Structural Resilience and Recovery of a Criminal Network after Disruption

A Simulation Study

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Introduction

- Disrupting criminal networks is one of the main appeals for applying SNA in criminology and criminal investigation. Several studies have investigated resilience of criminal networks and the effect of various types of disruption, such as the removal of central actors or actors with specific skills, on their structure (Bright, 2015; Carley et al., 2002; Wood, 2017).
- Research has only recently started to acknowledge the fact that criminal networks tend to recover after a disruption (Duijn et al., 2014; Duxbury & Haynie, 2020; Duxbury & Haynie, 2019). The recovery may even strengthen the cohesion of a disrupted network.
- This study uses a real-world street gang network (Grund & Densley, 2014; 2016) as a basis for simulating the effect of disruption and subsequent recovery on its structure.
- Design of the study - 4 stages:
  1. describing network structure
  2. assessing generative mechanisms using stationary stochastic actor-oriented model (sSAOM; Snijders & Steglich 2015)
  3. applying various disruption techniques
  4. using the sSAOM model parameters to simulate the response of actors

Stage 1 - Network structure

The network maps the ties among 54 members of a street gang from London, originally collected by (Grund & Densley, 2014). The network is well-connected, decentralized, and cohesive with short geodesic distances between actors and considerable clustering with compactness = 0.52. Degree and betweenness centrality partially overlap with the ranking in the gang's hierarchy.

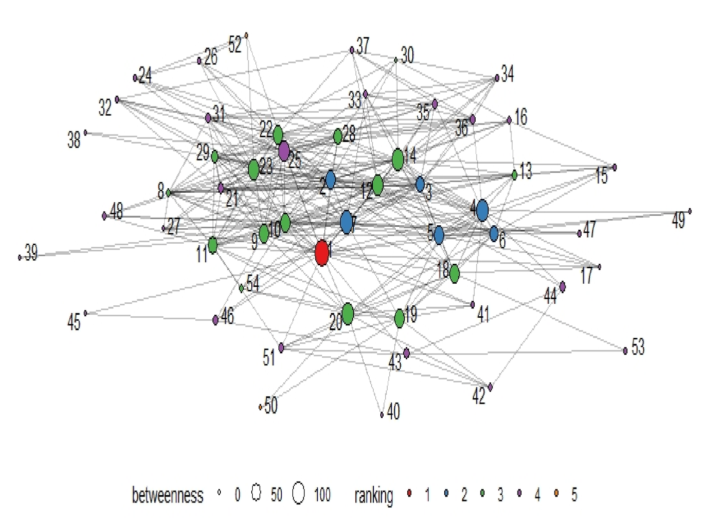

Figure 1: London gang network sociogram based on Kamada-Kawai layout. Size of nodes corresponds to their betweenness and their color refers to their position within the gang's hierarchy.

Stage 2 - Generative mechanisms

Types of mechanisms

- Trust-enhancing mechanisms = stimulate tie creation in configurations that foster trust
- Risk-reducing mechanisms = prevent tie creation in configurations that increase visibility (Diviák et al., 2021)

Stationary SAOM

- A modification of the SAOM (Snijders, 1996; 2001; Snijders et al., 2010) used for cross-sectional data by fixing the rate function (Snijders & Steglich 2015)
- Two algorithms for undirected data were used with very similar results (forcing model and unilateral initiative and reciprocal confirmation model; Snijders & Pickup, 2016)

effect	estimate	SE
degree	**-1.68**	**0.49**
trust-enhancing		
GWESP	**1.41**	**0.23**
age similarity	**0.79**	**0.29**
same ethnic	**0.32**	**0.12**
rank similarity	0.17	0.26
risk-reducing		
degree act+pop	**0.02**	**0.01**
age ego	0.07	0.05
betweenness	**-0.31**	**0.07**
prison ego	-0.10	0.27
arrests ego	0.01	0.28

Table 1: Stationary SAOM results (rate function = 20).

Stage 3 - Disruption strategies

Nine different disruption strategies based on previous research and the network under study were simulated by removing certain actors from the network. The impact of each disruption strategy was measured by its effect on the network's compactness.

- 5 strategies aimed at the most central actors: top 1 degree & betweenness, top 3 degree, top 5 degree, top 3 betweenness, top 5 betweenness
- 3 strategies aimed at larger number of marginal (lowest degree & betweenness) actors: top 5, top 8, and top 11 most marginal actors
- 1 strategy aimed at seven actors in the two highest ranks in the hierarchy of the gang

