to inform methods of predicting the timing and locations of future events.

Our analysis was developed to support tactical decisions, whereas many threat assessments are strategic in focus. This is not to say there are no weaknesses in the approach outlined here – we do not claim to predict acts of macroterrorism, a term coined to describe spectacular acts of terrorism resulting in large losses of life (Woo, 2007) – but that the bulk of predictions of terrorist/insurgent activity are not operationally relevant. In the current study then, the question of central interest was whether there exists a regularity in the timing and location of insurgent attacks that might inform their subsequent prediction.

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[2] Although recently the success rate of attacks has roughly halved.

[3] These data come from the Total Number of Insurgents Detained or Killed and Number of Daily Attacks by Insurgents graphs and the Estimated Strength of Insurgency Nationwide table in O'Hanlon and Kamp (2006). The respective footnotes indicate that, unsurprisingly, these data are imprecise to some degree, although we think that they reflect the general perception that the Iraqi insurgency appears resilient to considerable personnel depletion (10 per cent per month) without a corresponding drop in activity.

Table 1 Example of a summary contingency table (data are fictitious)

		Distance between events in pair		
		0–100 m	*101–200 m*	*201–300 m*
Time between events in pair	1 day	421	221	189
	2 days	246	209	91
	3 days	102	237	144

Data

To investigate the research question, we were provided with 3 months of insurgent incident information from Iraq. The data attribute fields included incident number (to distinguish separate incidents), location in latitude and longitude coordinates and date. This amounted to almost 2,168 records. The time frame these data covered was from 4 February 2004 to 30 April 2004.[4] Of all the incidents, 916 (about 40 per cent) were labelled IED. This was easily the largest single category and as such the analysis is restricted to this type of incident.

Owing to the uniqueness of these data we have not been in a position to explore varieties of IED events, nor to determine the reliability of the coding of events. Some of the other categories present but not included in this analysis were labelled "landmine", "suicide bomber", "vehicle borne IED" and "grenade", but their frequencies were so low that their exclusion was unlikely to impact the results.

Methodology

The technique used here has been developed by the authors in other research (Johnson *et al.*, 2007) to investigate the communicability of burglary risk. Simply put, we applied an epidemiological model of infectious diseases to test for the communicability of future risk. The same approach has been used here.

To summarise as concisely as practicable, for a set of data, each observation is compared with every other (n cases generates $n(n-1)/2$ pairs) and the space and time difference of each pair computed. A contingency table is then populated to summarise the distribution of pairs at various space-time combinations. For example, table cells represent how many events occurred within 100 m and 1 day of each other, how many occurred within 101–200 m and 2 days, and so on. In this way, we populate a contingency table (see Table 1), and this can be used to summarise the patterns observed for the whole data set.

As with burglary patterns in residential neighbourhoods, the pattern of potential targets is assumed to be plentiful and not an inhibiting factor in the analysis. Equally, in Baghdad, the distribution of potential targets (across both the resident population and coalition forces) is deemed to be widespread and prolific for the purposes of this analysis. This means that the opportunities for attacks are widespread and not a function of limited target availability.

[4] A minor note is that this is a time period in the U.S. occupation of Iraq after U.S. President George Bush declared "major combat operations in Iraq have ended".

Nevertheless, as will be explained below, unlike many tests of spatial clustering, complete spatial (or temporal) randomness is assumed not to be a feature of the expected distribution. Events are expected to cluster in some places more than others and this is accounted for in the analysis.

To briefly elaborate, it can be concluded that some form of communicability exists if many more pairs are observed to occur closer in space and time than would be expected on the basis of chance. Determining how many pairs of events would be expected to occur at the different space-time intervals (e.g. within 100 m and 1 day) is a methodological challenge, and it is one we address using a technique known as a Monte Carlo test where an expected distribution is generated from the observed distribution.[5]

A number of commonly used inferential statistical tests used for studying the spatial distribution of events assume that events may occur at any location at any time with equal probability. This is quite unrealistic as this (null hypothesis) implies events could occur in illogical locations (residential burglaries in public parks, say). Employing a Monte Carlo test generates an expected distribution that better reflects the underlying morphology of location being studied, as well as any variation in the timing of events.

Having derived the expected distribution of events, the observed frequency for each cell is compared to what would be expected on the basis of chance. A *P*-value is calculated for every cell. This is the probability of obtaining the observed results if the null hypothesis – space-time independence – is true. The inferential test is one sided, meaning that we are only interested in departures from expectation in a certain direction. Therefore we are not interested in any difference, but instances where there is an excess of pairs compared to what we would expect under the null hypothesis situation. As the analysis presented here is exploratory, we chose a range of space-time thresholds to locate these departures from space-time independence.

Results

Figure 1 displays the results of the analysis. It shows three tables of IED pair frequencies using different space-time bandwidths. Each cell represents a space-time combination and is shaded according to whether the *P*-value of that cell is less than 0.05. The extent of shading is determined by the ratio of observed to expected pairs. This measure of effect size is a useful companion to the *P*-value because as cell frequencies become larger it is increasingly easier for small differences between observed and expected frequencies to be identified as statistically significant.

As mentioned before, for the hypothesis test applied, for any particular cell we are only concerned with the identification of an abundance of event pairs; that is, instances where there are more pairs than we would expect if we assumed the location and timing of IED attacks were unrelated. It should be noted that pairs of incidents with no spatial distance (IED attacks at the same location) have been excluded from the analysis, as have pairs of incidents that occurred on the same day as each other.

[5] The idea is that the observed data is just one realisation of the process. Randomly shuffling dates among events allows other realisations to be created. A total of 999 realisations were created to form an expected distribution. The observed distribution is added to make a sample size of 1,000.

