Introduction to the Mathematics of Gun Violence

Presenter: Shelby Scott
Moderator: Dr. Louis Gross

Today's Moderator:

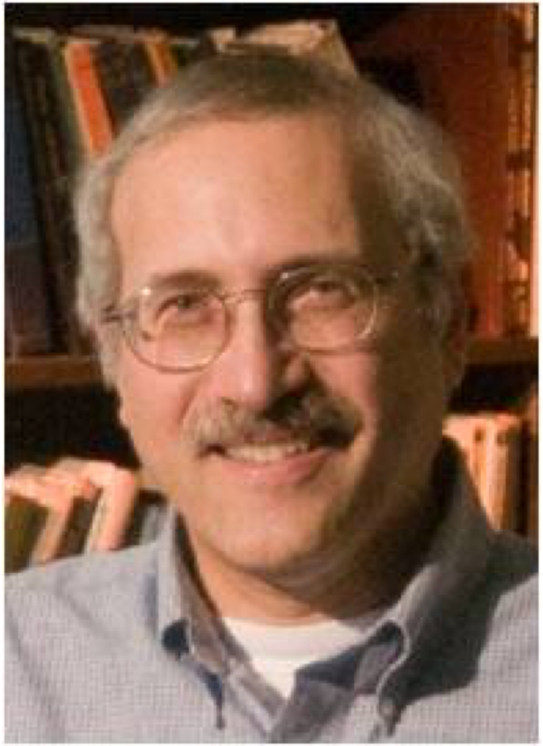
Dr. Louis J. Gross, PhD

Director, *NIMBioS*

Professor of Ecology and Evolutionary

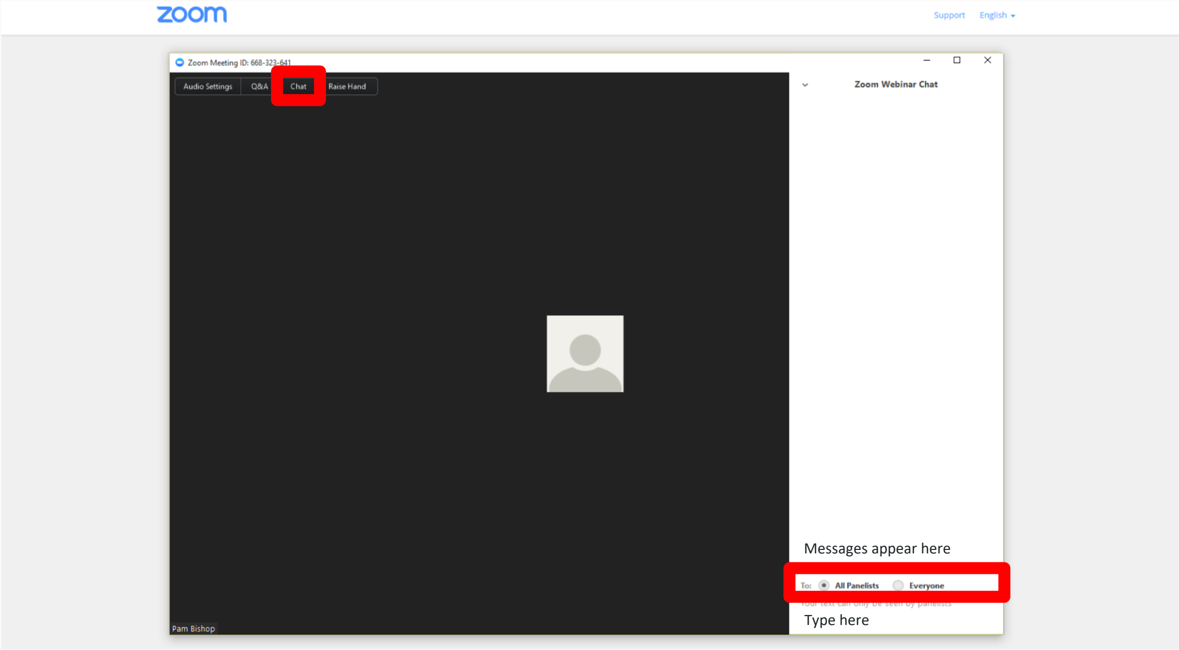
Biology and Mathematics,

University of Tennessee, Knoxville



NIMBioS is supported by the National Science Foundation through NSF Award #DBI-1300426, with additional support from The University of Tennessee, Knoxville. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

HOW TO INTERACT TODAY



Today's Presenter:

Shelby M. Scott

PhD Candidate, *University of Tennessee, Knoxville*

This project was supported in part by a fellowship award through the National Defense Science and Engineering Graduate (NDSEG) Fellowship Program, sponsored by the Air Force Research Laboratory (AFRL), the Office of Naval Research (ONR) and the Army Research Office (ARO).

NDSEG
NATIONAL DEFENSE SCIENCE & ENGINEERING GRADUATE FELLOWSHIP

Objectives of the Mathematics of Gun Violence Workshop

- Review the existing approaches on the mathematics and modeling of gun violence
- Identify and prioritize areas in the field that require further research
- Develop cross-disciplinary collaborations to gain new perspectives
- Suggest research and data-collection that could assist evidence-based policy recommendations

Objectives of the Mathematics of Gun Violence Workshop

- **Review the existing approaches on the mathematics and modeling of gun violence**
- **Identify and prioritize areas in the field that require further research**
- Develop cross-disciplinary collaborations to gain new perspectives
- Suggest research and data-collection that could assist evidence-based policy recommendations

Webinar Objectives

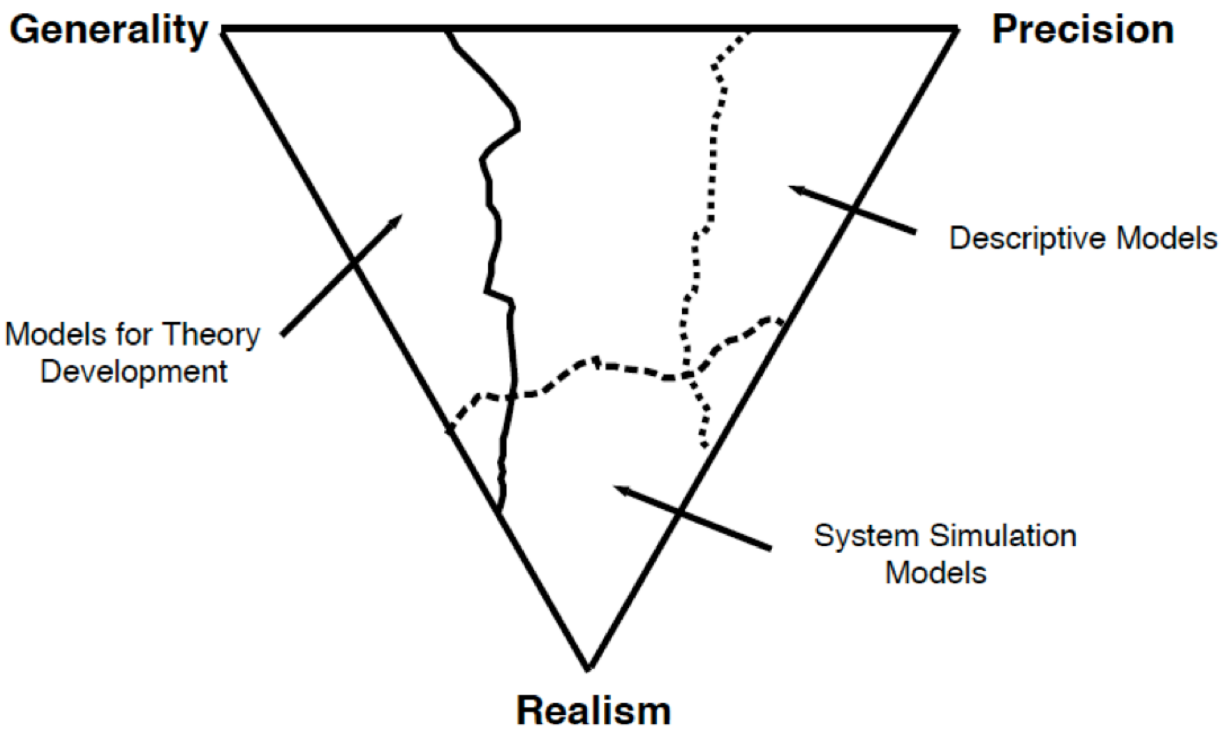
- Terminology
  - The process of modeling
  - Mathematical models
  - Statistical models
  - Gun crime
- Existing Gun Crime and Gun Violence Models
  - Analyzing spatio-temporal distribution of gun crime and gun violence
  - Impacts of constraining gun availability on crime and violence
  - Effects of population characteristics on crime and violence
  - Intervention attempts and their impacts
- Questions

Terminology

Objectives of Models

- Provide a framework to assemble bodies of facts/observations (standardize data collection)
- Clarify hypotheses and chains of argument
- Identify key components in systems
- Allow investigation while accounting for societal or ethical constraints
- Provide the ability to consider spatial and temporal change simultaneously
- Prompt tentative and testable hypotheses
- Serve as a guide to decision making in circumstances where action cannot wait for detailed studies
- Provide a means to look at general patterns and trends
- Predict how a system will behave under different management, and control the system to meet some objective

Models and tradeoffs



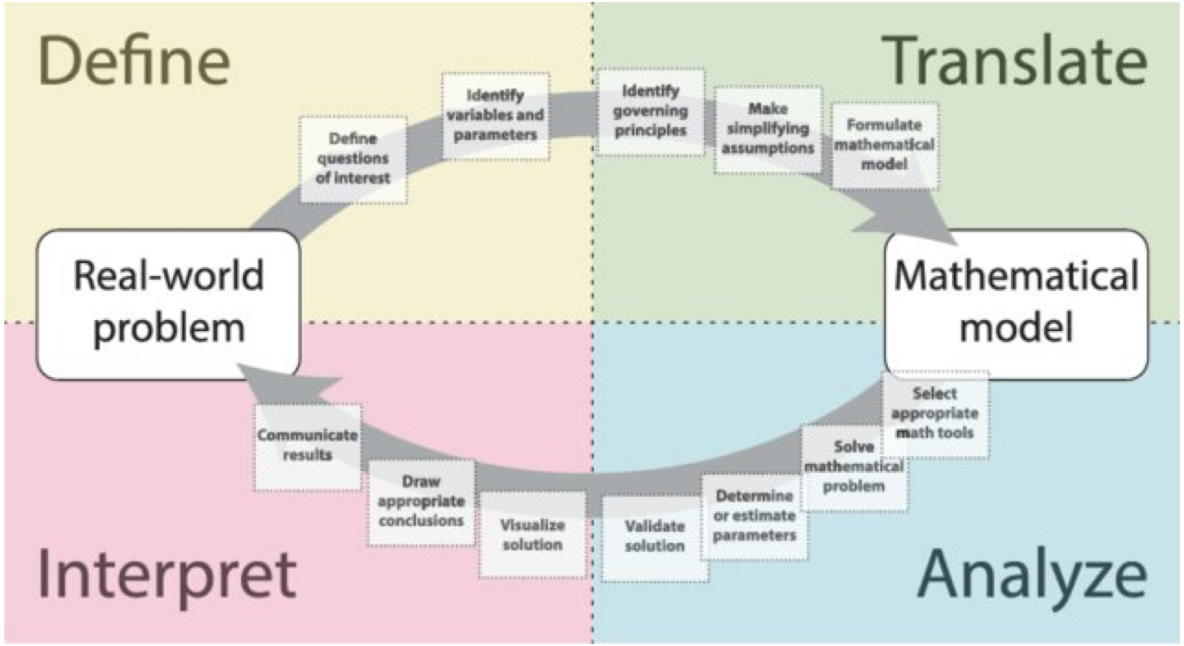
No one model can do everything!