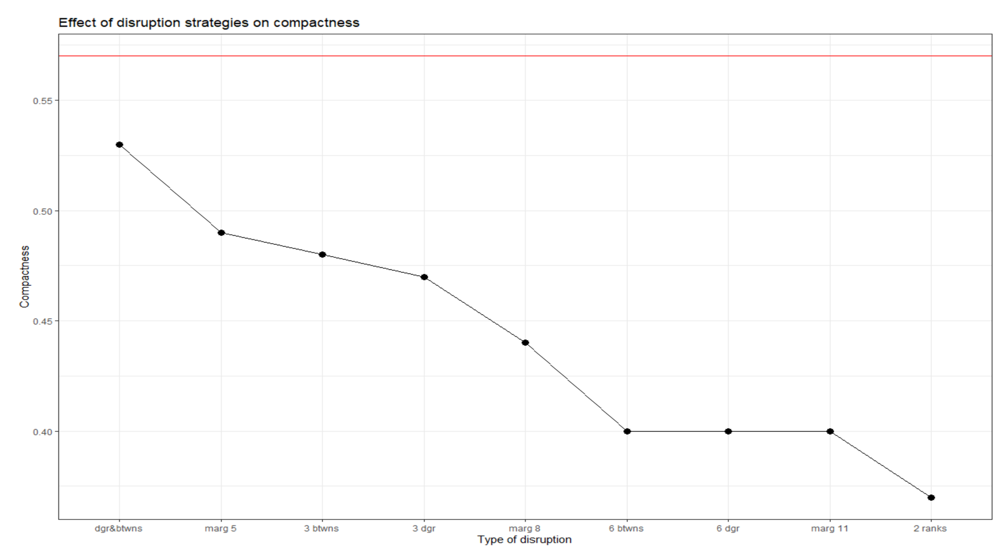

Figure 2: Immediate effect of disruption strategies on compactness. Red line represents the baseline value.

Stage 4 - Recovery scenarios

- Recovery scenarios were simulated for each disruption strategy by increasing or decreasing parameter values of statistically significant estimates and subsequently simulating from the resulting model.
- Simulated recovery scenarios:
  1. increasing triadic closure
  2. increasing homophily on ethnicity
  3. increasing brokerage
  4. decreasing preferential attachment

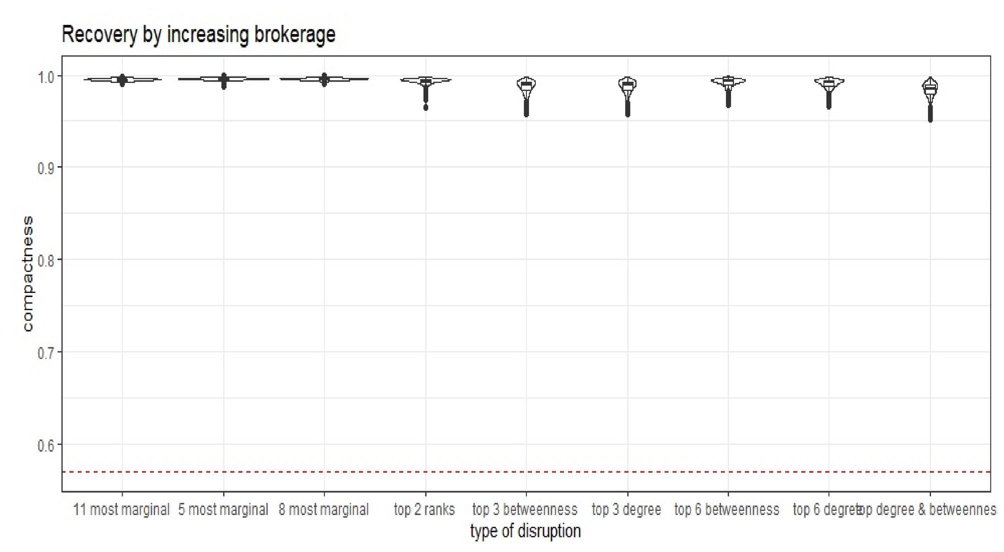

Figure 3: Violin plot of the effect of increasing brokerage on compactness of the network. Red line represents the baseline value. 1,000 networks simulated for disruption strategy.

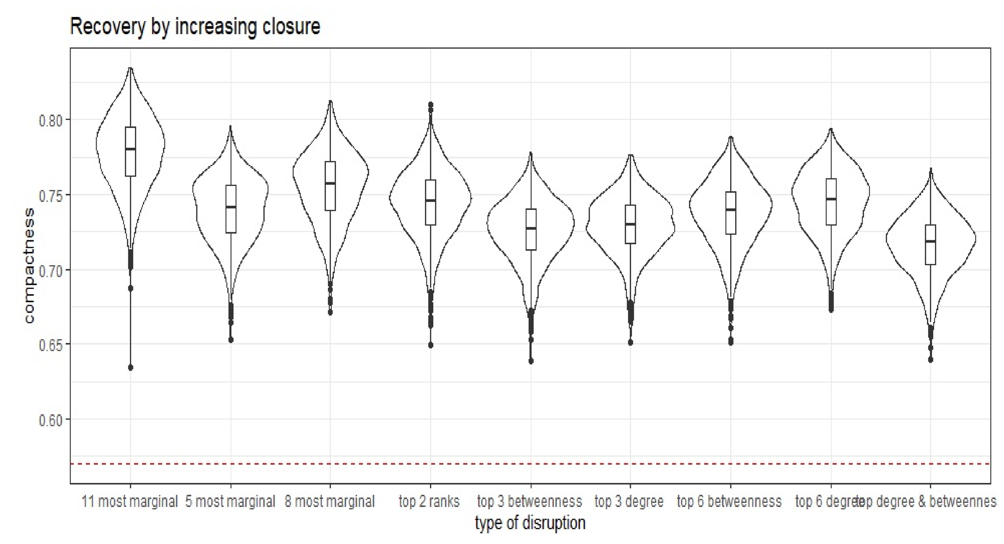

Figure 4: Violin plot of the effect of increasing closure on compactness of the network. Red line represents the baseline value. 1,000 networks simulated for disruption strategy.

