

Spatio-Temporal Models of Gun Crime In Chicago, IL

Departmental Exit Seminar

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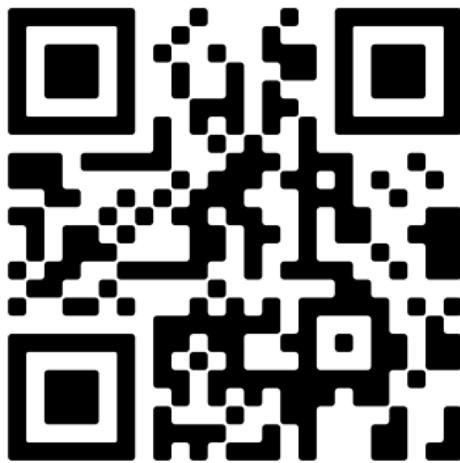
Acknowledgements



- Dr. Louis J. Gross
- Dr. Nina Fefferman, Dr. Sergey Gavrilets, Dr. Suzanne Lenhart
- NIMBioS Investigative Workshop: Mathematics of Gun Violence
- Writing Groups: Society for Mathematical Biology and Twitter Criminology
- UTK Department of Ecology and Evolutionary Biology
- Funding: ASEE NDSEG Fellowship, NIH/NIGMS - IMSD #R25GM086761

Preliminaries

shelbymscott.github.io

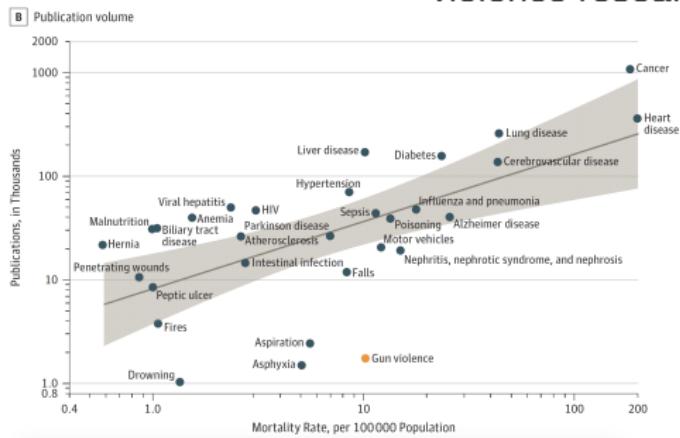


Overview

- 1 Motivation
- 2 Cellular Automata Models
- 3 Is Gun Crime an Epidemic?
- 4 What is the Appropriate Time Step?
- 5 How Do We Know How Many States We Need?
- 6 What Are the Underlying Contributors to Crime?
- 7 Model Preliminary Results
- 8 Conclusions and Future Work
- 9 Further Acknowledgments and Questions

The Cost of Gun Violence in the United States

- Gun violence costs the United States \$229 billion annually
- It leads to the death of 36,000 individuals and the non-fatal injury of 85,000 others
- Homicide is the leading cause of death in black males aged 10-24
- 75% of homicides involve the use of a firearm
- (Kellerman 1993) Having a gun in the home increases the risk for homicide occurring in the home
- (1996) Dickey Amendment removes CDC funding for gun violence research



Stark 2017, Joint Economic Committee 2019, APA 2013, CDC 2017, Kellerman 1993

Missing Quantitative Models in the Literature

Major Question	Mathematical Models						Statistical Models					
	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Analyzing the Spatio-Temporal Distribution	•	•		•			•			•	•	
Impacts of Constraining Gun Availability	•		•	•			•	•				
Effects of Population Characteristics	•		•	•			•	•		•	•	•
Intervention Attempts and their Impacts	•		•				•	•		•	•	•

Individual Cost of Gun Violence

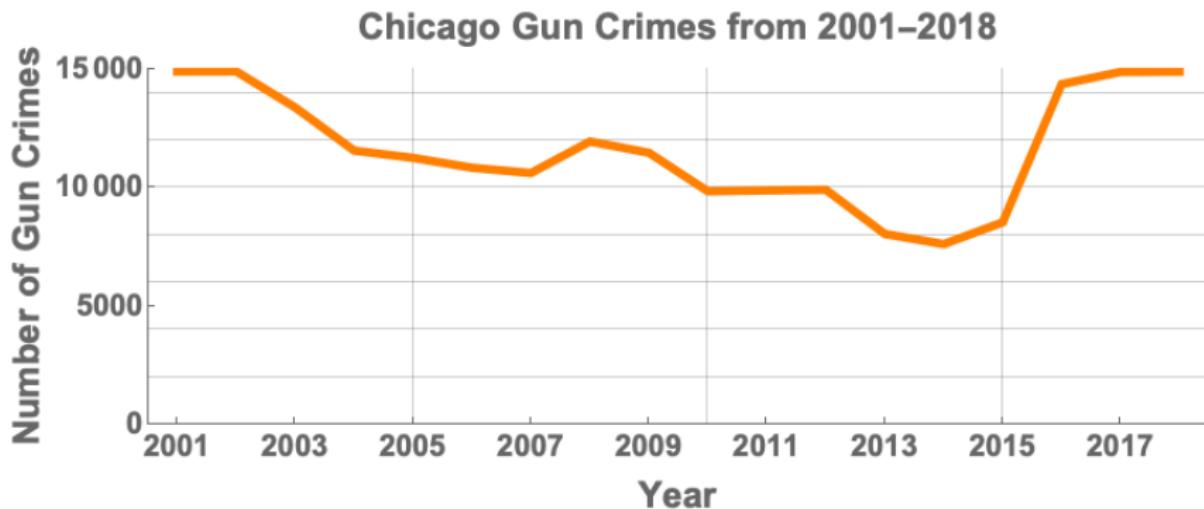
- Adults reporting exposure to gun violence as children showed an increased likelihood for chronic health conditions and risky behaviors

Health Outcome	Risk Increase
Heart Disease	2.2
Stroke	2.4
Chronic obstructive lung disease (COPD)	3.9
Hepatitis	2.4
Ecstasy Use	9.2
Marijuana use	2.9
Poor mental health	2.7
Involvement in juvenile justice system	3.5
Use of substances during sex	6.5
Lack of condom use during sex	2.2

Byrdsong 2016 and Voisin 2016

The Impact of Gun Crime in Chicago

- Past studies have shown a diffusion of gun crime in both space and time
- Between 2015 and 2016 there was a 68% increase in gun crimes, disproportionately affecting disadvantaged neighborhoods
- Data used for this study:
 - Chicago city crime dataset, 2001 - 2017
 - Selected socio-economic indicators in Chicago, 2008 - 2012



Project Initialization

- (2016) Math 582: Mathematical Ecology Class Project
- Create an epidemic model of gun violence in the United States

Objective (working): To determine methods to reduce gun violence in a region of the United States while maximizing distribution of guns in that area.

Methods:

Use SEIR Model

- Susceptible - Those who own or have access to a gun.
- Exposed - Those who have committed precursor crimes.
- Infectious - Those who have committed acts of violence with a gun.
- Removed - Those who are incarcerated and those who have no access to guns.

Add Stochasticity

- Attempt to account for lives potentially saved due to gun usage (as in a case where a person uses a gun in order to stop someone from taking a multitude of lives)

Use OCT

- Discover optimal level of policy to help achieve goal

- Redirection: Use spatio-temporal modeling to observe the epidemic spread of gun crime in Chicago, Illinois.