Model evaluation

- Given the many objectives for models, we should expect there to be multiple criteria for determining whether a model is useful
- Before developing a model, criteria should be established for evaluating its use
- Evaluation procedures should account for constraints of data, effort, resources, and computation
- Evaluation criteria should be taken into consideration when assessing methods, level of detail, scale, and what can be ignored when deciding on a model

Mathematical models

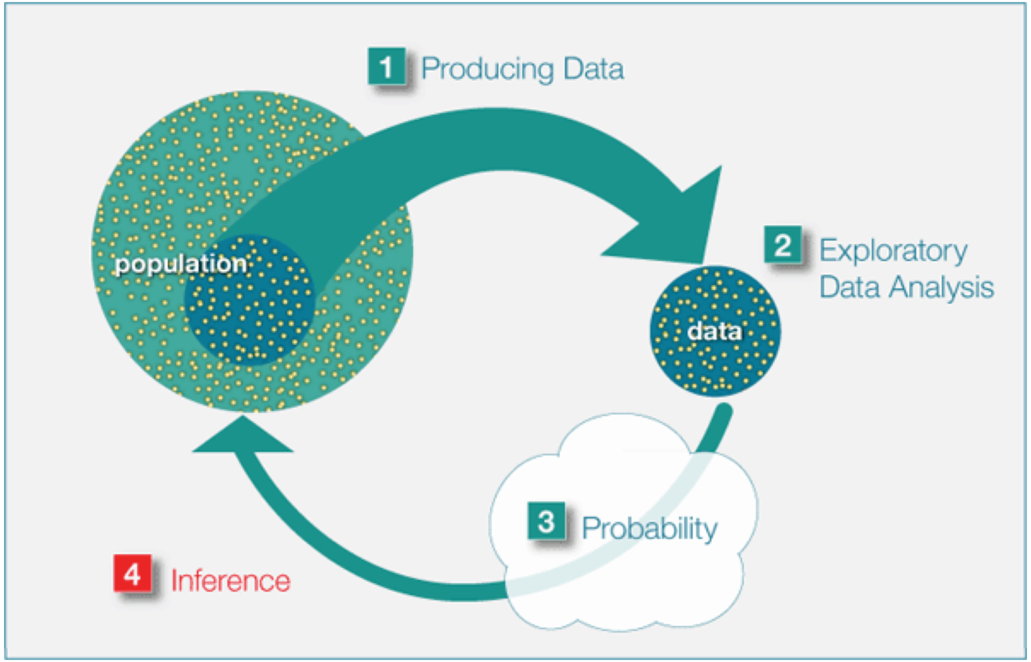
Elucidate key features of a system and ignore what is not relevant to the specific question to be answered



Smith? 2008, Yong et al. 2015

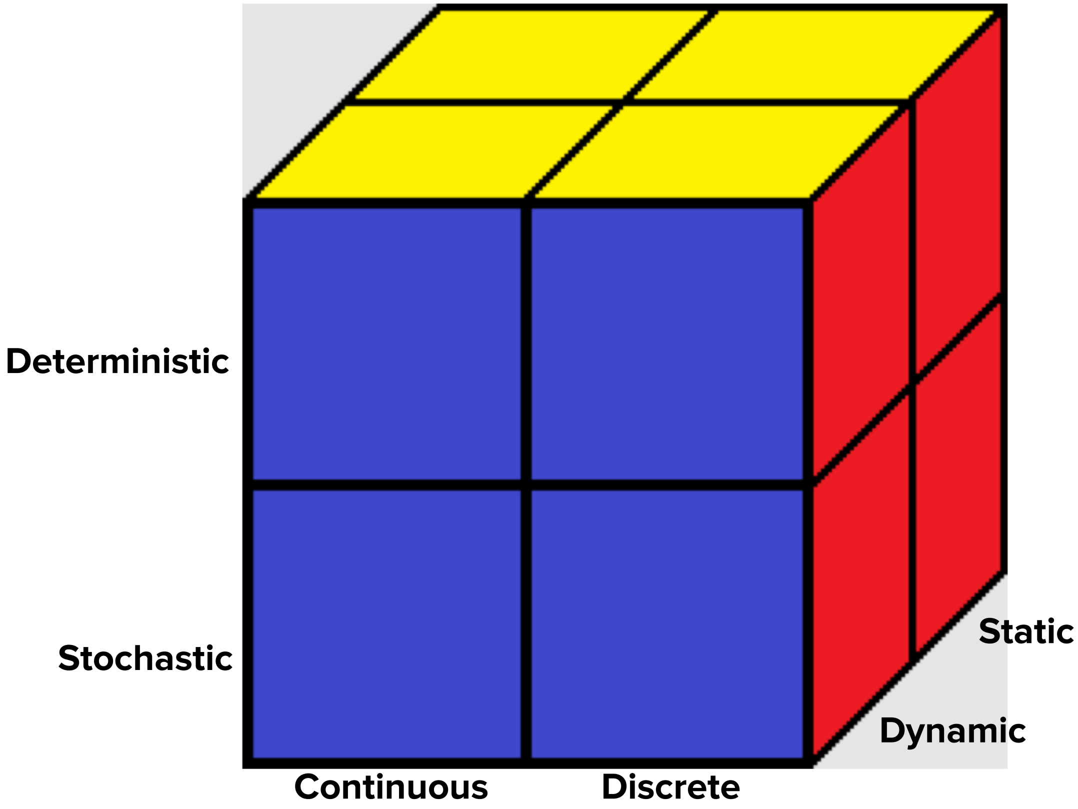
Statistical models

Methods of determining the properties of a given system in terms of relationships between system components



https://bolt.mph.ufl.edu/6050-6052/unit-4/

Types of Models



Types of Models

- **Deterministic** - assumes the outcomes are completely determined by the model
- **Stochastic** - Focuses on the probability distributions of various outcomes in the system
- **Continuous** - allows variables to change at any point in time
- **Discrete** - tracks changes to variables in discrete time steps
- **Dynamic** - describes how a system changes over time
- **Static** - describes the state of a system at one point in time

Otto and Day 2011

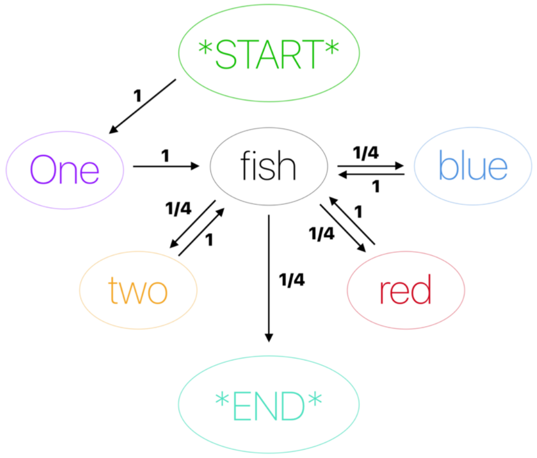
Examples of Mathematical Models

- Deterministic, dynamic, continuous
- Example: Ordinary differential equation (ODE) model of infectious disease spread (Kermack-McKendrick)

$$\frac{dS}{dt} = -\beta\frac{SI}{N}$$
$$\frac{dI}{dt} = \beta\frac{SI}{N} - \gamma I$$
$$\frac{dR}{dt} = \gamma I$$

http://www.public.asu.edu/~hnesse/classes/sir.html

- Stochastic, dynamic, discrete
- Example: Markov model of sentence structure



One fish two fish red fish blue fish

https://hackernoon.com/from-what-is-a-markov-model-to-here-is-how-markov-models-work-1ac5f4629b71

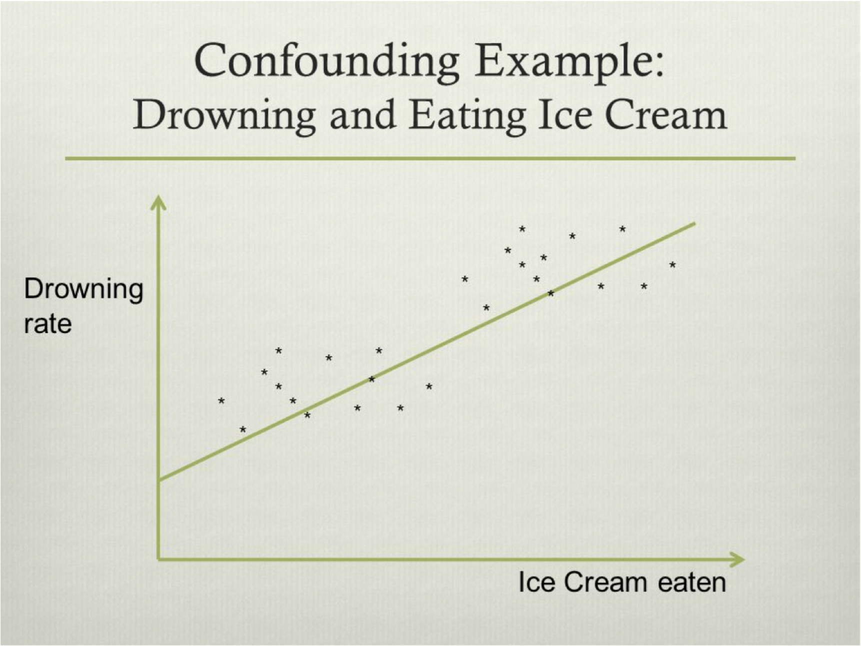
Types of Statistical Models

- **Regression** - Method to determine relationships between two or more variables
- **Time Series Analysis** - Analyzes patterns in a sequence of observations over time
- **Markov Models** - Used to explain cases in which the future of the process depends only on the present, not the past
- **Spatial Modeling** - assesses the relationship between events and their spatial distribution
- **Multivariate Statistics** - considers simultaneous interactions between a number of factors

Bennyan et al., 2003, Box et al., 2015, Draper and Smith 2014, Ripley 2004, Tinsley and Brown 2000, Unkel et al., 2011