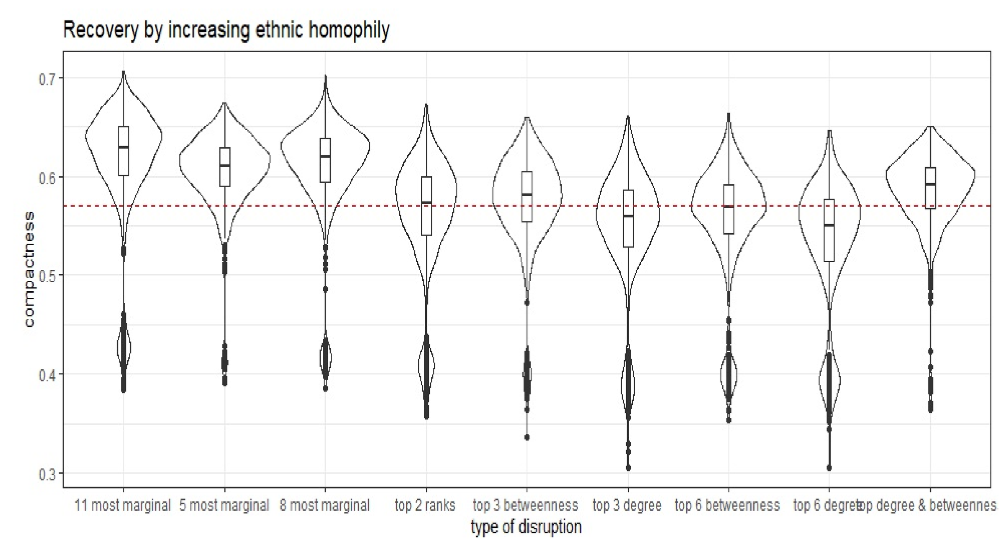

Figure 5: Violin plot of the effect of increasing ethnic homophily on compactness of the network. Red line represents the baseline value. 1,000 networks simulated for disruption strategy.

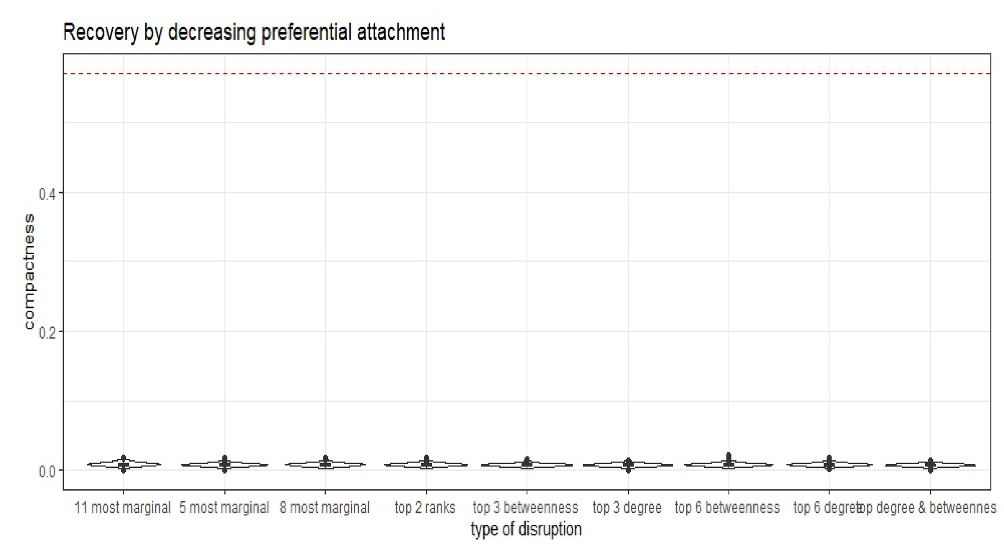

Figure 6: Violin plot of the effect of decreasing preferential attachment on compactness of the network. Red line represents the baseline value. 1,000 networks simulated for disruption strategy.

Conclusion

- While different disruption strategies vary in their immediate impact on the compactness of the street gang network, they show very little variance within all the four simulated recovery scenarios.
- In three recovery scenarios, the networks become more compact, while the structure disintegrates in the last scenario in which preferential attachment is decreased.
- From a network disruption perspective, the mechanisms that drive the recovery are far more important that the disruption strategies.
- There is still work to be done in sensitivity analyses and simulating other recovery scenarios.

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References
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