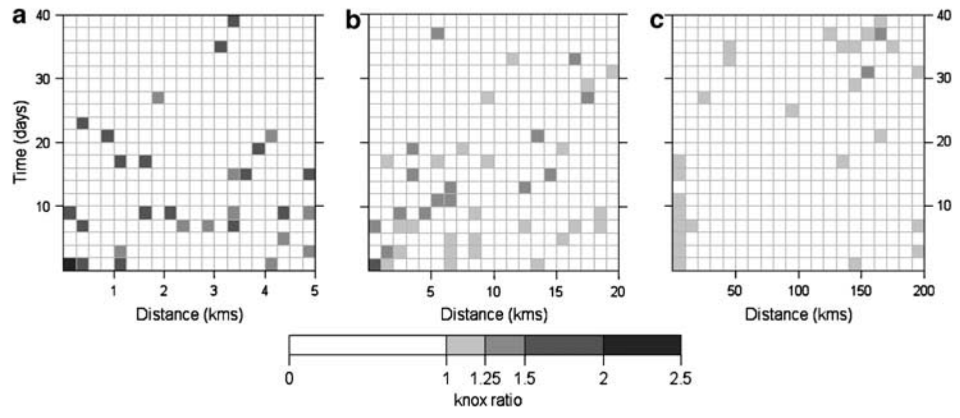

Figure 1. Patterns of space-time dependence at different space thresholds. (a) Refers to space increments of 250 m and time increments of 2 days; (b) refers to space increments of 1 km and time increments of 2 days; and (c) has the same time increment as (b) but increase in space by units of 10 km. Pairs of IED attacks at the same location (zero distance) are not included in the first column of cells. Cells are shaded depending on whether the number of pairs is significantly greater ($P < 0.05$) than the expected pair count.

Increments in the bandwidths considered for the elapsed time between event pairs are constant across the three figures but differ for space. The finest resolution of analysis is displayed on the left, with each grid corresponding to 250 m intervals, and the largest resolution to the right, each grids corresponding to 10 km. Across all three figures there is a core of cells in the lower left which display departures from space-time independence. Taken as a group, this suggests a range of communicability. Larger differences in cell frequencies were observed for smaller increments in space.

In summary, the emergent trends are consistent with the hypotheses discussed in the introduction and enumerate the distances and times over which these patterns emerge. For the period of time studied, the risk of IED attacks appears to have communicated to nearby locations for a short period of time, regardless of the level of resolution. According to these results, the highest risk of future IED attacks is a distance of up to 1 km for a period of 2 days after an IED attack.

In work not presented here we were able to refine the spatial resolution to a much finer, more operationally useful bandwidth. In order to prevent adaptation and maximise any benefits of a security response to these attacks, we do not present these particular results; however, when this analysis is conducted, the pattern remains, suggesting that there is clear evidence of space-time clustering in the pattern of IED activity in Iraq.

Implications and further analysis

The results represent a proof of concept that the risk of IED attacks is communicable. This may not be surprising but provides formal evidence that is compatible with the suggestion that insurgents are organised and the spatio-temporal pattern of attacks is far from random. These patterns, and the methods used, have implications for the prediction of where IED attacks may next occur, given knowledge of the recent pattern of events (see Bowers *et al.*, 2004).

From an operational perspective, the knowledge that a further attack is more likely within 2 days and 1 km allows security forces and the police to organise a localised response that, while having to mobilise quickly, is not required to remain *in situ* for periods longer than a few days. Furthermore, it also provides an opportunity to mobilise local community resources and request extra vigilance from the local community. It is known that community vigilance after destructive incidents often wanes after time, but in this case the evidence suggests that it is only required for a few days so the natural vigilance decay that occurs when nothing happens or as time passes is not an issue.

From a theoretical perspective, it is revealing to discover that terrorist attacks in an insurgency environment appear to follow basic principles originally explored for the description of property crime. Terrorist attacks appear to follow basic patterns that reflect rational choice target selection and Zipf's least effort principle. While the authors are not aware of any articulation that insurgent attacks should be fundamentally different than other criminal and aberrant behaviour, it is reassuring to produce evidence that these patterns hold. As a result, we suggest that it may prove fruitful to apply further thought and crime reduction principles from environmental criminology to the study of insurgent activity.

We suggest the following analyses be carried out to identify and understand patterns in insurgent incident data:

(a) Sequential mapping in time of incidents (i.e. mapping "time slices" of data) to determine whether some areas have a stable level of risk, and in particular, or whether there exist seasonal patterns to the location of insurgent activity.
(b) Sequential mapping of *pairs* of incidents that occur close in both space and time to see if they follow the same or different vectors revealed in part (a). This is critical. If these near repeats are the product of hot spots, then there is little point in using an esoteric model (used here) when basic techniques (kernel density estimation) could be employed. We feel there is little danger of this occurring for a range of reasons, not least that the observed space-time clustering suggests that risks are not elevated for long periods of time as they are in hot spots.
(c) Only pairs of attacks are considered in this analysis; in future research it would be possible to extend the methodology to examine longer event series (say 3, 4, 5, or more events that occur close to each other in space and time) to help us understand more precisely how the risk of attack spreads.
(d) In further analyses, additional data for an extended period of time should be used. This would help validate the reliability of the findings and also determine if seasonal patterns emerge.

There may very well be alternative reasons, other than the least effort principle suggested here, to explain the patterns of IED risk communicability. The sectarian nature of the Iraqi insurgency could dictate the rhythm of IED events, or the patterns might be influenced by coalition troop movements or actions. In any case, the data used for this analysis were not sufficiently detailed to provide causal insight. However, until an appropriate data source is identified, the simplest explanation for the patterns observed is that insurgents are constrained in space and time and select targets in a rational fashion.

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