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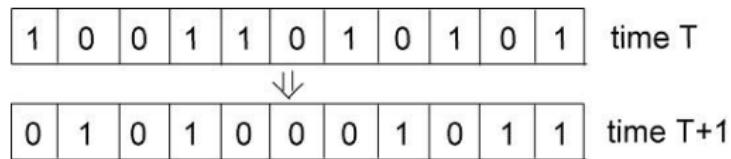
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Cellular Automata

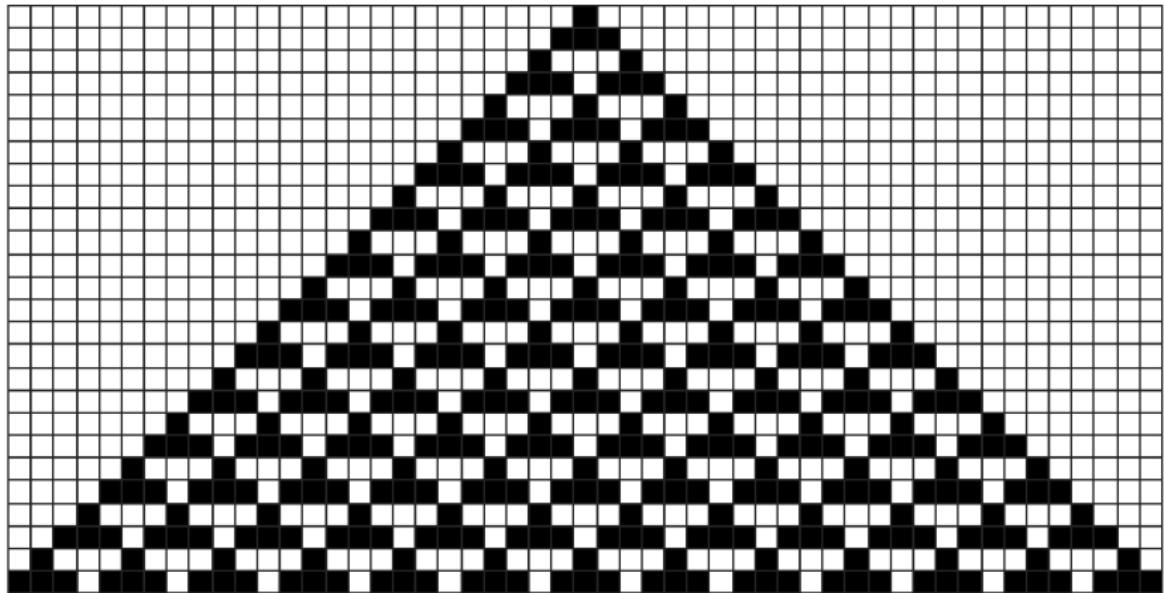
- *Cellular automata*: consist of a lattice of cells, each existing in a state. Local rules govern how these states change over time.
- Discrete in time and space
- Simplest CA: one-dimensional with two states “0” and “1.”



Sum	Example	New Value
5	11111	0
4	11101	1
3	01101	0
2	10001	1
1	01000	0
0	00000	0

Cellular Automata Models

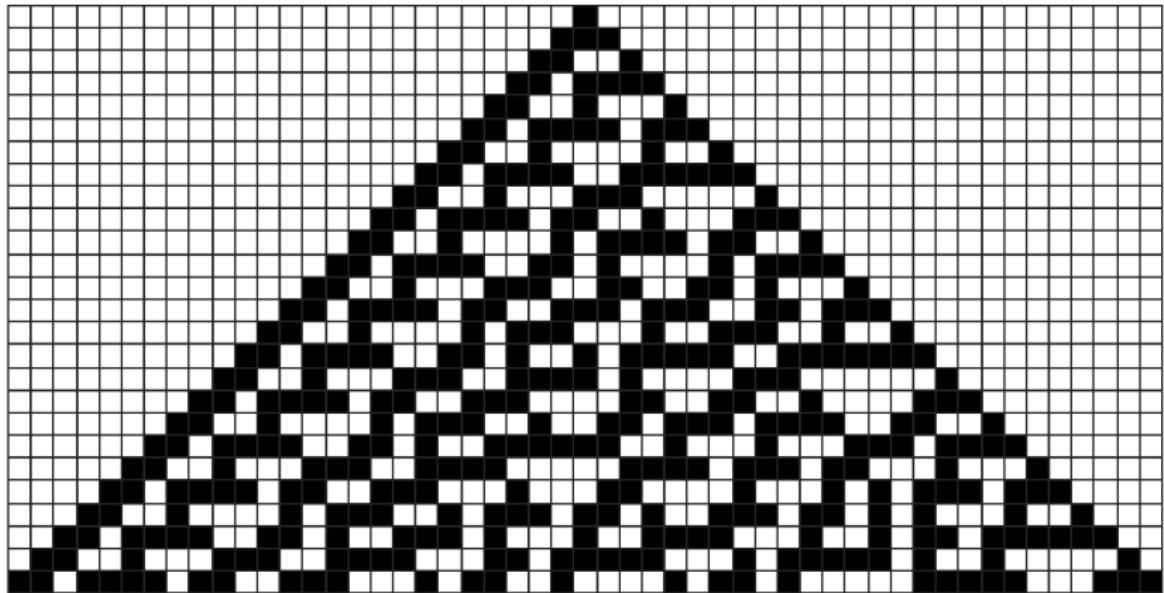
Rule 54



Wolfram Alpha

Cellular Automata Models

Rule 30

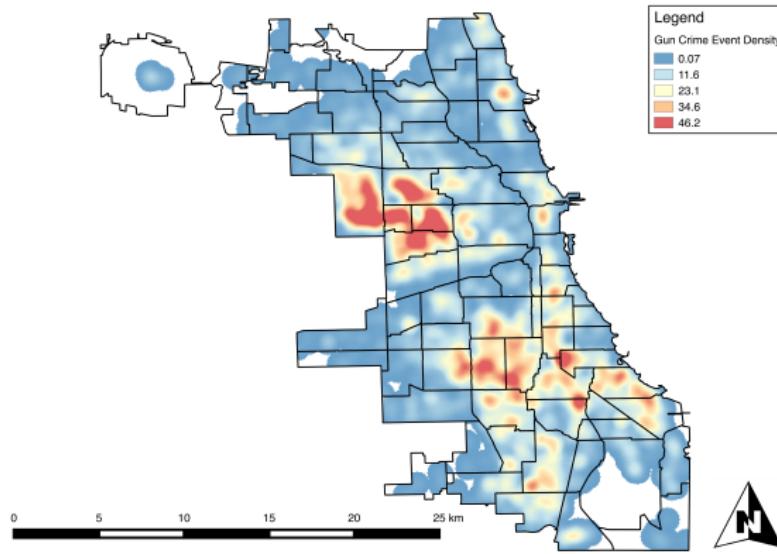


Wolfram Alpha

Applying Cellular Automata to Gun Crime in Chicago

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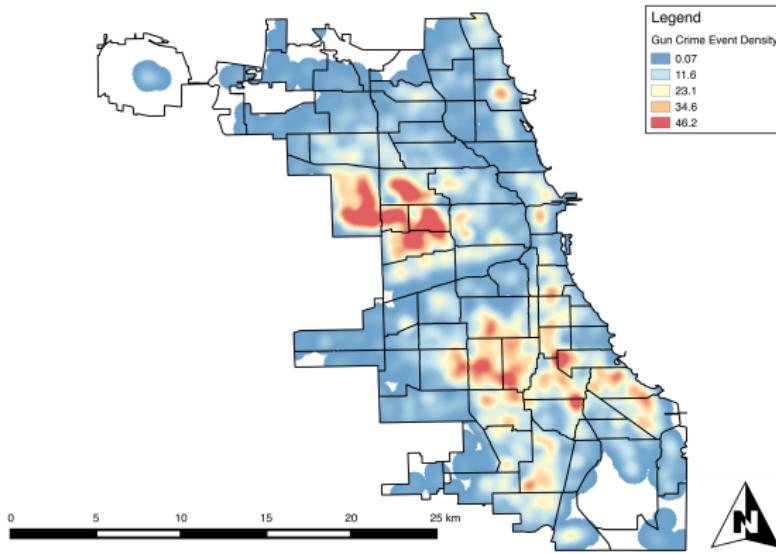
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- Spatial units
- Temporal units
- Cell states
- Transition rules



