IS GUN VIOLENCE CONTAGIOUS?

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Is Gun Violence Contagious? A Spatiotemporal Test

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Abstract

Objectives Existing theories of gun violence predict stable spatial concentrations and contagious diffusion of gun violence into surrounding areas. Recent empirical studies have reported contradictory evidence of such spatiotemporal diffusion of gun violence. However, existing space/time interaction tests cannot readily distinguish spatial and temporal clustering from spatiotemporal diffusion. This leaves us an open question whether gun violence actually is contagious or merely clusters in space and time. Compounding this problem, gun violence is subject to considerable measurement error with many nonfatal shootings going unreported to police.

Methods Using point process data from an acoustical gunshot locator system and a combination of Bayesian spatiotemporal interaction process modeling and classical space/time interaction tests, this paper distinguishes between clustered but non-diffusing gun violence and clustered gun violence resulting from diffusion.

Results This paper demonstrates that contemporary urban gun violence in a metropolitan city does diffuse in space and time, but only slightly.

Conclusions These results suggest that a disease model for the spread of gun violence in space and time may not be a good fit for most of the geographically stable and temporally stochastic process observed. And that existing space/time tests may not be adequate tests for spatiotemporal gun violence diffusion models.

Keywords Gun violence · Contagion · Spatiotemporal methods

1. Introduction. Spatiotemporal forecasting of crime has been the focus of considerable attention in recent years as academic researchers, police departments, and commercial entities have all sought to build forecasting tools to predict when and where crimes are likely to occur (Perry et al., 2013). The earliest crime forecasting tools consisted of nothing more than pin-maps (See, for example, Figure 1). Prior week’s crimes were mapped and qualitative assessments of density, location, stability and significance were
Background

• Empirical observations:
  – ~ 10K fatal homicidal shootings per year in U.S.
  – ~ 50K non-fatal shootings per year in U.S.
  – Most shootings are spatially clustered within city neighborhoods
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  – Loftin (1986)
  – Tita and Cohen (1999), Messner et al. (1999)
  – Fagan et al. (2007), NRC (2012), Butts et al. (2015)
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• Research Question:
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- Contribution:
  - Using a Hawkes process Model and AGLS data to separate endemic from epidemic clustering
Existing Tests for Violence Contagion

- Using Knox test, Ratcliffe and Rengert (2012) report clustering of firearm assaults at <2 weeks and <400 ft
  - How do we know that this clustering is reactive rather than stable and stochastic?
  - How do we overcome low count aggregation problems?

Source: Ratcliffe and Rengert (2012)
Gun Violence in Washington, D.C. 2010-2012

- Highly clustered in time (macro-scale)
Gun Violence in Washington, D.C. 2010-2012

- Highly clustered in time (macro-scale)
- Highly clustered in time (micro-scale)

(b) Hour of week trends
Gun Violence in Washington, D.C. 2010-2012

- Highly clustered in time (macro-scale)
- Highly clustered in time (micro-scale)
- Highly clustered in space

(c) AGLS
Gun Violence in Washington, D.C. 2010-2012

- Highly clustered in time (macro-scale)
- Highly clustered in time (micro-scale)
- Highly clustered in space
- **Highly clustered in space-time**

(d) Ripley’s K-Function
Gun Violence in Washington, D.C. 2010-2012

- A null hypothesis of CSR/CSTR is implausible
- But what does a scalable infectious spatiotemporal point process model look like and can it be estimated with conventional violence data?
Spatial and Temporal Distributions of Firearm Assaults and Shots Fired in Washington, D.C., 2011

Acoustically located gunshot

Firearm Assaults

AGLS

Photo by U.S. Army RDECOM
Methods

• Hawkes Process Model

\[ \lambda(x, y, t) = m_0 \cdot \mu(x, y, t) + \theta \sum_{i} \omega \exp(-\omega(t - t_i)) \frac{1}{2\pi\sigma^2} \exp\left(-\frac{(x - x_i)^2 + (y - y_i)^2}{2\sigma^2}\right) \]

– Background Intensity
  • Kernel Density Estimation
    – Gaussian Spatial Kernel
    – Separable components
      \[ \hat{\mu}(s, t) = m_0 \cdot \hat{\mu}(s)\hat{\mu}(t) \]

– Conditional Intensity
  • \[ \mathcal{L}(t_1, \ldots, t_n|\theta, \omega, \mu) = \prod_i \lambda(t_i) \exp\left(-\int_{t=0}^{t_i} \lambda(t) dt \right) \]

