Handguns and Hotspots

Spatio-Temporal Models for Gun Crime in Chicago, IL

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EVOLUTIONARY BIOLOGY

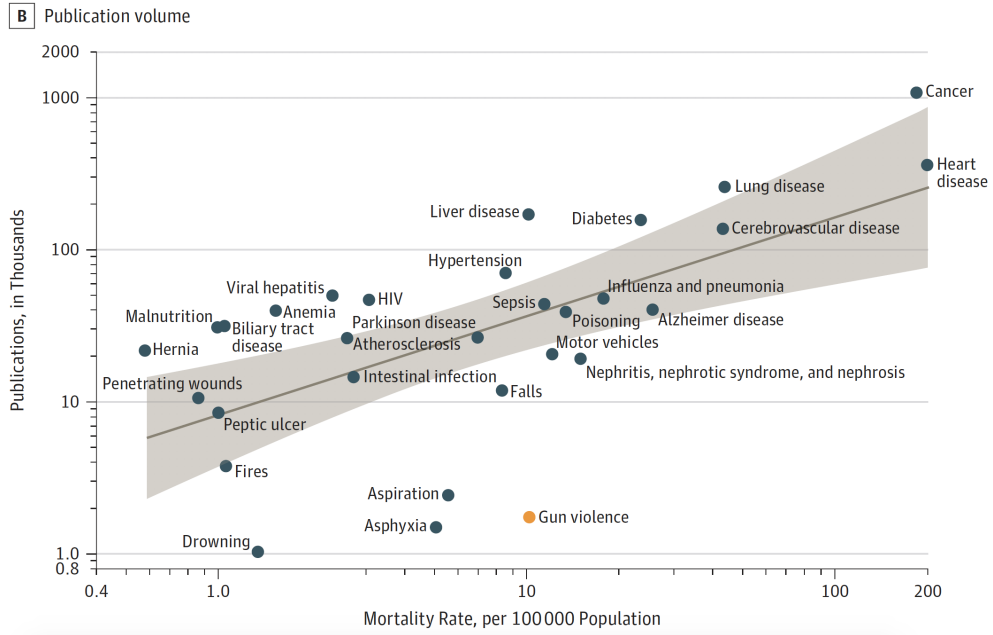
Overview

Overall Research Goals

- Observe and predict the spread of gun crime in Chicago, Illinois, using data-informed cellular automata models
- Test ways to control the spread of gun crime in these models with a variety of intervention methods
- Switching gears: Share the importance of interdisciplinary work in the path to graduate school

The Cost of Gun Violence in the United States

- Gun violence costs the United States $229 billion annually
- It leads to the death of 31,000 individuals and the non-fatal injury of 78,000 others
- Homicide is the leading cause of death in black males aged 10-24
- 80% 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



Individual Cost of Gun Violence

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

Health Outcome	**Risk Increase**
Heart Disease	2.2
Cancer	1.9
Stroke	2.4
Chronic obstructive lung disease (COPD)	3.9
Diabetes	1.6
Hepatitis	2.4