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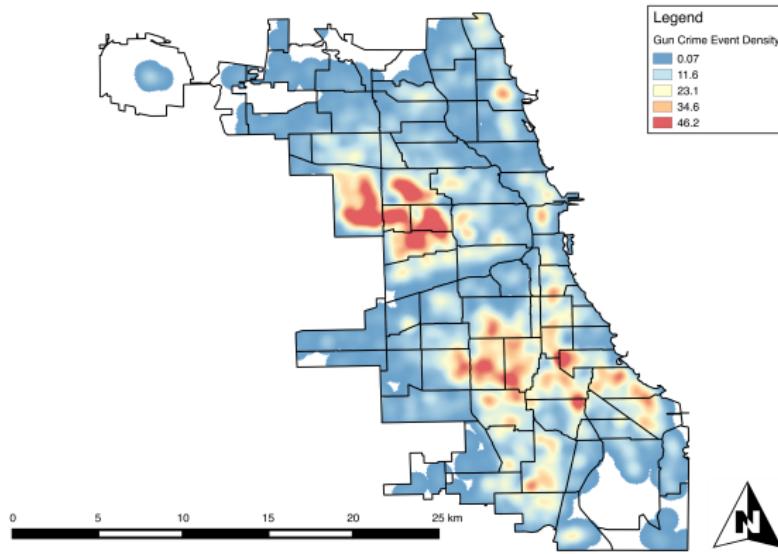
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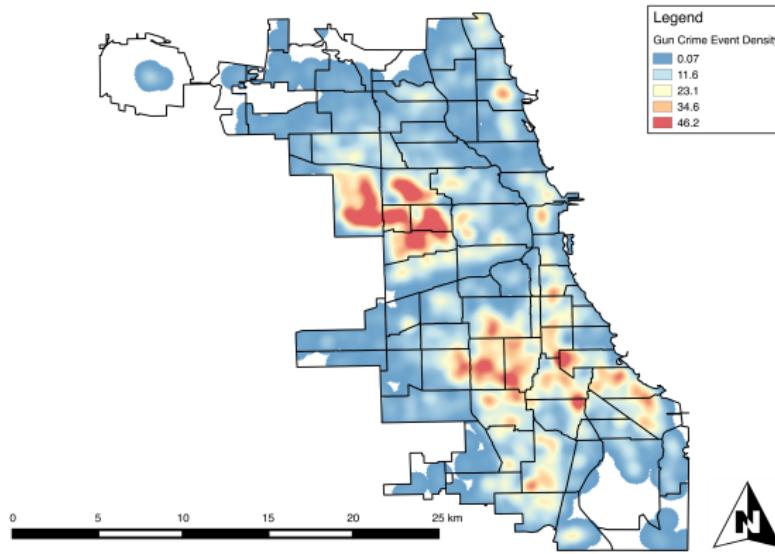
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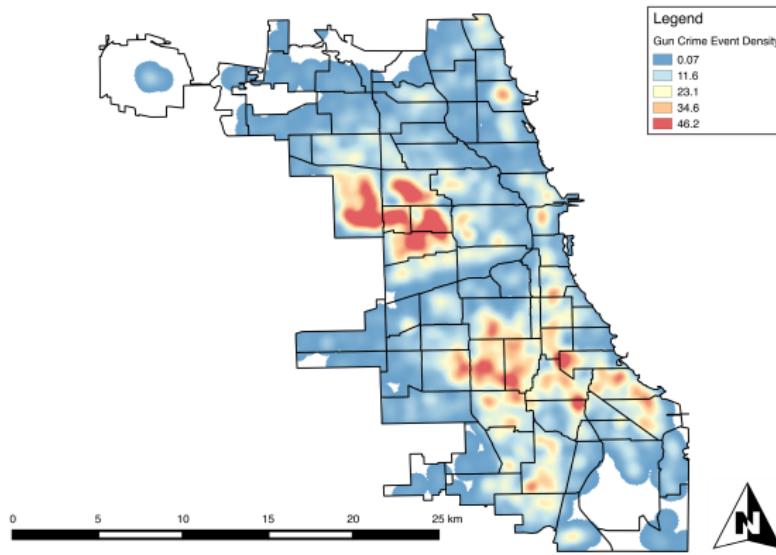
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Does Gun Crime Spread in Space and Time?

- Method: Bayesian spatio-temporal point process (Loeffler and Flaxman 2017)
- Goal: Distinguish between clustered but non-diffusing gun crime and clustered gun crime resulting from diffusion
- More simply: is gun crime an epidemic?

Conditional Intensity

$$\lambda(x, y, t) = m_0 \mu(x, y, t) + \theta \sum_{i:t_i < t} \omega \exp(-\omega(t - t_i)) \frac{1}{2\pi\sigma^2} \exp(-((x - x_i)^2 + (y - y_i)^2 / (2\sigma^2)))$$

- Triggering kernels for both space (x, y) and time (t)
- $\mu(x, y, t)$: background intensity, weighted by m_0
- θ : the average number of shootings triggered by any particular shooting
- σ : spatial length scale
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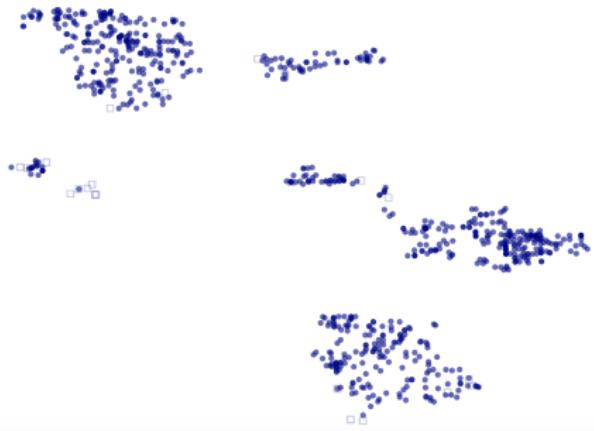
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Results of Point Process

Subset of Chicago data

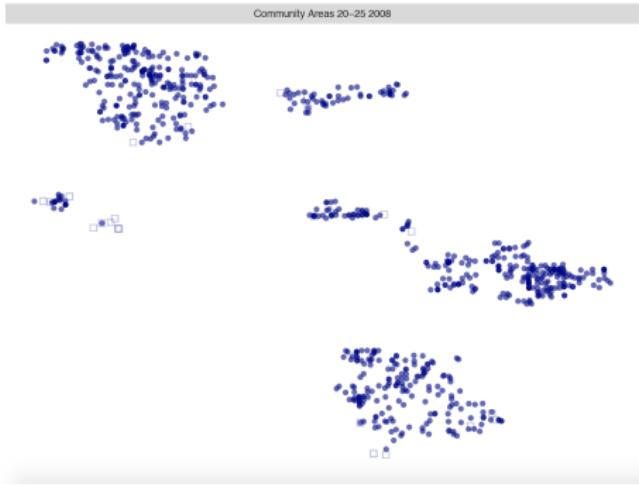
Community Areas 20-25 2008



- Overall question: Do gun crimes “trigger” one another in space and time?
- Answer: yes
- For every 100 crimes observed at a given location, we expect the next 93 crimes that occur to be correlated with the initial 100 crimes
- We expect them to happen very soon after (~ 12 hours) and within a close geographic radius (~ 1.6 km).