– Ratio of intensities provides fraction of events attributed to each intensity
  • For event \( i \) at location \( (x_i, y_i, t_i) \)
    \[ r_i = m_0 \cdot \mu(x_i, y_i, t_i) / \lambda(x_i, y_i, t_i) \]
Results

- 0.89 endogenous intensity
- 0.11 conditional intensity
- Note: very similar to motive split of fatal shootings (.84/.16)
- Temporal lengthscale is 12 mins
- Spatial lengthscale is 230 meters
- Note: more consistent with reactive behavior than extended retaliation
Classified Gunshot Events

Background (blue) versus “triggered” (red) shootings, by year.
Chicago Preliminary Results (2016-2018)

- 0.24 endogenous intensity
- 0.76 conditional intensity
- Note: pretty similar to motive split of fatal shootings (.34/.66)
- Temporal lengthscale is 72 days
- Spatial lengthscale is 0.32 km
- Note: more consistent with extended retaliation

Source: Chicago Tribune (2019)
Implications and Next Steps

• Gun violence is highly clustered in space and time
  – Null hypothesis of CSR/CSTR randomness will always be rejected

• Using a space-time interaction test with space-time heterogeneity
  – In DC, most clustering is well-described by an endemic process
  – A small fraction is consistent with a Hawkes-type diffusion process
  – Triggered events occur within a narrow space-time radius

• Replication in cities with different gang structures
  – In Chicago, most violence is consistent with diffusion.
  – Trigger events occur over larger distances and greater times

• Replication with different types of violence--

• Other approaches to estimating underlying intensity
Questions?

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References
1. C. Loftin, Bulletin of the New York Academy of Medicine 62, 550 (1986).
2. National Research Council (U. S.). Understanding and preventing violence (National Academy Press, Washington, DC, 1993).
3. J. Fagan et al., The Cambridge Handbook of Violent Behavior and Aggression, (Cambridge University Press, New York, 2007), pp. 688–726.
4. NRC, Contagion of Violence - Workshop Summary, Tech. rep., Institute of Medicine and National Research Council of the National Academies, Washington, D.C. (2012).
5. W. Skogan, S. Hartnett, N. Bump, J. Dubois, Evaluation of CeaseFire-Chicago, Tech. rep., U.S. Department of Justice, Washington, D.C. (2009).
6. D. W. Webster et al., Journal of Urban Health 90, 27 (2012).
7. S. D. Johnson, Journal of Experimental Criminology 4, 215 (2008).
8. G. O. Mohler et al., Journal of the American Statistical Association 106, 100 (2011).
9. M. Short et al., Proceedings of the National Academy of Sciences 107, 3961 (2010).
10. M. Townsley et al., British Journal of Criminology 43, 615 (2003).
11. J. Cohen, G. Tita, Journal of Quantitative Criminology 15, 451 (1999).
12. J. D. Morenoff, R. J. Sampson, S. W. Raudenbush, Criminology 39, 517 (2001).
13. G. Tita, J. Cohen, Spatially Integrated Social Science (Oxford University Press, New York, 2004), pp. 171–204.
14. J. H. Ratcliffe, G. F. Rengert, Security Journal 21, 58 (2008).
15. A. Braga, A. Papachristos, D. Hureau, Journal of Quantitative Criminology 26, 33 (2010).
16. R. Rosenfeld, T. Bray, A. Egley, Journal of Quantitative Criminology 15, 495 (1999).
17. S. F. Messner, et al., Journal of Quantitative Criminology 15, 423 (1999).
18. G. Tita, G. Ridgeway, Journal of Research in Crime and Delinquency 44, 208 (2007).
19. A. Papachristos, American Journal of Sociology 115, 74 (2009).
20. G. d. Tarde, The Laws of Imitation (H. Holt, 1903).
21. J. Coleman, E. Katz, H. Menzel, Sociometry 20, 253 (1957).
22. N. A. Christakis, J. H. Fowler, New England Journal of Medicine 357, 370 (2007).
23. M. Short, G. Mohler, P. J. Brantingham, G. Tita, Discrete and Continuous Dynamical Systems 19, 1459 (2014).
24. MPD, A Report on Juvenile and Adult Homicide in the Distict of Columbia, Tech. rep., Metropolitan Police Department Washington, D.C. (2006).