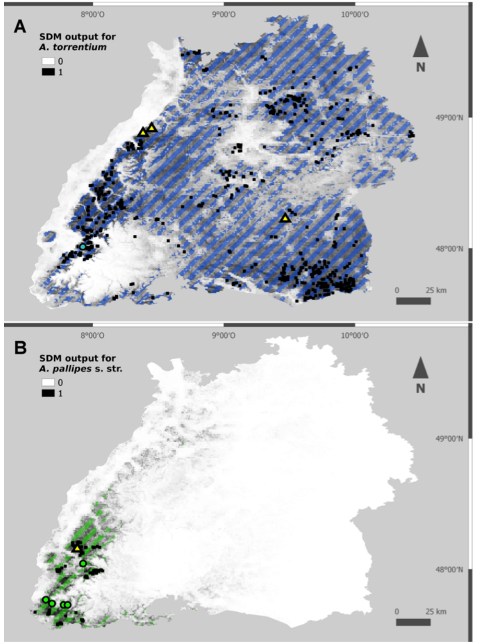
Examples of Statistical Models

- Regression
- Example: ice cream and drowning



https://slideplayer.com/slide/3379840/

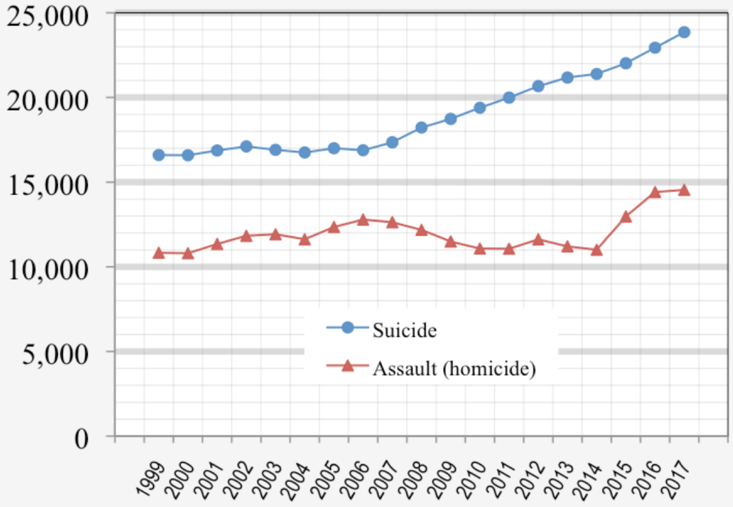
- Spatial Modeling
- Species distribution of endangered crayfish



https://www.researchgate.net/publication/312497333_Niche-based_species_distribution_models_and_conservation_planning_for_endangered_freshwater_crayfish_in_south-western_Germany

Gun Violence and Crime in the United States (2011)

- 467,321 persons were victims of a crime committed with a firearm
- Firearm crimes comprised 8% of all violent crimes (rape, assault, etc.)
- There were 11,101 firearm homicides
- Firearms were used in:
  - 68 % of murders
  - 41 % of robbery offenses
  - 21 % of aggravated assaults

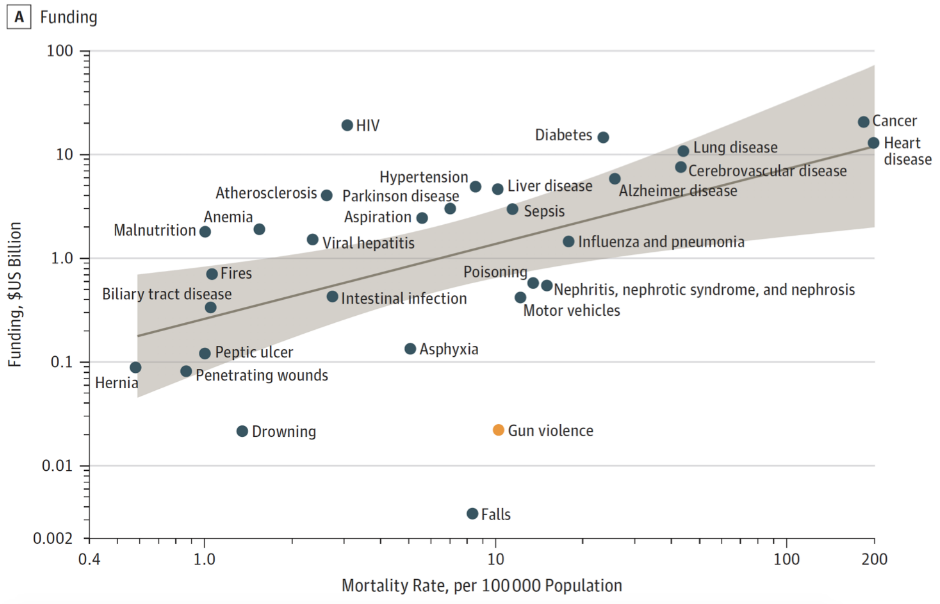


Gun-related deaths in the United States

https://injuryfacts.nsc.org/home-and-community/safety-topics/guns/data-details/
https://www.nij.gov/topics/crime/gun-violence/pages/welcome.aspx

Gun violence research - some history

- (1993) Kellerman et al. publish *Gun ownership as a risk factor for homicide in the home*
- (1996) Dickey Amendment: “none of the funds made available for injury prevention and control at the Centers for Disease Control and Prevention (CDC) may be used to advocate or promote gun control”
- (2012) Extended to also cover the National Institutes of Health (NIH)
- (2017) Gun violence is the least-researched cause of death and the second least-funded cause of death after falls



Kellerman et al. 1993, Rostron 2018, Stark and Shah 2017, Winker et al., 2016

Existing Gun Violence and Gun Crime Models

Analyzing Spatio-temporal Distribution of Gun Violence and Gun Crime

Spatial Statistics Approaches

- Method: Distance matrices and *K*-functions for spatial dependence
  - Question of interest: Is there a concentration of shootings near schools?
  - Reference: Barboza 2018
- Method: Bayesian spatio-temporal point process
  - Question of interest: Distinguish between clustered but non-diffusing gun violence and clustered gun violence resulting from diffusion
  - Reference: Loeffler and Flaxman 2017
- Method: Network-based computation methods
  - Question of interest: Estimate the strength and extent of the spatial influence of physical features on gun violence
  - Reference: Xu and Griffiths 2017
- Method: Cluster detection
  - Question of interest: Investigate whether different homicide types have different patterns of clustering and movement
  - References: Zeoli et al., 2015

Methods of Hot Spot Analysis

- Methods:
  - Marked point process
  - Growth curve regression
- Questions of interest::
  - Show how point process models of crime can be extended to capture both short-term and long-term patterns of risk
  - Uncover distinctive developmental trends in gun assault incidents at street segments and intersections

$$\lambda(x, y, t) = \mu(x, y) + \sum_{t>t_i} g(x - x_i, y - y_i, t - t_i, M_i). \quad (6)$$

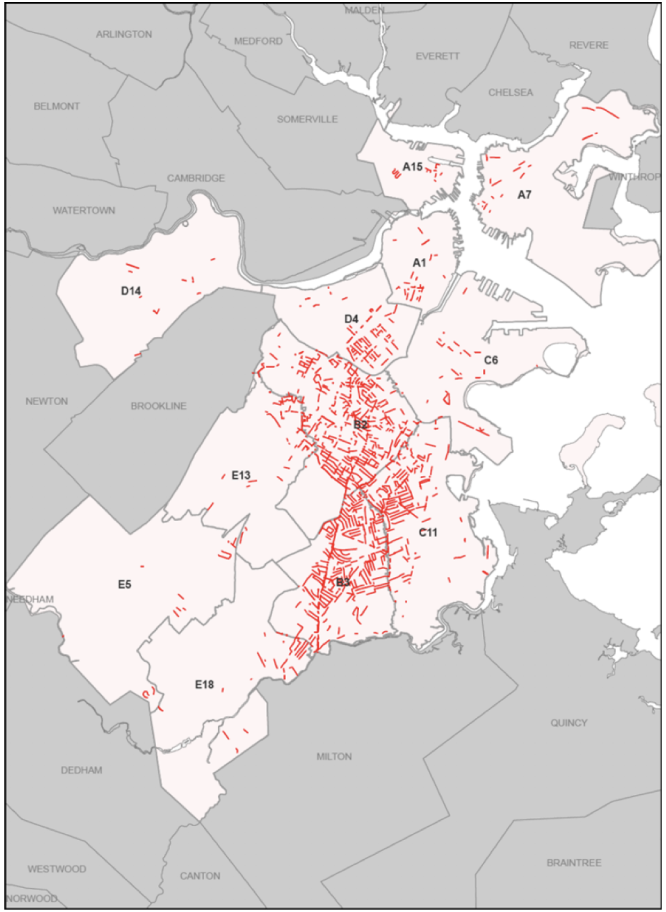


Fig. 5 The spatial distribution of micro places with stable and volatile concentrations of serious gun violence in Boston

Mohler 2014, Braga et al., 2010

Other Methods of Cluster Detection and Analysis

- Method: Risk Terrain Modeling (RTM) with environmental risk factors
- Question of interest: Investigate the application of RTM to forecast gang violence and predict future gang assaults and gang homicides
- Reference: Valasik et al., 2018

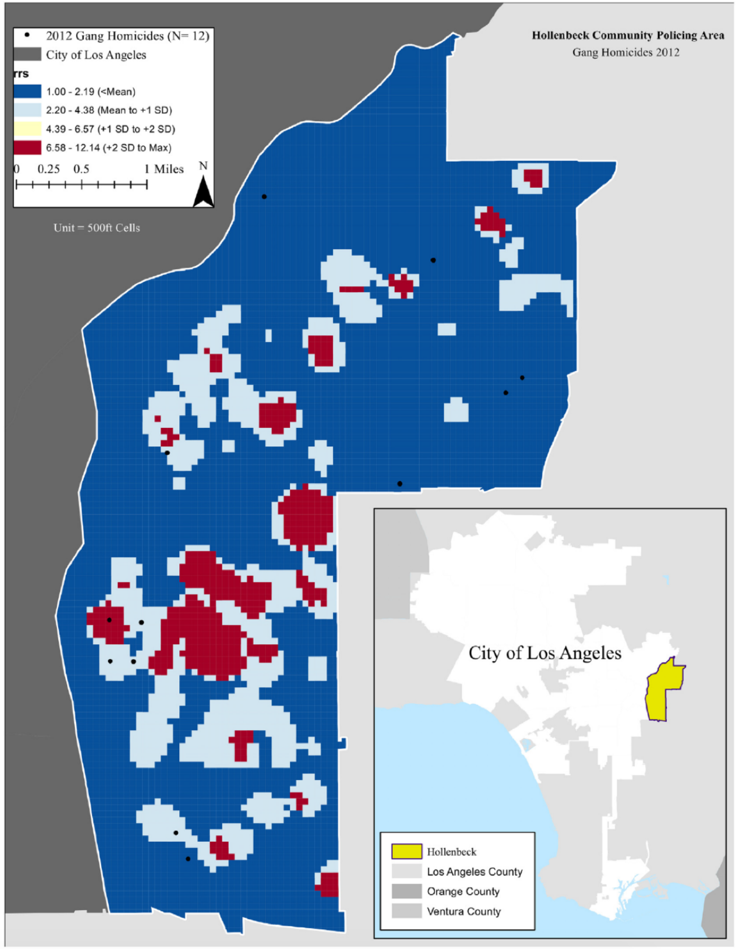


Fig. 2. Final risk map and gang homicides in 2012.