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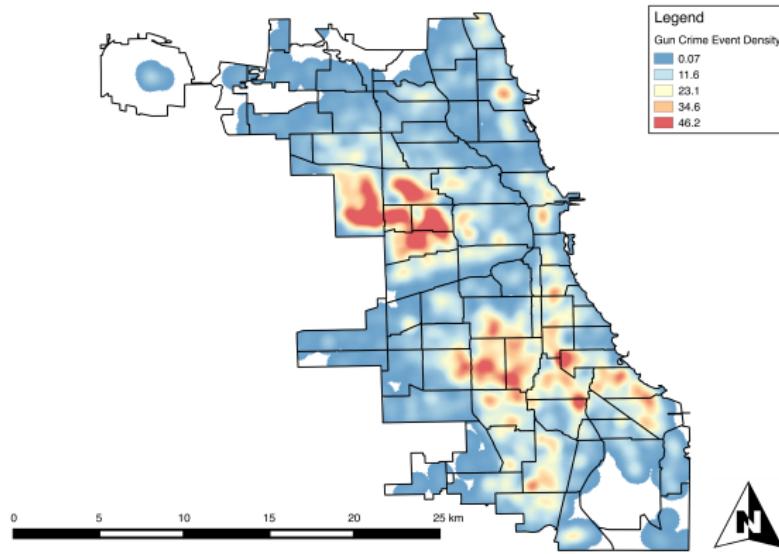


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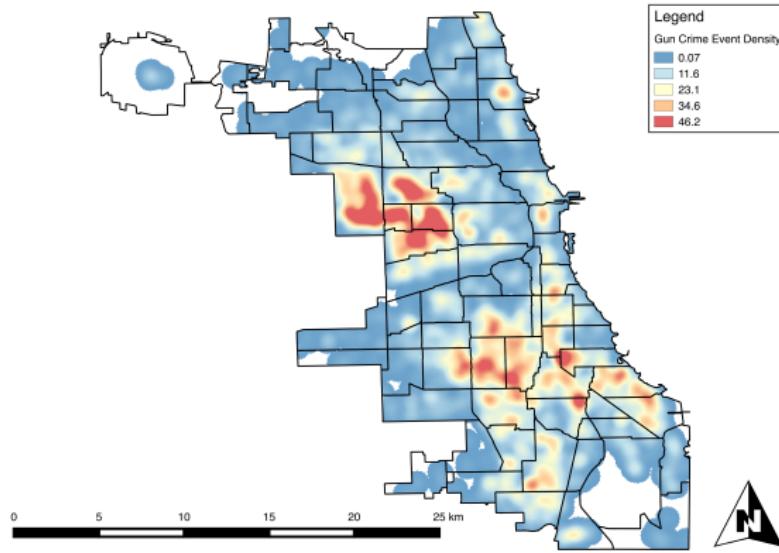
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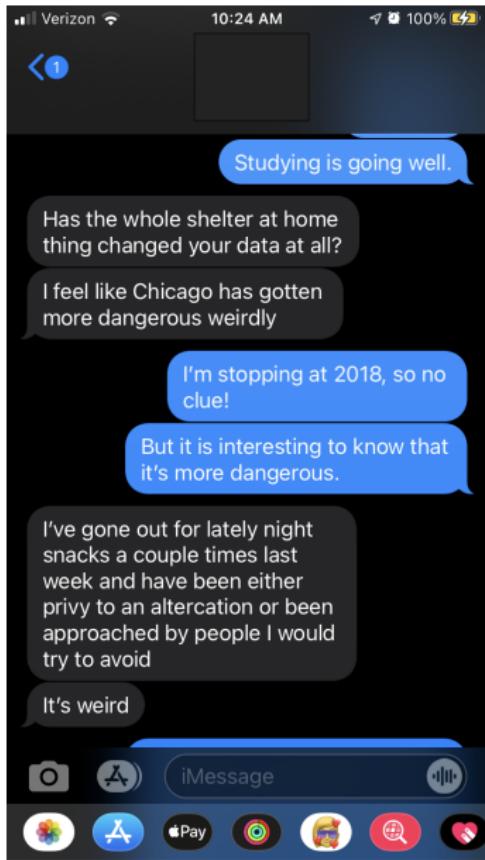


Significant Events Impact Crime

- March 26, 2020: Text from friend in Chicago
- April 3, 2020: Meeting with Lou, during which this topic was mentioned
- July 31, 2020: First manuscript submitted to Science for publication

The Takeaways:

- Research ideas can come from anywhere
- “A quick little paper,” is never quick
- In fact, a quick little paper can become a dissertation chapter

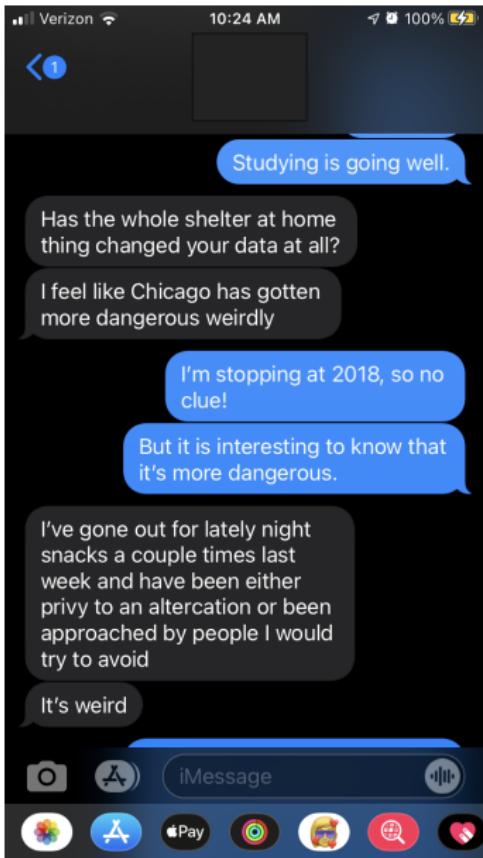


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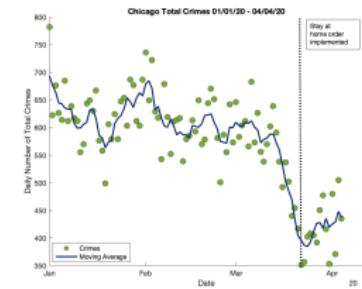
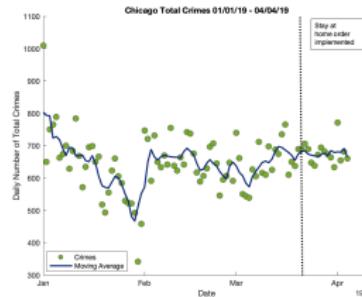
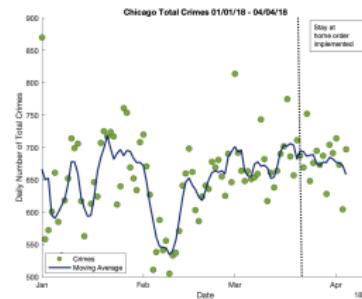
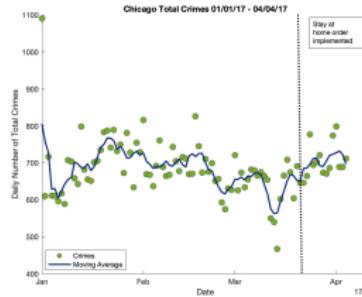
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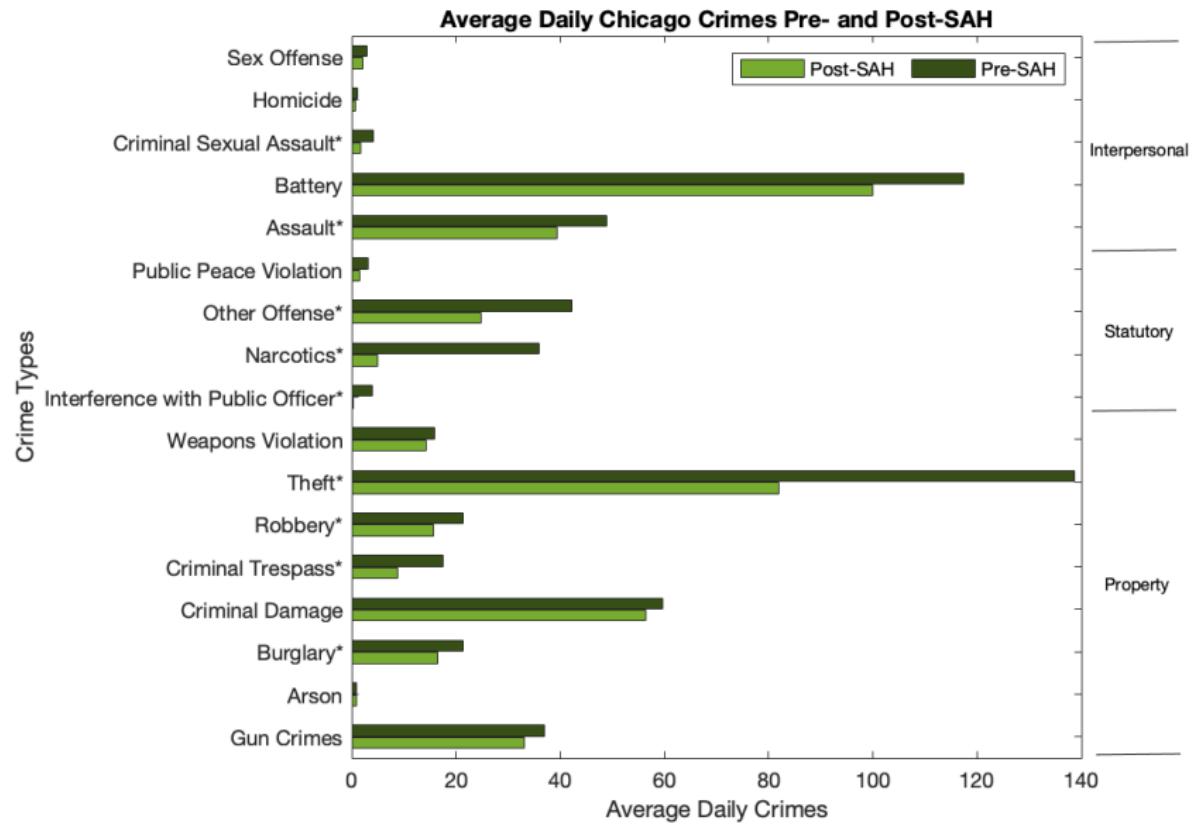