Byrdsong 2016

Individual Cost of Gun Violence

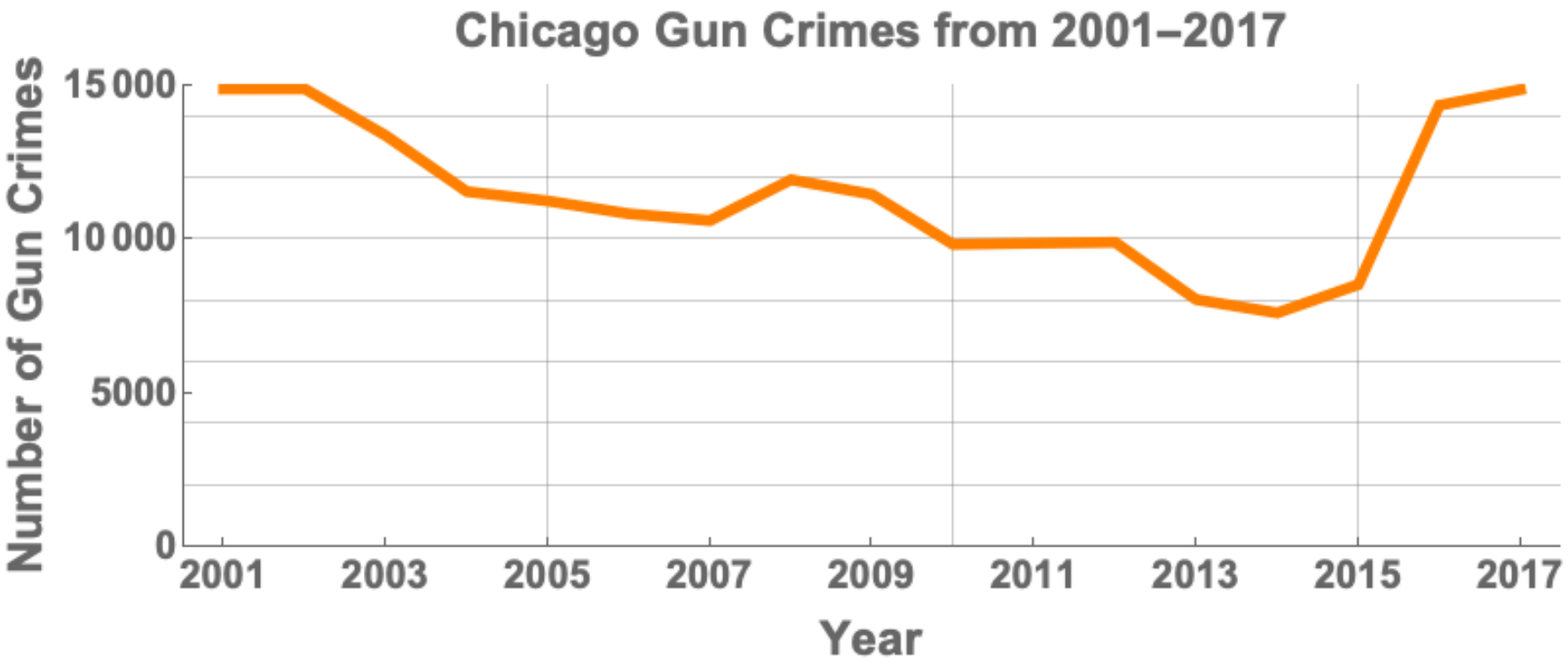
- Exposure to community violence also affects mental health, substance use, school engagement, juvenile justice involvement, and STI risk behaviors in youth

Health Outcome	Risk Increase
Poor mental health	2.7
Delinquent behaviors	2.1
Involvement in juvenile justice system	3.5
Low school bonding	1.5
Poor student-teacher connectedness	1.7
Cigarette smoking	2.9
Ecstasy use	9.2
Codeine use	4.6
Alcohol consumption	2.2
Marijuana use	2.9
Use of substances during sex	6.5
Lack of condom use during sex	2.2
Unplanned pregnancy or impregnation	2.0