Comparing Hot Spots to RTM

- Objective: Assess the possible differences in the accuracy and precision of two methodological mapping techniques as predictors of gun crime
- Method: RTM, Nearest Neighbor Hierarchical (Nnh)

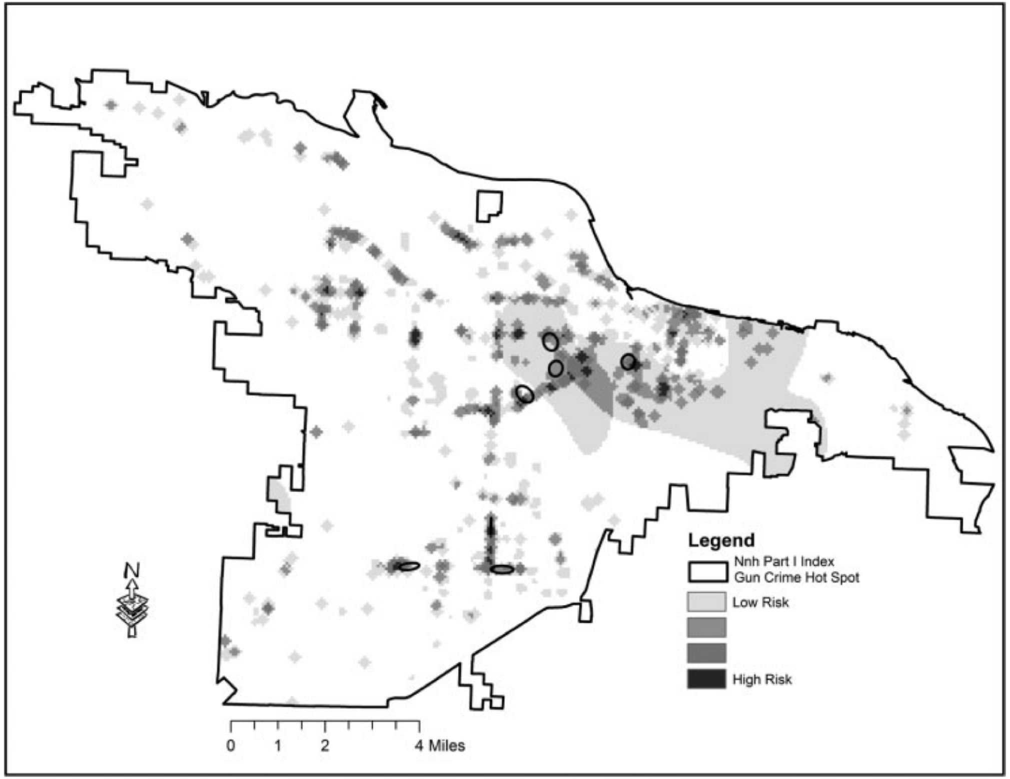


Figure 1. RTM risky areas and Nnh hot spots in Little Rock, Arkansas.

Drawve et al., 2014

Impacts of Constraining Gun Availability on Violence and Crime

Mathematical Modeling of Gun Constraints

- Method: Game Theory
  - Question of interest: Construct a simple victim-criminal interaction model to provide insights about the desirability of gun crime legislation
  - Reference: Taylor 1995
- Method: Game Theory and Probabilistic Analysis
  - Question of interest: Present a mathematical framework to analyze the debate about gun control
  - Reference: Wodarz and Komarova 2013

Statistical Analysis of Gun Constraints

- Regression
  - Two stage least-squares
    - Question of interest: Determine the effects that gun control restrictions and gun prevalence have on rates of violence and crime
    - Reference: Kleck and Patterson 1993
  - Limited information maximum likelihood
    - Question of interest: Examine the relationship between gun availability and crime in a cross-national sample of cities
    - Reference: Altheimer 2010
- Cross-sectional Time Series
  - Question of interest: Determine whether restrictiveness-permissiveness of state gun laws or gun ownership are associated with mass shootings
  - Reference: Reeping et al. 2019

Effects of Population Characteristics on Violence and Crime

Modeling the Effects of Population Characteristics

- Method: Probabilistic Contagion Model
  - Question of interest: Evaluate the ability of a social network epidemic model to predict who will become a victim of gun violence
  - Reference: Green et al., 2017
- Method: Network Modeling
  - Question of interest: Examine the role of neighborhood-level criminal networks in shaping the distribution of crime throughout cities
  - Reference: Bastomski et al., 2017

Statistical Analysis of Population Characteristics

- Method: Multivariate Statistical Methods
  - Question of interest: Examine the epidemiology of nonfatal firearm violence on the Westside of Chicago
  - Question of interest: Assess the relationship between perceived collective efficacy, its subscales of social cohesion and informal social control, and exposure to gun violence
  - Reference: Fitzpatrick et al. 2018, Riley et al. 2017
- Method: Trend analysis, regression
  - Question of interest: Examine Chicago crime data to see if there is evidence of a "Ferguson Effect" and to see if the availability of illegal firearms can explain the violence rise in Chicago
  - Question of interest: Examine the relationships between isolated youth, illegal gun availability, structural disadvantage, and Southern culture with gun crime
  - Reference: Towers and White 2017, Dierenfeldt et al. 2017
- Method: Machine learning and random forest algorithms
  - Question of interest: Identify an optimal set of predictors for urban interpersonal firearm violence rates using a broad set of community characteristics
  - Reference: Goin et al. 2017

Statistical Analysis of Population Characteristics

- Objective: Explore whether or not contagion is evident in more high-profile incidents, such as school shootings and mass killings
- Method: Contagion model
- Results: Mass killings involving firearms are incented by similar events in the immediate past, as are school shootings

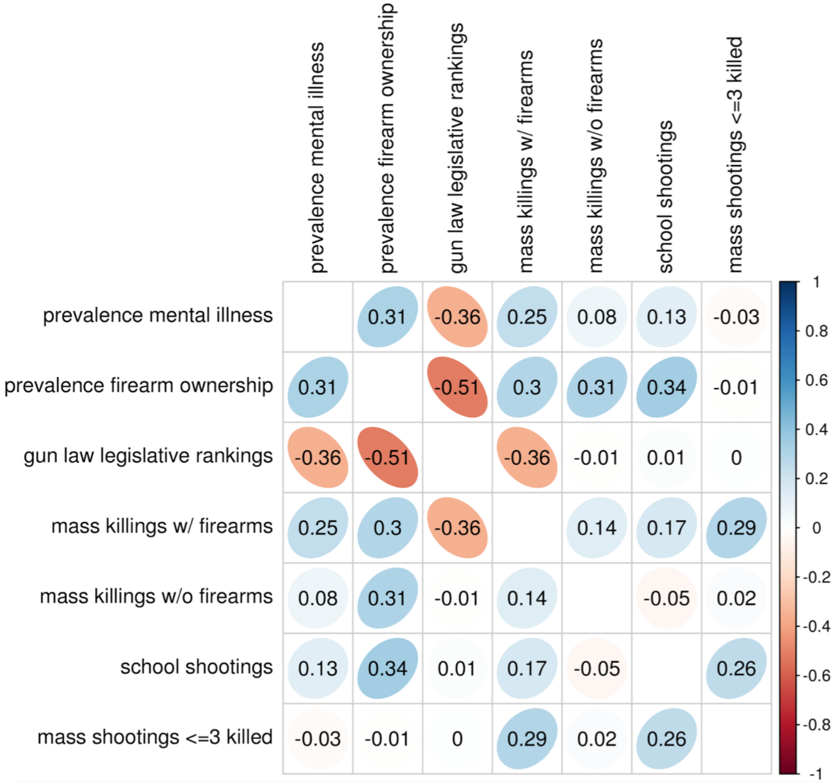


Fig 2. Relationship of state prevalence of firearm ownership, mental illness, and state rankings of strength of firearm legislation, to the state incidence of mass killings, school shootings, and mass shootings.

Towers 2015

Intervention Attempts and their Impacts

Modeling Intervention Attempts and their Impacts

- Method: Ordinary Differential Equations
  - Question of interest: Introduce a Susceptible-Transmitter-Victim epidemic model to explore the impact of violence interruption on the spread of violence
  - Reference: Wiley et al. 2016

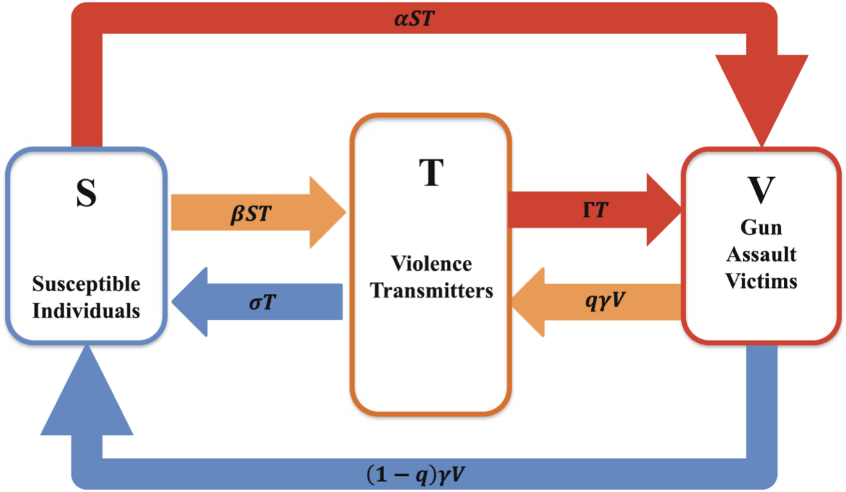


Fig. 1 Flow diagram for STV model

Statistical Analysis of Intervention Attempts and their Impacts

- Method: Autoregressive Integrated Moving Average (ARIMA) Models
  - Question of interest: Test the impacts of Project Longevity on group-involved shootings and homicides in New Haven, Connecticut
  - Question of interest: Identify the impact of the Strategic Subjects List (SSL) pilot on individual- and city-level gun violence and to test possible drivers of results
  - References: Sierra-Arevalo et al. 2017, Saunders et al. 2016
- Method: Multivariate and exploratory structural equation modeling
  - Question of interest: Measure perceived norms and viewpoints regarding gun violence in response to implementing the Safe Streets intervention in Baltimore, Maryland
  - Reference: Milam et al. 2017
- Method: Bayesian hierarchical models
  - Question of interest: Test the relationship between neighborhood misdemeanor policing and homicide
  - Reference: Cerda et al. 2009

Conclusions

Conclusions

- There is limited published research on the mathematics of gun violence and gun crime
- The majority of models are statistical in nature, with most using regression methods
- A number of models have analyzed the spatio-temporal spread of crime and observed the effects of population characteristics
- Fewer published studies observe the impacts of constraining gun availability and intervention attempts

Other Mathematical Approaches to Gun Violence and Gun Crime

- Difference Equations
- Partial Differential Equations (PDEs)
- Cellular Automata
- Agent-Based Models (ABMs)
- Optimal Control Theory

Questions?