Impact of COVID-19 on Crime

- January 24, 2020: First case of COVID-19 in Chicago
- March 9, 2020: State of Emergency declared
- March 21, 2020: Stay at Home order implemented



Do the Impacted Crime Types Differ?



Do Headlines Hold?

- There are multiple claims about temporal patterns of gun crime in Chicago, IL.
- Goal: Test whether these hypotheses hold

Experts Discuss Cook County Gun Violence: 744 Deaths In 2017

Leading clinical experts gathered in Cook County this week to discuss gun violence as a public health issue.

 **Carrie Frillman**, Patch Staff 

Posted Thu, Feb 1, 2018 at 10:09 am CT

Chicago's brutal summer of gun violence

7:30 / By Bridget Brennan

Posted Tue 2 Oct 2018 at 3:03pm, updated Tue 2 Oct 2018 at 5:47pm

36 people shot in Chicago over Memorial Day weekend, marking a reduction in gun violence

Aamer Madhani USA TODAY

Published 11:05 a.m. ET May 29, 2018 | Updated 1:59 p.m. ET May 29, 2018

43 shot, 5 fatally, in Halloween weekend gun violence

Published October 29, 2018 | Chicago | FOX 32 Chicago

Chicago shootings leave at least 4 dead, 12 wounded over MLK weekend

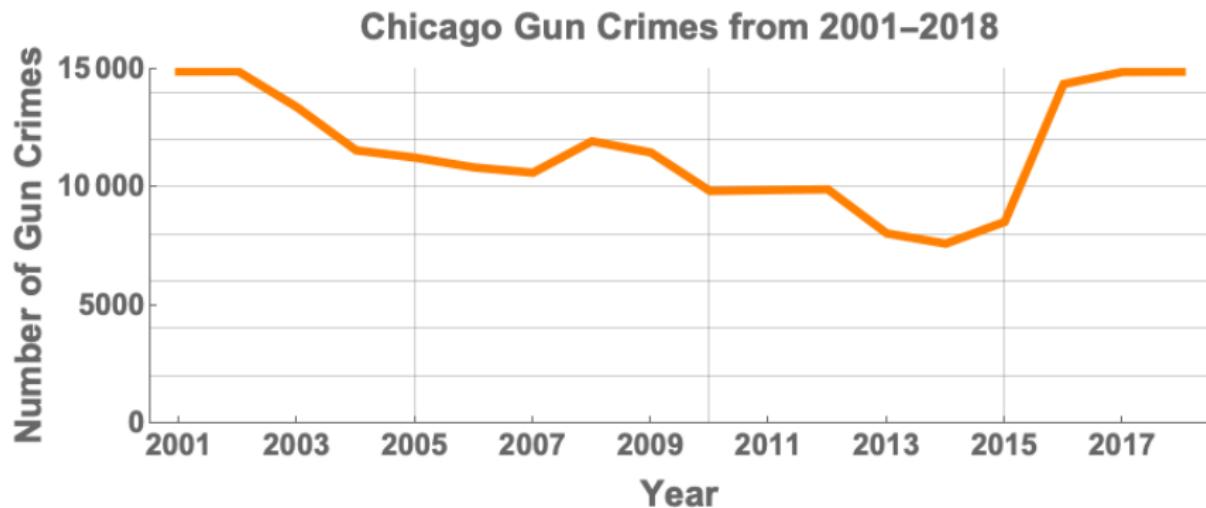
Chicago's deadliest Memorial Day weekend since 2015: 10 shot dead, 39 wounded

The weekend's victims include a 16-year-old boy killed Saturday in Washington Park and a man fatally shot in a Lawndale attack that injured three others.

By Sun-Times Wire | Updated May 26, 2020, 9:12am CDT

Temporal Analysis Results

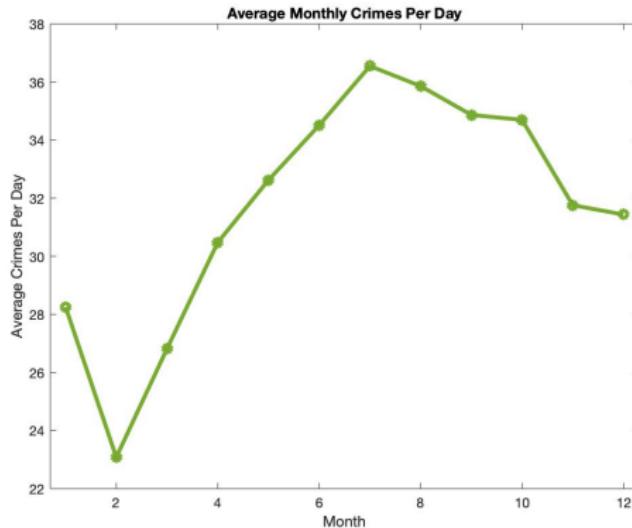
- Are there yearly patterns in gun crime?
- Method: t -tests



- Yes
- Significantly higher years: 2001, 2002, 2016, 2017, 2018
- Significantly lower years: 2013, 2014, 2015

Temporal Analysis Results

- Are there monthly patterns in gun crime?
- Method: *t*-tests



- Yes
- February has significantly lower crime than other months

Temporal Analysis Results

- Are there daily patterns in gun crime? Are there holiday patterns?
- Method: outlier analysis
- and t -tests

Holiday	Month	p -value	CI	σ	t -stat	Result
New Year's Eve	December	0.43	[−3.64, 8.32]	8.83	0.80	0
New Year's Day	January	9.8523×10^{-5}	[6.39, 17.32]	8.07	4.41	1
Memorial Day	May	0.33	[−3.86, 11.27]	11.17	1.00	0
July 4 th	July	0.58	[−4.95, 8.74]	10.11	0.56	0
Labor Day	September	0.69	[−5.04, 7.53]	9.28	0.40	0
Halloween	October	0.09	[−1.07, 13.46]	10.73	1.73	0
Thanksgiving	November	4.05×10^{-5}	[−16.67, −6.62]	7.41	−4.71	1
Christmas	December	3.04×10^{-7}	[−15.98, −8.23]	5.72	−6.35	1

- Yes, but not as much as the media reports
- There do not seem to be patterns in which days are outliers between years
- New Year's Day shows significantly higher crime than the rest of January
- Thanksgiving and Christmas show significantly lower crime than the months in which they fall
- When extended to a moving average, many of these patterns dissolve

