MOBILITY ACROSS CRIMES: STATISTICALLY VALIDATED NETWORKS AND TEMPORAL PATTERN RECOGNITION

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ABSTRACT: Criminal careers can be categorised as either general or specialised. A key challenge in studying crime specialisation is determining which crimes should be considered similar and which should be considered distinct from the criminal's perspective. We conducted an empirical study involving a large group of Swedish suspects to address this issue. The primary objective was to investigate generalist and specialist behaviour in crime. By employing directed network analysis, our study aimed to uncover temporal patterns of criminal specialisation. Specifically, we examined the temporal connections between different types of crimes to reveal distinct patterns in criminal behaviour. The findings indicate that individuals who were suspected of at least two crime types within each of the five communities throughout their criminal careers demonstrated varying patterns of specialisation evolution. In contrast, some individuals consistently maintained high levels of generalism. These results highlight the diverse paths individuals take in their criminal behaviour and contribute to our understanding of the dynamics of criminal specialisation over time.

KEYWORDS: communities and criminal specialisation, complex networks, criminal temporal patterns.

1 Introduction

Specialisation in criminal behaviour has significant implications for comprehending the root causes of crime (Piquero, 2000). Theories, such as those focusing on the relationship between brain functioning and delinquency, which includes brain damage (Neylan, 1999) and low or unstable serotonin levels (Alm *et al.*, 1996), assume that violent crime is the specialisation of aggressive individuals. Similar contemplations are applicable to theories that explore the interactions between genetic and social factors that can lead to violence (Wolfgang *et al.*, 1967). Sutherland's differential association theory (Sutherland *et al.*, 1992) postulates that crime is learned behaviour, thereby suggesting high crime specialisation. Thus, criminal specialisation is a multifaceted issue that is central to criminology, crime prevention, and enforcement (Loeber & Farrington, 1998). In this study, we analyse the Swedish national register of individuals suspected of criminal offences, which comprises about 750,000 individuals that have been suspected of at least 2 crimes in Sweden from 1995 to 2016. The database includes information such as age and sex of the suspects, the types of crimes (521 categories) they have been suspected of, and the date (or period) when the crime was committed. The aim of this work is to discover temporal patterns of criminal specialisation. We utilise directed network analysis to study the temporal association between crime types to reveal these temporal patterns in criminal behaviour.

2 Statistically validated temporal networks

We used a statistically validated network approach for temporal network analysis (SVTN) to assess specialisation in crime. Additionally, to accommodate the database's heterogeneity caused by suspects involved in different numbers of crimes, we partitioned the database into multiple subsets, S_f, according to the number of crimes per criminal. Further details on this can be found in Tumminello *et al.*, 2013. We tested the null hypothesis of random co-occurrence between two crimes, a and b, using the hypergeometric distribution.

$$pvalue(n^f_{ab}) = \sum_{x=n^f_{ab}}^{min(n^f_a, n^f_b)} \frac{\binom{n^f_a}{x}\binom{N^f-n^f_a}{n^f_b-x}}{\binom{N^f}{n^f_b}}, \tag{1}$$

where N^f is the number of criminals in subset S^f, n^f_a (n^f_b), is the number of criminals that committed crime a (b) in the subset S^f, and n^f_{ab} is the number of criminals who were suspected (with a temporal direction) of both crimes, a and b.

The null hypothesis of random co-occurrences exactly takes into account the heterogeneity of both the types of crimes, a and b, by conditioning to n^f_a and n^f_b (Tumminello *et al.*, 2013). We calculated the *p-values* in every subset S^f

to construct a weighted network of crime types based on the excess of co-occurrence. Then, we used the FDR correction for multiple hypothesis testing (Benjamini & Hochberg, 1995) to adjust the *p-values*. In contrast to the study conducted by (Tumminello *et al.*, 2013), this work's novelty lies in incorporating the temporal element in hypothesis testing, enabling us to examine the temporal progression of criminal specialisation. Our SVTN is a weighted directed network with labelled links. Indeed, it comprises four types of links, which are defined as follows:

- **JO:** a and b jointly occur (undirected link) $a - b$;
- **PR:** crime a precedes crime b if a occurred before b, $a \xrightarrow{PR} b$;
- **CO:** b contains a if crime a occurred entirely within the time interval in which crime b was perpetrated, $a \multimap b$;
- **PO:** crime a and b partially overlap if b begins after a and ends after a, $a \xrightarrow{PO} b$.

As seen in the list above, there are two types of links, namely PR and PO, that are temporally directed. These two link types provide information about the temporal progression of criminal activity and are considered separately from the other link types. By concentrating on these links, we developed a weighted directed False Discovery Rate (FDR) network, in which each link corresponds to a statistically significant *p-value* (5% threshold) after the FDR correction, while the weight is determined by the total number of subsets S^f in which the link is significant.

3 Preliminary results

We utilised the MapEquation (Edler *et al.*, 2022) to identify the hierarchical structure of communities within the network. We discovered five primary communities, each consisting of a minimum of 20 crime types that subsequently divided into smaller communities. These large communities represent distinct types of criminal specialisation: 1) fraud, forgery, and taxation (120 crime types); 2) assault, rape, and persecution (198 crime types); 3) drugs, narcotics, attempted homicide, and homicide with a firearm (85 crime types); 4) theft and arson (66 crime types), and 5) violence against unacquainted victims (28 crime types)[*]. Individuals who were suspected of at least two crime types within each

[*] In addition, there are three smaller communities that do not further split into more specific ones: environmental crimes (20 crime types), human trafficking for forced labour (2 crime types), and robbery from a shop or a taxi (3 crime types).

community during their criminal career exhibited different patterns of specialisation evolution. Some groups achieved high levels of specialisation early on, while others maintained relatively high levels of generalism even later in their careers.

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