Workshop Website:

http://www.nimbios.org/workshops/WS_gunviolence

References

- J C Benneyan, R C Lloyd, and P E Plsek. *Statistical process control as a tool for research and healthcare improvement*. BMJ Quality & Safety, 12(6):458-464, 2003.
- George E.P. Box, Gwilym M. Jenkins, Gregory C. Reinsel, and Greta M. Ljung. T*ime Series Analysis: Forecasting and Control*. Wiley Series in Probability and Statistics. John Wiley & Sons, Inc., 2015.
- Norman R. Draper and Harry Smith. *Applied Regression Analysis*. Wiley Series in Probability and Statistics. John Wiley & Sons, Inc., 2014.
- Sarah P. Otto and Troy Day. *A Biologist's Guide to Mathematical Modeling in Ecology and Evolution*. Princeton University Press, 2011.
- RD Ripley. *Spatial Statistics*. John Wiley & Sons, Inc., 1981, 2004.
- Smith?, Robert *Modelling Disease Ecology with Mathematics*, volume 2 of *AIMS Series on Differential Equations & Dynamical Systems*. American Institute of Mathematical Sciences, 2008.
- Howard E.A. Tinsley and Steven D. Brown. *Multivariate statistics and mathematical modeling*. In Handbook of Applied Multivariate Statistics and Mathematical Modeling, pages 3-36. Academic Press, San Diego, 2000.
- Steen Unkel, C. Paddy Farrington, Paul H. Garthwaite, Chris Robertson, and Nick Andrews. *Statistical methods for the prospective detection of infectious disease outbreaks: a review.* Journal of the Royal Statistical Society: Series A (Statistics in Society), 175(1): 49-82 2012.
- Yong, Darryl & Levy, Rachel & Lape, Nancy. *Why No Difference? A Controlled Flipped Classroom Study for an Introductory Differential Equations Course*. PRIMUS. 25. 907-921, 2015.

References

- Gia Barboza-Salerno. *A secondary spatial analysis of gun violence near Boston schools: a public health approach.* Journal of Urban Health, 95(3):344{360, 04 2018.
- Arthur L. Kellermann, Frederick P. Rivara, Norman B. Rushforth, Joyce G. Banton, Donald T. Reay, Jerry T. Francisco, Ana B. Locci, Janice Prodzinski, Bela B. Hackman, and Grant Somes. *Gun ownership as a risk factor for homicide in the home*. New England Journal of Medicine, 329(15):1084-1091, 1993.
- C Loeffler and S Flaxman. *Is gun violence contagious? a spatiotemporal test.* Journal of Quantitative Criminology, August 2018.
- A. Rostron *The Dickey Amendment on Federal Funding for Research on Gun Violence: A Legal Dissection.* Am J Public Health., 108(7):865-867, 2018.
- DE Stark and NH Shah. F*unding and publication of research on gun violence and other leading causes of death*. JAMA, 317(1):84-86, 2017.
- Margaret A Winker, Kamran Abbasi, and Frederick P Rivara. *Unsafe and understudied: the US gun problem*. BMJ, 352, 2016.
- Jie Xu and Elizabeth Griffiths. *Shooting on the street: Measuring the spatial influence of physical features on gun violence in a bounded street network*. Journal of Quantitative Criminology, 33(2):237-253, Jun 2017.
- April M. Zeoli, Sue Grady, Jesenia M. Pizarro, and Chris Melde. *Modeling the movement of homicide by type to inform public health prevention efforts*. American Journal of Public Health, 105(10):2035-2041, 2015.

References

- Anthony A. Braga, Greg Zimmerman, Lisa Barao, Chelsea Farrell, Rod K. Brunson, and Andrew V. Papachristos. *Street gangs, gun violence, and focused deterrence: Comparing place-based and group-based evaluation methods to estimate direct and spillover deterrent effects*. Journal of Research in Crime and Delinquency, 2010.
- Grant Drawve, Stacy C. Moak, and Emily R. Berthelot. *Predictability of gun crimes: a comparison of hot spot and risk terrain modelling techniques*. Policing and Society, 26(3):312-331, 2016.
- Gary Kleck and E. Britt Patterson. *The impact of gun control and gun ownership levels on violence rates*. Journal of Quantitative Criminology, 9(3):249-287, 1993.
- George Mohler. *Marked point process hotspot maps for homicide and gun crime prediction in Chicago*. International Journal of Forecasting, 30:491-497, 2014.
- Paul M Reeping, Magdalena Cerda, Bindu Kalesan, Douglas J Wiebe, Sandro Galea, and Charles C Branas. *State gun laws, gun ownership, and mass shootings in the US: cross sectional time series*. BMJ, 364, 2019.
- Robert Taylor. *A game theoretic model of gun control*. International Review of Law and Economics, 15(3):269-288, 1995.
- Matthew Valasik. *Gang violence predictability: Using risk terrain modeling to study gang homicides and gang assaults in East Los Angeles*. Journal of Criminal Justice, 58:10 { 21, 2018.
- Dominik Wodarz and Natalia L. Komarova. *Dependence of the firearm-related homicide rate on gun availability: A mathematical analysis*. PLOS ONE, 8(7):1{13, 07 2013.

References

- Sara Bastomski, Noli Brazil, and Andrew V. Papachristos. *Neighborhood co-offending networks, structural embeddedness, and violent crime in Chicago*. Social Networks, 51:23-39, 2017.
- Rick Dierenfeldt, Timothy C. Brown, and Rocio A. Roles. *Re-considering the structural covariates of gun crime: An examination of direct and moderated effects*. Deviant Behavior, 38(2):208{225, 2017.
- Veronica Fitzpatrick, Myles Castro, Jacquelyn Jacobs, Nadew Sebro, Jhoanna Gulmatico, Maureen Shields, and Sharon Marie Homan. *Nonfatal firearm violence trends on the westside of Chicago between 2005 and 2016*. Journal of Community Health, 2018.
- Dana E. Goin, Kara E. Rudolph, and Jennifer Ahern. *Predictors of firearm violence in urban communities: A machine-learning approach*. Health & Place, 51:61 – 67, 2018.
- Ben Green, Thibaut Horel, and Andrew B Papachristos. *Modeling contagion through social networks to explain and predict gunshot violence in Chicago, 2006 to 2014*. JAMA Internal Medicine, 2017.
- Carley Riley, Brita Roy, Nurit Harari, Anita Vashi, Pina Violano, Ann Greene, Georgina Lucas, Jerry Smart, Teresa Hines, Stacy Spell, Sharon Taylor, Barbara Tinney, Maurice Williams, and Emily A. Wang. *Preparing for disaster: a cross-sectional study of social connection and gun violence.* Journal of Urban Health, 94(5):619-628, 2017.
- S Towers, A Gomez-Lievano, M Khan, A Mubayi, and C Castillo-Chavez. *Contagion in mass killings and school shootings*. PLoS ONE, 10(7):e117-259, 2015.
- Sherry Towers and Michael D. White. *The Ferguson effect, or too many guns?* Significance, 14(2):26-29, 2017.

References

- Magdalena Cerda, Melissa Tracy, Steven F. Messner, David Vlahov, Kenneth Tardi, and Sandro Galea. *Misdemeanor policing, physical disorder, and gun-related homicide: A spatial analytic test of "broken-windows" theory*. Epidemiology, 20(4):533-541, 2009.
- Adam J. Milam, Shani A. Buggs, C. Debra M. Furr-Holden, Philip J. Leaf, Catherine P. Bradshaw, and Daniel Webster. *Changes in attitudes toward guns and shootings following implementation of the Baltimore Safe Streets intervention*. Journal of Urban Health, 93(4):609-626, 2016.
- Jessica Saunders, Priscillia Hunt, and John S. Hollywood. *Predictions put into practice: a quasi-experimental evaluation of Chicago's predictive policing pilot*. Journal of Experimental Criminology, 12(3):347-371, 2016.
- Michael Sierra-Arevalo, Yanick Charette, and Andrew V. Papachristos. Evaluating the effect of Project Longevity on group-involved shootings and homicides in New Haven, Connecticut. Crime & Delinquency, 63(4):446-467, 2017.
- Shari A. Wiley, Michael Z. Levy, and Charles C. Branas. *The Impact of Violence Interruption on the Diffusion of Violence: A Mathematical Modeling Approach*, pages 225-249. Springer International Publishing, 2016.

Spatial Statistics Approaches

- Question: Is there a concentration of shootings near schools?
- Method: Distance matrices and *K*-functions to determine spatial dependence
- Results: There is non-random clustering of shootings and a greater number of shootings were clustered within short distances of schools than would be expected if there were no spatial dependence

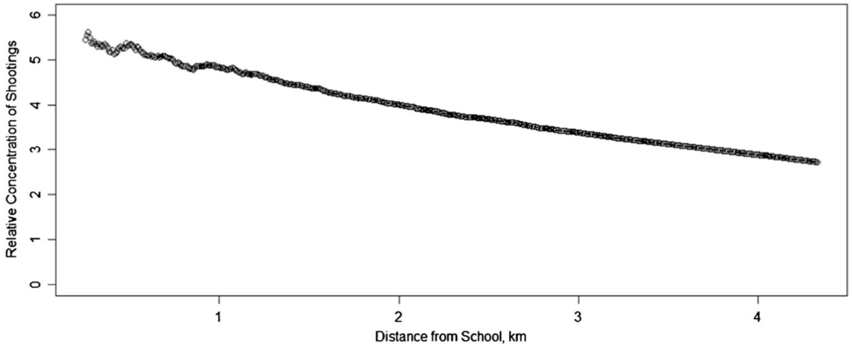


Fig. 10 Relative concentration of shootings and distance from Boston Public School (km)

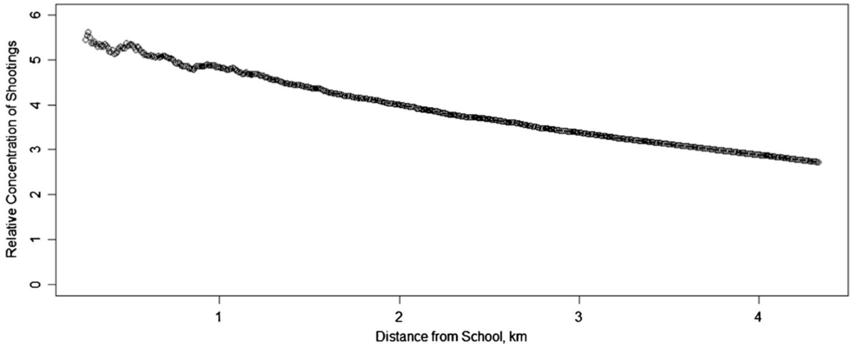


Fig. 10 Relative concentration of shootings and distance from Boston Public School (km)

Barboza 2018

Spatial Statistics Approaches

- Objective: Distinguish between clustered but non-diffusing gun violence and clustered gun violence resulting from diffusion
- Method: Bayesian spatio-temporal point process and classic space/time interaction tests
- Results: Contemporary urban gun violence does diffuse in both space and time, but only slightly

$$\lambda(x,y,t) = m_0 \cdot \mu(x,y,t) + \theta \sum_{i:t_i<t} \omega \exp(-\omega(t-t_i))$$

$$\frac{1}{2\pi\sigma^2} \exp\left(-\left((x-x_i)^2 + (y-y_i)^2\right)/(2\sigma^2)\right)$$