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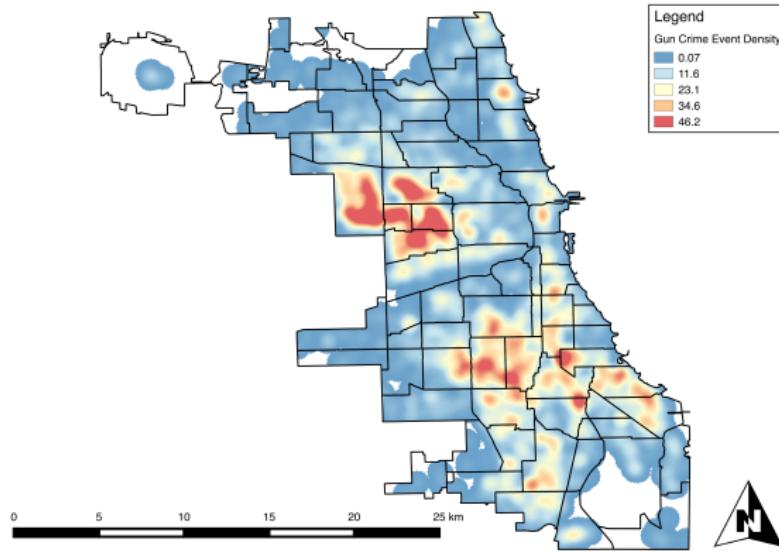
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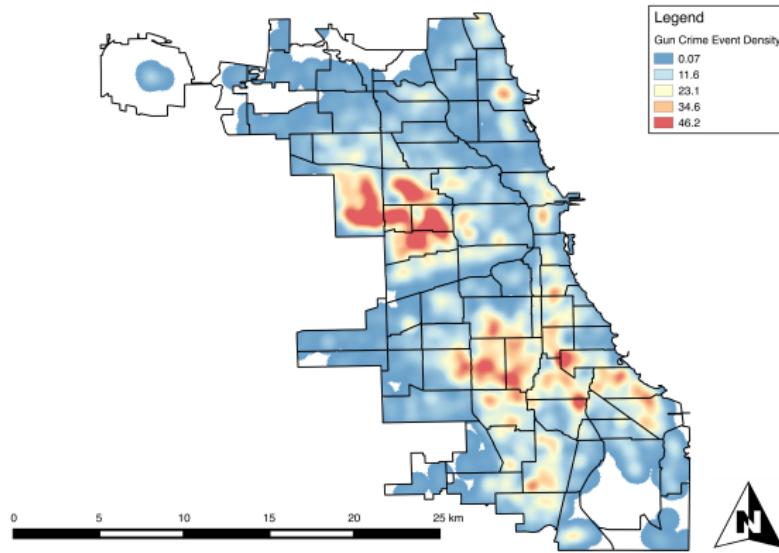
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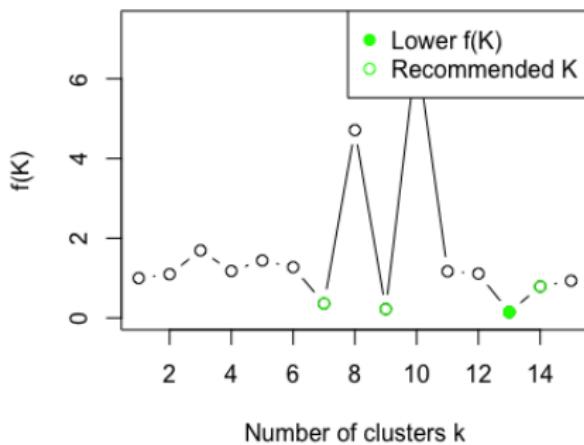
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Determining Number of States

- Purpose: find the appropriate number of states based on clusters of average gun crime
- Method: k -selection algorithm

$f(k)$ finds 13 clusters

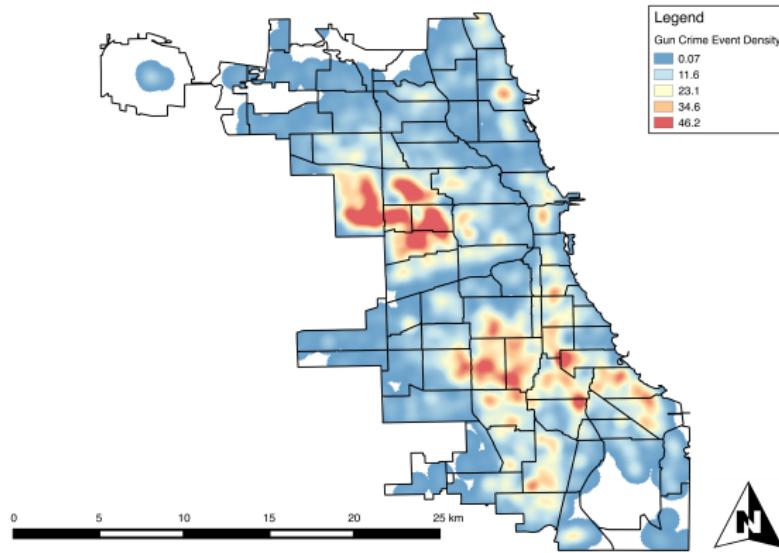


- Result: There are **13 different levels of gun crime**, which can then be categorized into low, medium, and high categories.

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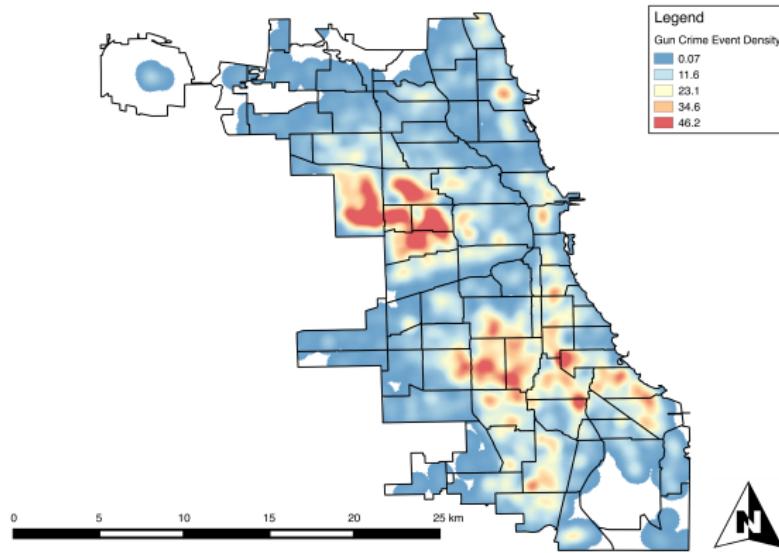
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Applying Cellular Automata to Gun Crime in Chicago

Need to determine:

- Is gun crime an epidemic in Chicago? → yes.
- Spatial units → **community areas of Chicago**
- Temporal units → **weeks**
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Which socio-economic conditions impact the number of gun crime events?