Voisin 2016

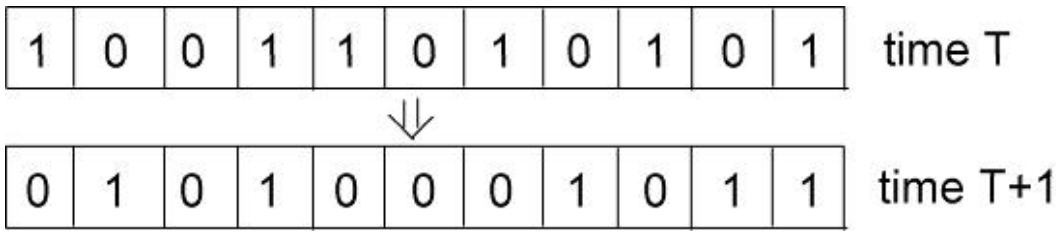
The Impact of Gun Crime in Chicago

- 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



Cellular Automata

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

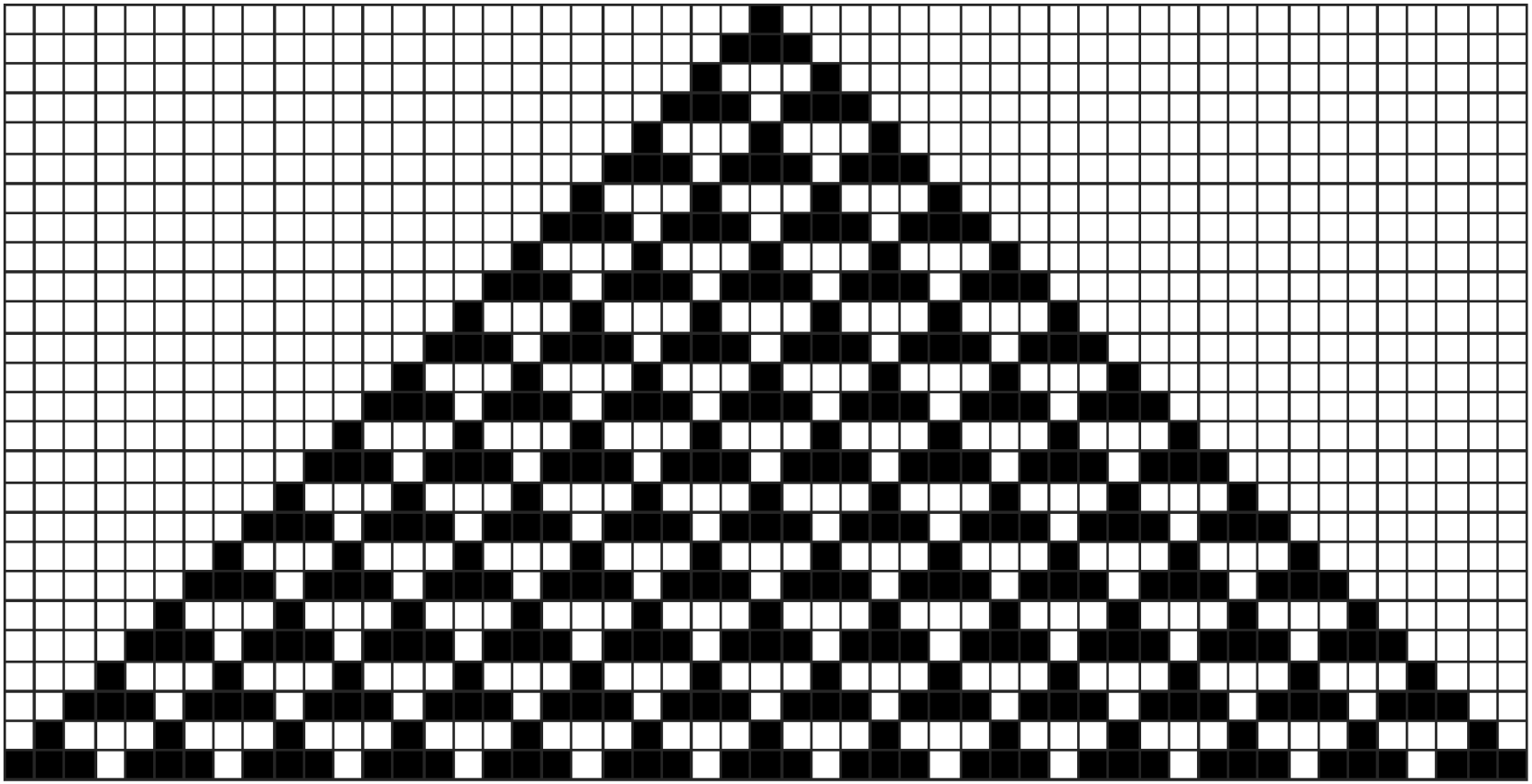


Sum	Example	New Value
5	11111	0
4	11101	1
3	01101	0
2	10001	1
1	01000	0
0	00000	0