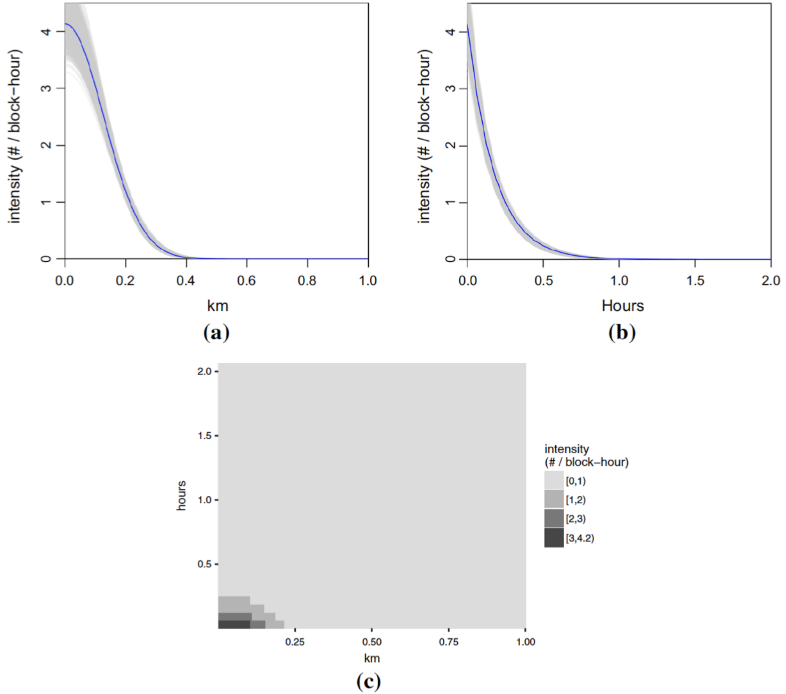


Fig. 2 The self-excitatory component of the Hawkes process, corresponding to the product of a spatial and temporal kernel, is visualized in space **a** at time $t = 0$, in time **b** at distance $s = 0$, and in space/time **c**. In **a** and **b** the *blue line* is the mean of the posterior distribution. The *gray lines* show samples from the posterior distribution, reflecting the (small amount) of posterior uncertainty in the parameter estimates (Color figure online)

Loeffler and Flaxman 2017

Spatial Statistics Approaches

- Objective: Estimate the strength and extent of the spatial influence of physical features on gun violence
- Method: Network-based computation methods
- Results: Liquor stores, grocery stores, bus stops, and residential foreclosures are shooting attractors in Newark, NJ and the magnitude is strongest in the immediate vicinity of each physical feature

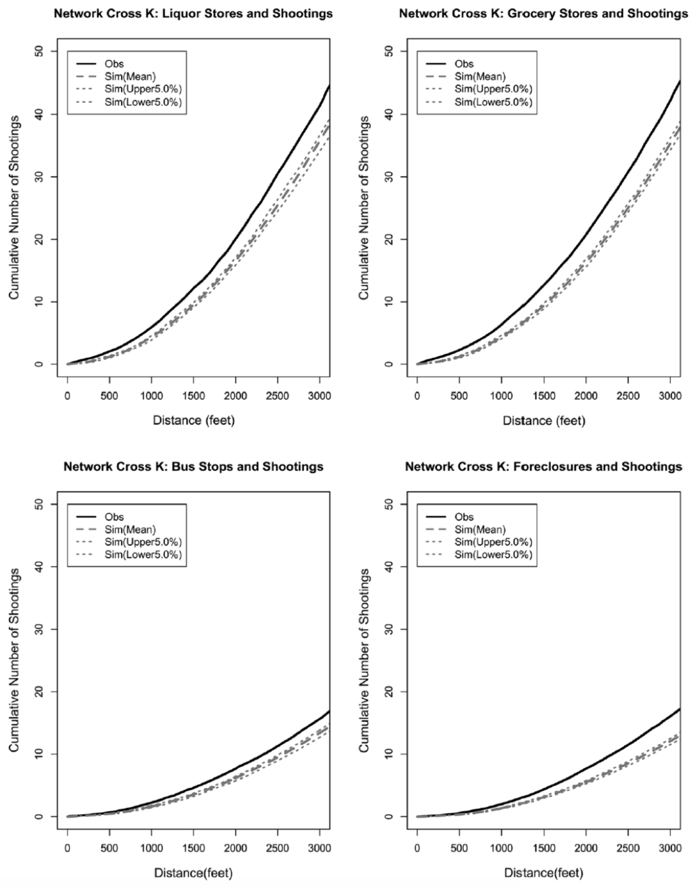


Fig. 1 Network Cross K Function identifying attractors of gun violence in Newark, NJ 2012

Xu and Griffiths 2017

Spatial Statistics Approaches

- Objective: Investigate whether different homicide types have different patterns of clustering and movement
- Methods: Cluster detection
- Results: Gang motivated homicides cluster and diffuse and overlap with revenge and drug-related homicides. Escalating disputes and non-intimate partner familial homicides cluster but do not diffuse. Intimate partner and robbery homicides do not cluster

$$(1)\quad E[h] = p \times H/P, \qquad (2)\quad \left(\frac{h}{E[h]}\right)^{e}\left(\frac{H-h}{H-E[h]}\right)^{c-e} I(),$$

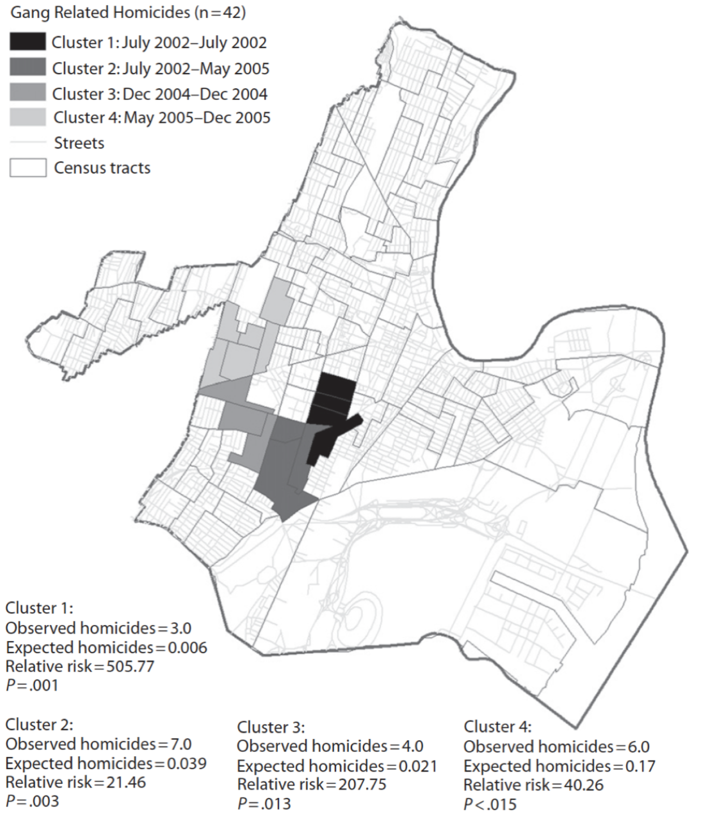


FIGURE 4—Space-time clusters of gang-motivated homicides: Newark, NJ, 1997–2007.

Zeoli 2015

Hot Spots

- Objective: Show how point process models of crime can be extended to capture both short-term and long-term patterns of risk
- Method: Marked point process
- Results: A marked point process performs better than classic hotspot methods

$$\lambda(x, y, t) = \mu(x, y) + \sum_{t>t_i} g(x - x_i, y - y_i, t - t_i, M_i). \quad (6)$$

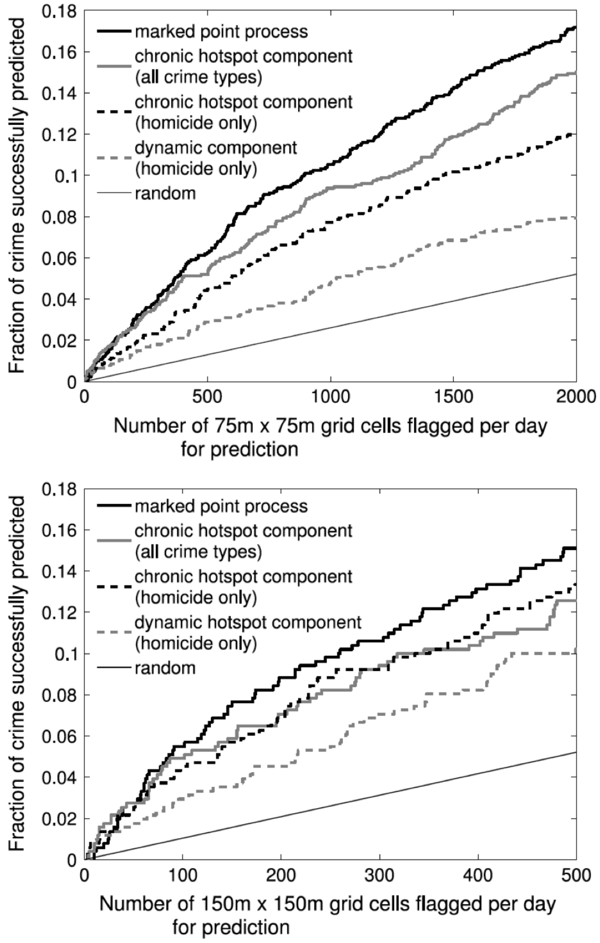


Fig. 1. Fraction of homicide crime predicted over 2010–2012 versus the number of grid cells flagged for intervention each day.

Mohler 2014

Modeling Gun Constraints

- Objective: Construct a simple victim-criminal interaction model to provide insights about the desirability of gun crime legislation
- Method: Game theory
- Results: Gun control laws that target criminals are more likely to be successful than those that attempt to induce a general scarcity of firearms

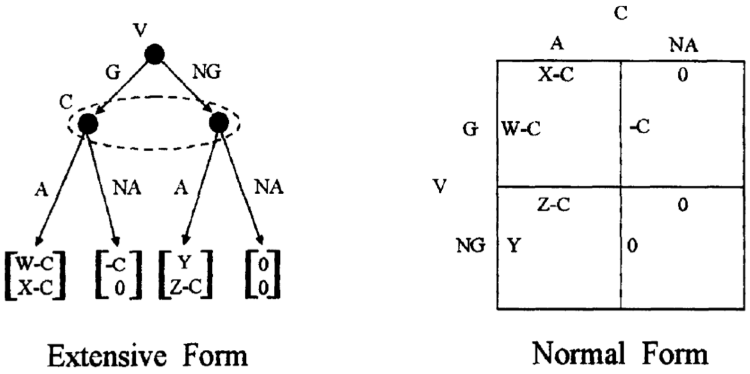


FIG. 1. The basic model.