- Method: Negative Binomial Regression with Subset Selection
- Factors tested:

- Crowding
- Poverty
- Unemployment
- Education level
- Dependents
- Per capita income

Predictor	Coefficient
Poverty	1.0344
Unemployment	1.1123
Dependents	- 0.9477

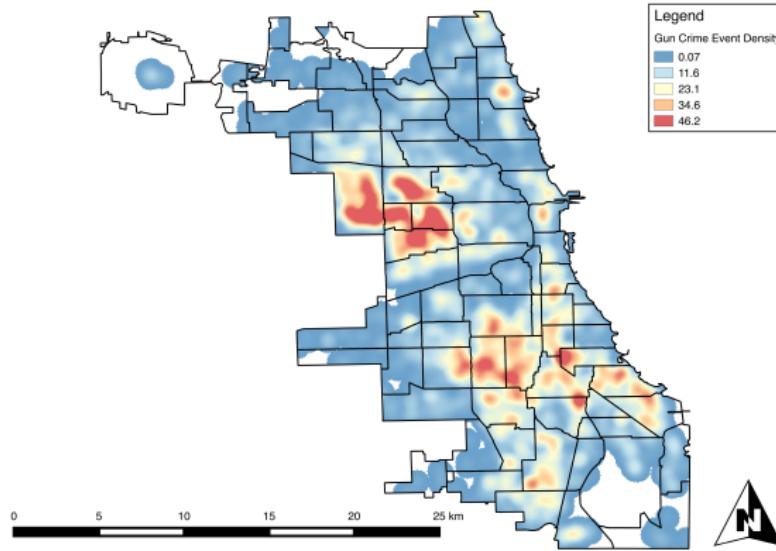
Regression Results

$$\log(\# \text{ Gun Crimes}) = 4.1258 + 0.0338 * \text{poverty} + 0.1064 * \text{unemployment} - 0.0537 * \text{dependents}$$

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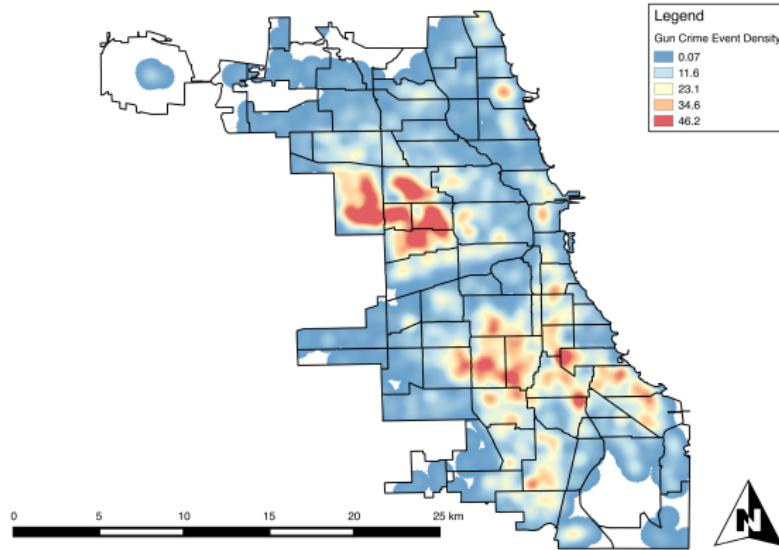
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Applying Cellular Automata to Gun Crime in Chicago

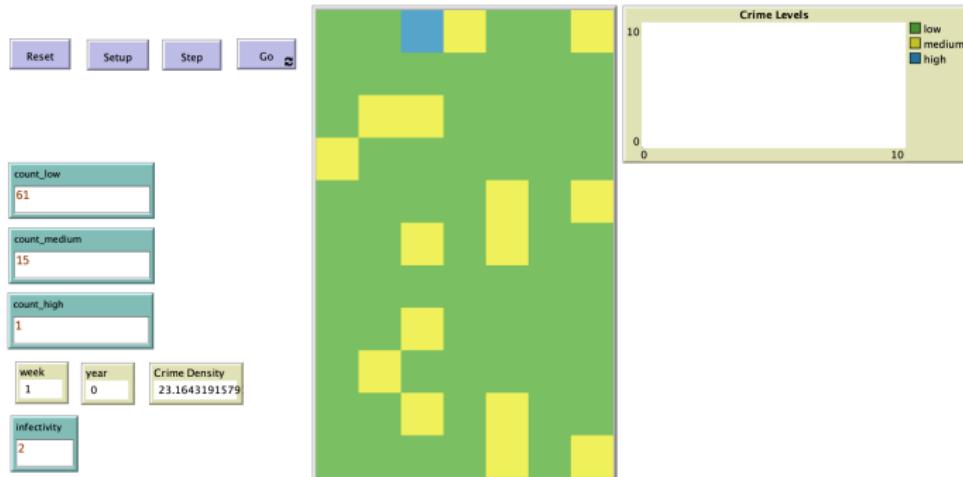
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Baseline Model Setup

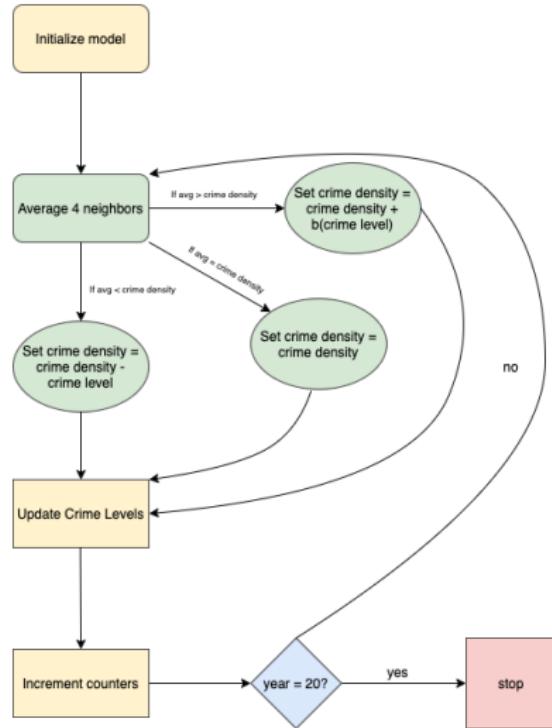
- The user defines how many of the 77 cells are in each crime category (low, medium, high)
- The cells in each category are given a random crime density and the corresponding level (1-13).
- Cells are randomly distributed in the lattice



Baseline Model Description

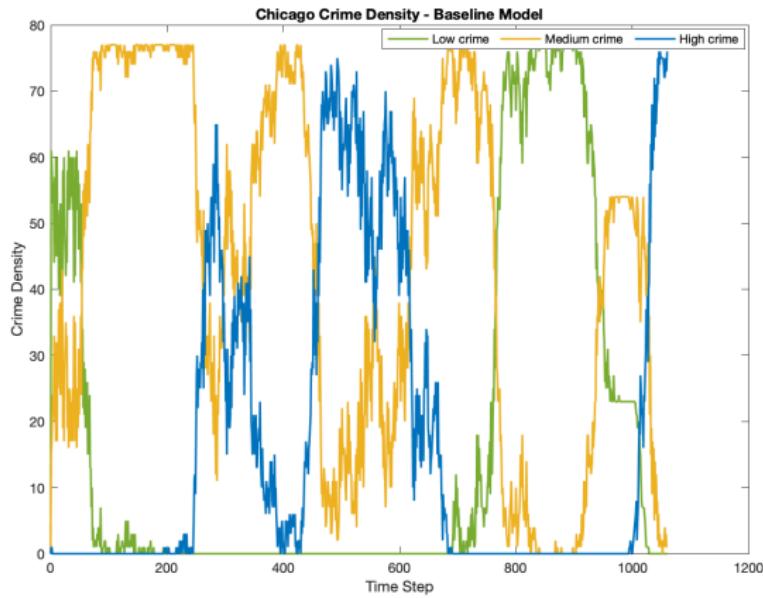
The idea:

- If an area is surrounded by high crime, it will increase its crime density.
- If it's surrounded by low crime, it will decrease its crime density.
- If it's surrounded by equal crime, it will maintain its crime density.