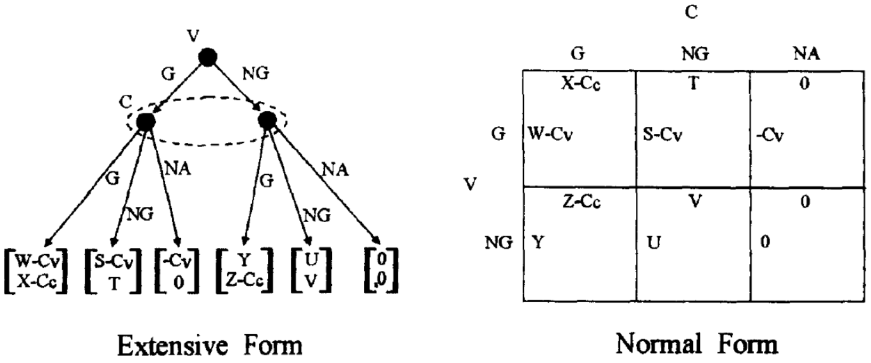


FIG. 3. A more complex model.

Taylor 1995

Modeling Gun Constraints

- Objective: Present a mathematical framework to analyze the debate about gun control
- Method: Probabilistic and game-theoretic analysis
- Results: To minimize the gun-related homicide rate, we must either have a ban on private firearms possession or allow the general population to carry guns

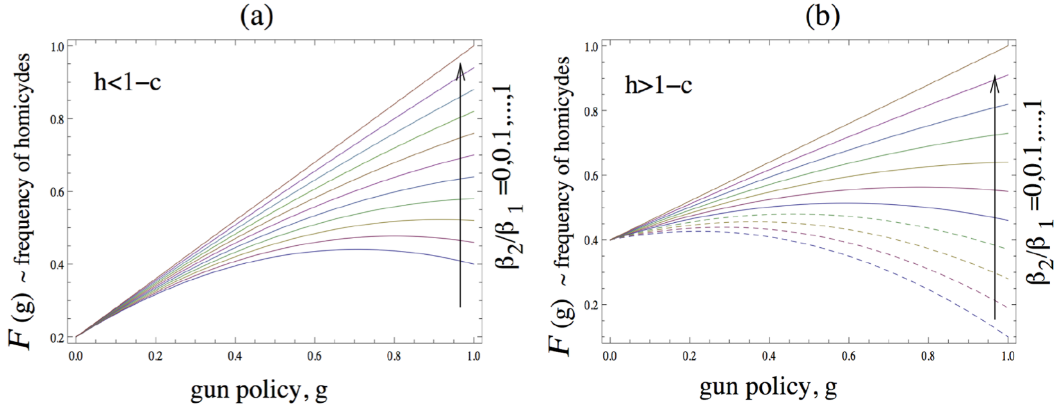


Figure 1. The rate of death caused by shooting in an one-against-one attack, as a function of the gun control policy, g, where $g=0$ corresponds to a ban of private firearm possession, and $g=1$ to the "gun availability to all" policy. (a) The fraction of people who possess the gun and have it with them when attacked is relatively low, $c=0.6<1-h$ with $h=0.2$. The different lines correspond to different values of β_2/β_1. For all values of β_2/β_1, the shooting death rate is minimal for $g=0$. (b) The fraction of people who possess the gun and have it with them when attacked is relatively high, $c=0.9>1-h$ with $h=0.4$. As long as condition (5) holds, the shooting death rate is minimal for $g=0$ (ban of private firearm possession, solid lines). If condition (5) is violated, then the shooting death rate is minimized for $g=1$ ("gun availability to all", dashed lines). doi:10.1371/journal.pone.0071606.g001

Wodarz and Komarova 2013

Statistical Analysis of Gun Restraints: Regression

- Objective: Determine the effects that gun control restrictions and gun prevalence have on rates of violence and crime
- Method: Two-stage least-squares regression
- Results:
  - Gun prevalence levels generally have no net positive effect on total violence rates
  - Homicide, gun assault, and rape rates increase gun prevalence
  - Gun control restrictions have no net effect on gun prevalence levels
  - Most gun control restrictions generally have no net effect on violence rates

Kleck 1993

Statistical Analyses of Gun Constraints: Regression

- Objective: Examine the relationship between gun availability and crime in a cross-national sample of cities
- Method: Limited information maximum least squares regression
- Results: Gun availability influences rates of assault, gun assault, robbery, and gun robbery

Altheimer 2010

Statistical Analysis of Gun Constraints: Time Series

- Objective: Determine whether restrictiveness-permissiveness of state gun laws or gun ownership are associated with mass shootings
- Method: Cross-sectional time series
- Results: States with more permissive gun laws and greater gun ownership had greater rates of mass shootings and a growing divide seems to be emerging between restrictive and permissive states

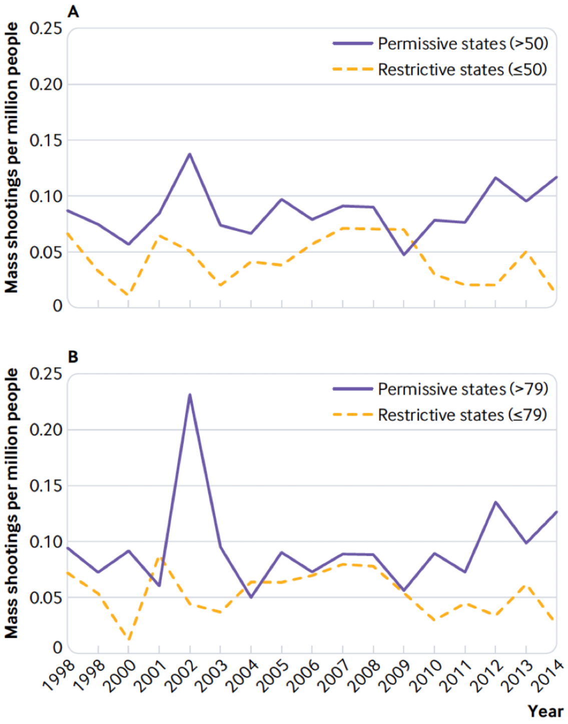


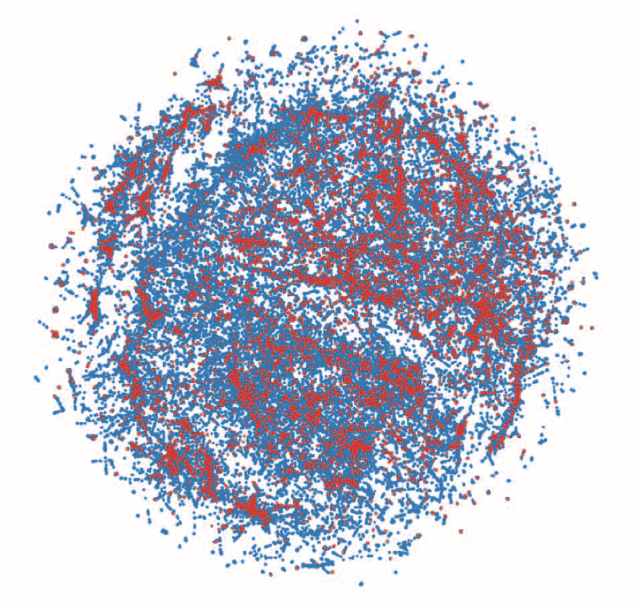
Fig 1 | Rates of mass shootings over time in restrictive versus permissive states for a restrictiveness-permissiveness score of 50 (A) and 79 (B). Years 1998-2014 were included because of the lag of the permissiveness score

Reeping 2019

Modeling the Effects of Population Characteristics

- Objective: Evaluate the ability of a social network epidemic model to predict who will become a victim of gun violence
- Method: Probabilistic contagion model
- Results: Gun violence follows an epidemic-like process of social contagion that is transmitted through networks

Figure 2. Graphical Representation of the Largest Connected Component of the Network



Each node represents a unique individual (N = 138 163). Red nodes identify subjects of a fatal or nonfatal gunshot injury (n = 9773); blue nodes represent people who were not subjects of gun violence (n = 128 390). Data are from the Chicago Police Department, as described in the Data subsection of the Methods section.

Green 2017

Modeling the Effects of Population Characteristics

- Objective: Examine the role of neighborhood-level criminal networks in shaping the distribution of crime throughout cities
- Methods: Network modeling
- Results: A neighborhood's embeddedness increases the local homicide rate, even after controlling for other factors

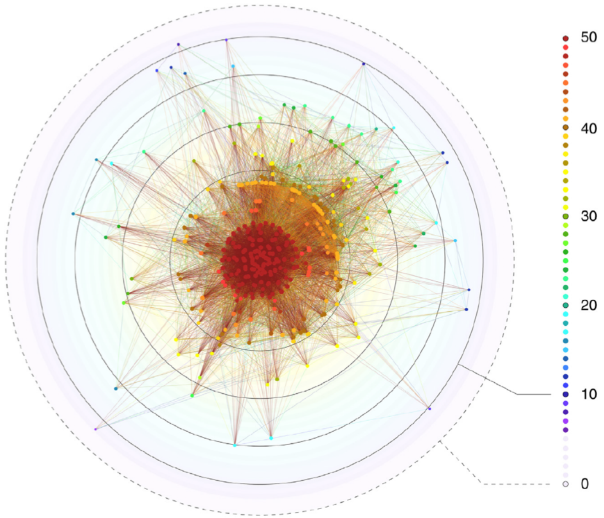


Fig. 1. Network k-core structure. The maximum k-core appears at the center, and consists of 123 neighborhood-nodes (approximately 36 percent of all nodes) that each have a degree of 50 or higher within this highly connected sub-community of nodes.

Bastomski 2017

Statistical Analysis of Population Characteristics

- Objective: Examine the epidemiology of nonfatal firearm violence on the Westside of Chicago
- Method: Pearson's Chi square, ANOVA
- Results: Nonfatal firearm violence is a major problem on the Westside of Chicago, particularly for young, black man, but the incidence of gun violence has not changed significantly between 2005 and 2016

Fitzpatrick 2018

Statistical Analysis of Population Characteristics

- Objective: Examine Chicago crime data to see if there is evidence of a “Ferguson Effect” and to see if the availability of illegal firearms can explain the violence rise in Chicago
- Method: Trend analysis, regression
- Results: There was no relationship between the timing of the 2014 Ferguson riots and the Chicago crime trends, but there is a significant association between the proliferation of firearms in Chicago and patterns in firearm-related violent crime

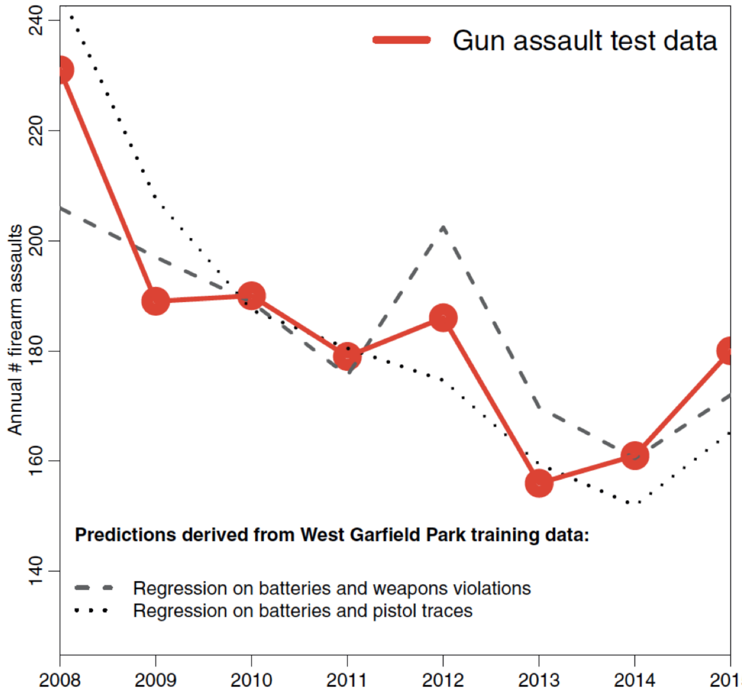


FIGURE 3 Test of the predictive capability of models for the annual number of firearm assaults, regressed on a training sample derived from data from the West Garfield Park community area, and tested with data from the Greater Grand Crossing community area