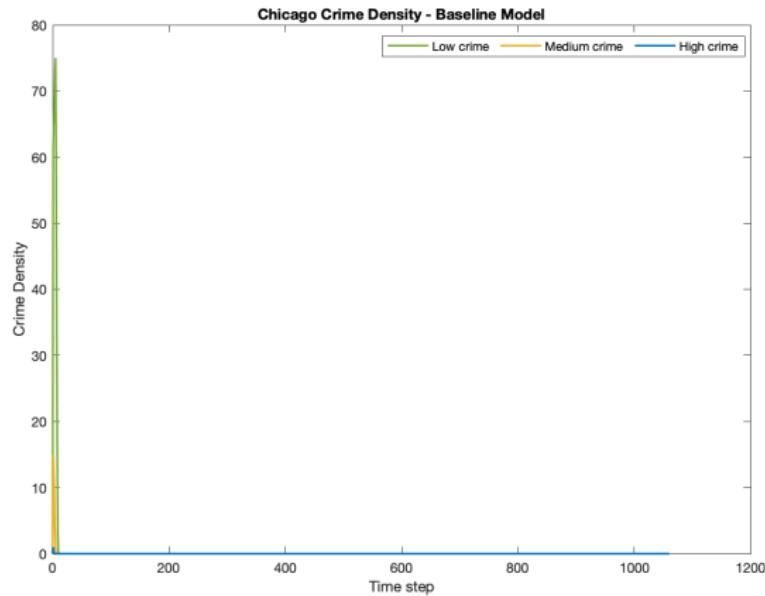
Baseline Model Results

- $L_I = 61$
- $M_I = 15$
- $H_I = 1$
- $\beta = 2$



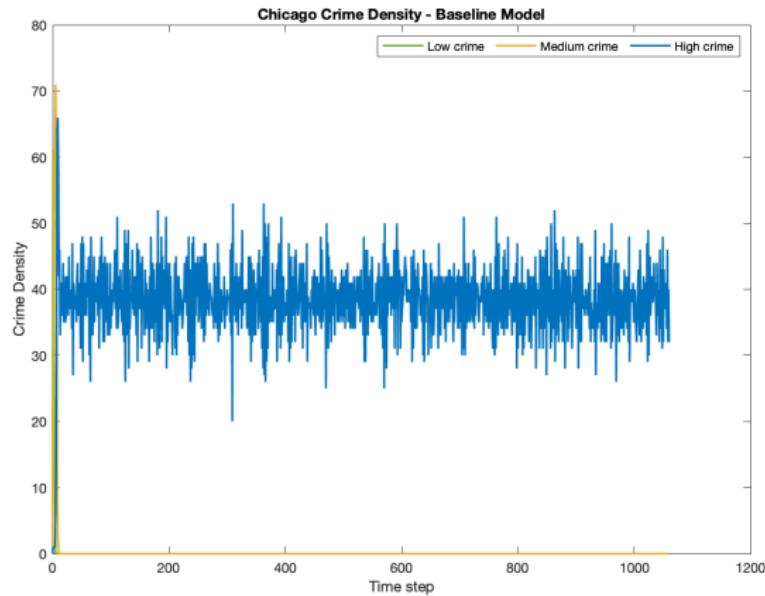
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- $H_I = 1$
- $\beta = 1$



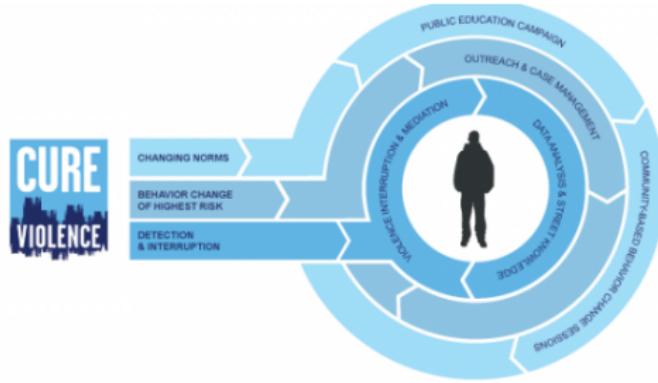
Baseline Model Results

- $L_I = 61$
- $M_I = 15$
- $H_I = 1$
- $\beta = 3$



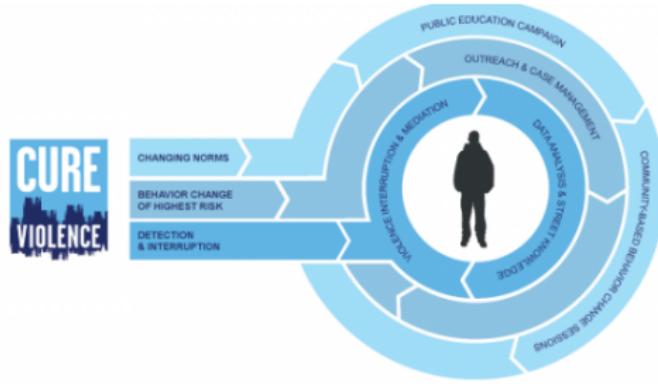
Inspecting the Baseline Model

- The model behavior changes drastically with changes in β
- As a reminder: β is the infectivity parameter
- This says, “how impactful is being surrounded by other high crime communities?”
- If infectivity of gun crime makes a significant difference, how can we decrease it?
- Intervention Attempts:
 - Policing strategies
 - Violence interruption
 - Community changes



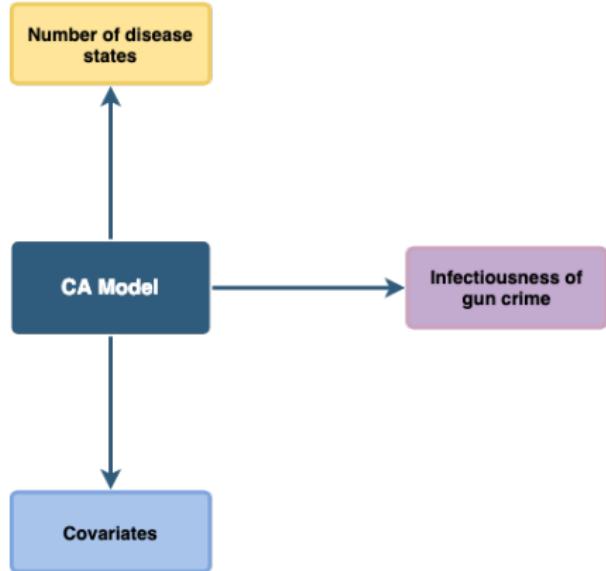
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Additions to the Baseline Model

- Temporal variations
- Socio-economic conditions
- Reductions or increases in stochasticity
- Applications of specific interventions in both space and time
- Additions of GIS data



Model Conclusions

- **Q1:** Does gun crime show epidemic characteristics in Chicago?
 - **A1:** Yes. Gun crime clusters and diffuses in space and time.
-
- **Q2:** Are there temporal patterns of Chicago gun crime?
 - **A2:** Yes, sort of. Significant events impact gun crime patterns, but there is some inflation of broader observations.
-
- **Q3:** How many different crime levels are in Chicago?
 - **A3:** There are 13 different crime levels present in Chicago
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- **Q4:** What factors contribute most to crime spread in Chicago?
 - **A4:** “Infectivity” seems to have a major impact, as do socio-economic conditions.

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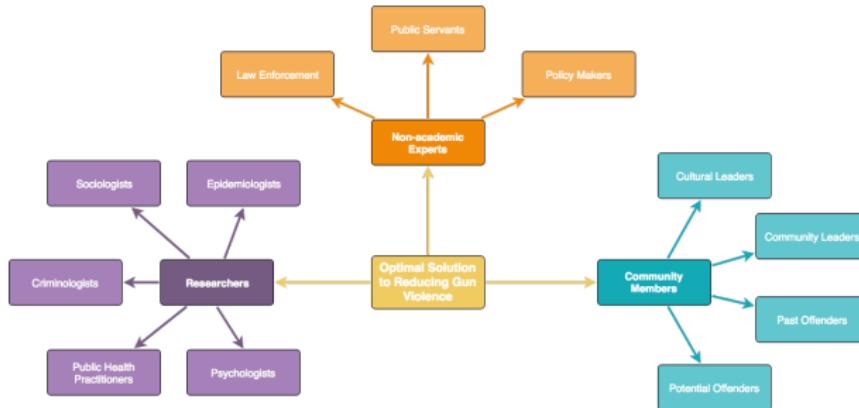
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Research Conclusions

- Gun crime and gun violence are major public health concerns in the United States
- There is a lack of research on gun crime in the United States
- There are far more factors contributing to gun crime outside the availability of guns
- This is all incredibly complicated. Evidence-based policy is the goal, but it may not be easily accessible.



Further Acknowledgments



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Questions?