Towers 2017

Statistical Analysis of Population Characteristics

- Objective: Assess the relationship between perceived collective efficacy, its sub scales of social cohesion and informal social control, and exposure to gun violence
- Method: Chi-squared test and linear regression
- Results: There is an association between perceived collective efficacy and exposure to gun violence, but community members can be activated to prepare themselves for future gun violence events

Riley 2017

Statistical Analysis of Population Characteristics

- Objective: Identify an optimal set of predictors for urban interpersonal firearm violence rates using a broad set of community characteristics
- Method: LASSO and random forest algorithm regression trees
- Results: A set of 18 predictive covariates explain 77.8% of the variance in firearm violence rates, many of which are related to education and socioeconomic conditions

$$f(x) = \sum_{m=1}^{M} c_m I(x \in R_m)$$

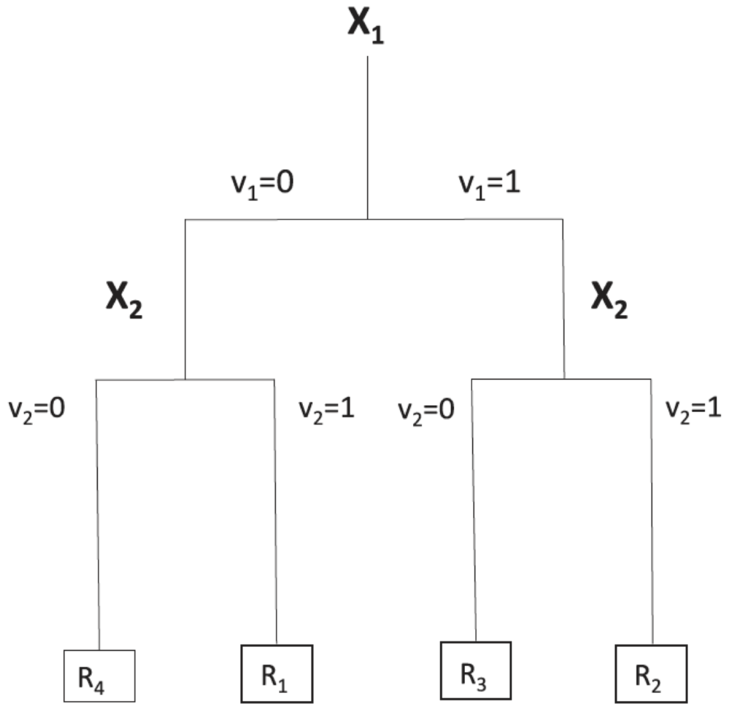


Fig. 2. A regression tree with two covariates.

Goin 2017

Statistical Analysis of Population Characteristics

- Objective: Examine the relationships between isolated youth, illegal gun availability, structural disadvantage, and Southern culture with gun crime
- Method: Binomial regression
- Results: Illegal gun availability and structural disadvantage maintain direct relationships with city-level gun crime counts

Dierenfeldt 2017

Modeling Intervention Attempts and their Impacts

- Objective: Introduce a Susceptible-Transmitter-Victim epidemic model to explore the impact of violence interruption on the diffusion of violence
- Method: Ordinary Differential Equations
- Results: Targeting all potential violence transmitters can reduce gun violence three times more than an intervention that only targets gun-owning individuals. Having individuals in the populations transmitting but not participating in gun violence is sufficient to sustain a gun violence epidemic

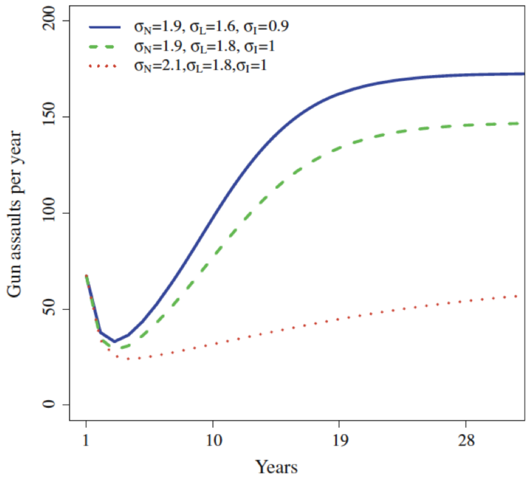


Fig. 3 Impacts of violence interruption on the incidence of gun assaults. This figure depicts effects of violence intervention efforts on total incidences of gun assaults (per 100,000 people) per year over 30 years. The *solid*, *blue line* represents baseline values, $\gamma = 44.35$, $q_N = .5$ $q_L = .51$, $q_I = .49$, $\Gamma_L = .05$, $\Gamma_I = .13$, $\beta = 2.1$, $\alpha_L = 0.004$, $\alpha_I = .006$, $\sigma_N = 1.92$, $\sigma_L = 1.62$, $\sigma_I = 0.87$, where the per capita gun assault rate is 172.17 at 30 years. The *dashed*, *green line* depicts a 10 % increase in violence intervention efforts in the LGO and IGO transmitter populations only ($\sigma_N = \sigma_L = \sigma_I = 1.9$ and all other parameters left at their baseline values), resulting in a decrease in the per capita gun assault rate to 76.9 at 30 years. The *dotted*, *red line* represents a 10 % increase from baseline values in violence intervention efforts ($\sigma_N = 2.11$, $\sigma_L = 1.78$, $\sigma_I = 0.96$, and all other parameters remained fixed at their baseline value) across all transmitter populations. The resulting per capita gun assault rate at 30 years is 55.58

Wiley 2016

Statistical Analysis of Intervention Attempts

- Objective: Test the impacts of Project Longevity on group-involved shootings and homicides in New Haven, Connecticut
- Method: Autoregressive Integrated Moving Average (ARIMA) Models
- Results: Project Longevity is associated with a reduction of almost five group-member involved incidents per month

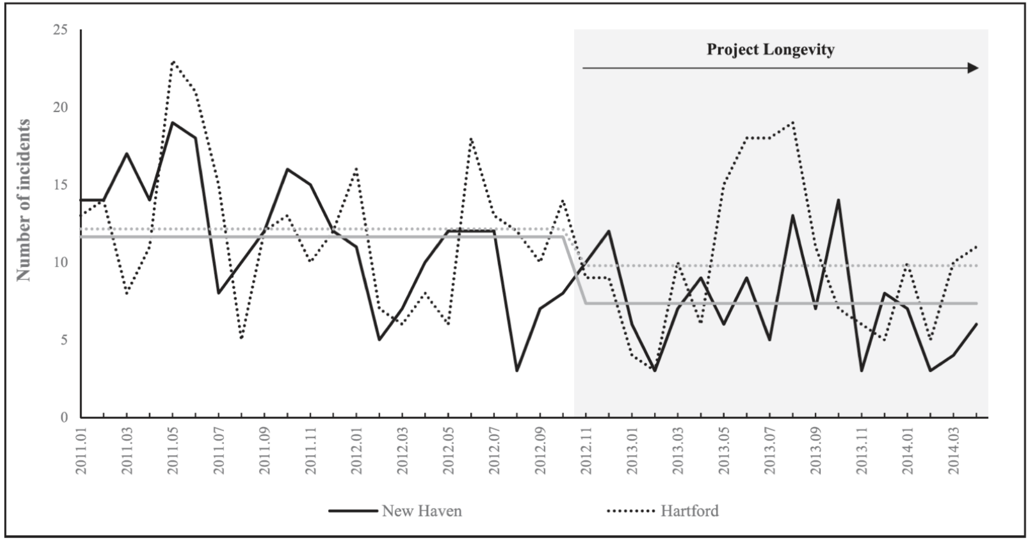


Figure 2. Monthly distribution of the shootings and homicides in New Haven and in Hartford before and during Project Longevity.

Sierra-Arevalo 2017

Statistical Analysis of Intervention Attempts

- Objective: Identify the impact of the Strategic Subjects List (SSL) pilot on individual- and city-level gun violence and to test possible drivers of results
- Method: Autoregressive Integrated Moving Average (ARIMA) models, mediation analysis
- Results: Individuals on the SSL are not more or less likely to become a victim of a homicide or shooting than the comparison group, but the treated group is more likely to be arrested for a shooting

Saunders 2016

Statistical Analysis of Intervention Attempts

- Objective: Measure perceived norms and viewpoints regarding gun violence in response to implementing the Safe Streets intervention in Baltimore, Maryland
- Methods: Chi-squared tests and exploratory structural equation modeling (ESEM)
- Results: There was greater improvement in attitudes towards violence in the intervention community following the implementation of the Safe Streets program

Milam 2017

Statistical Analysis of Intervention Attempts

- Objective: Test the relationship between neighborhood misdemeanor policing and homicide
- Method: Bayesian hierarchical models
- Results: Misdemeanor policing reduces homicide rates, but physical disorder is not a mediator of the impact of such policing

$$\Delta Y_{it} = \alpha_i + \beta_1 \Delta X_{arrests_{it}} + \beta_2 \Delta X_{publicassist_{it}} + \beta_3 \Delta X_{order_{it}} + XB_i + \lambda_i$$

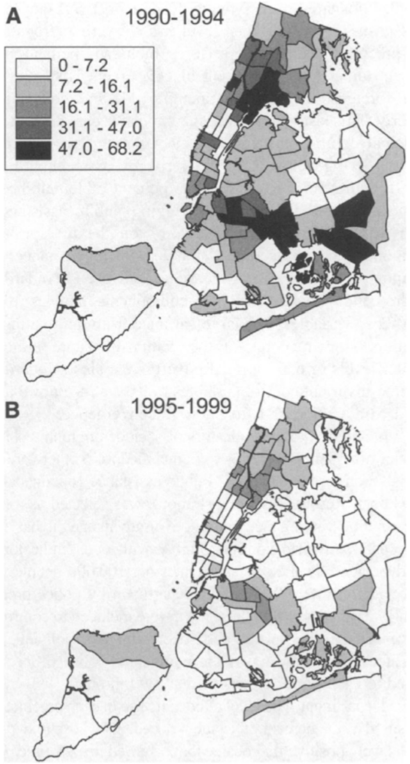


FIGURE 2. Average gun-related homicide rate per 100,000 population by police precinct, New York City; **A,** 1990–1994 and **B,** 1995–1999.

Cerda 2009