http://eric_rollins.home.mindspring.com/introProgramming/hw5.html

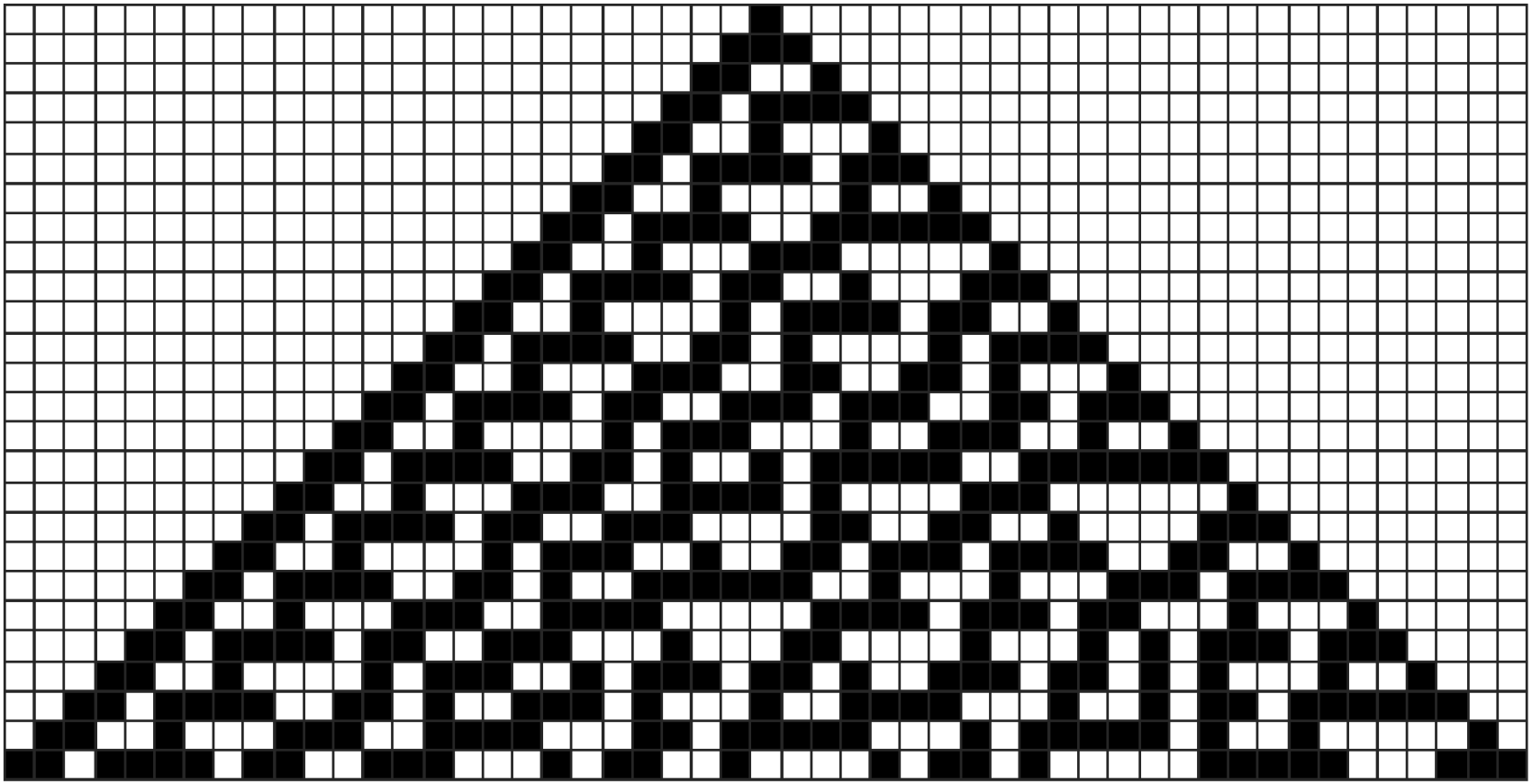
Cellular Automata Models

Rule 54



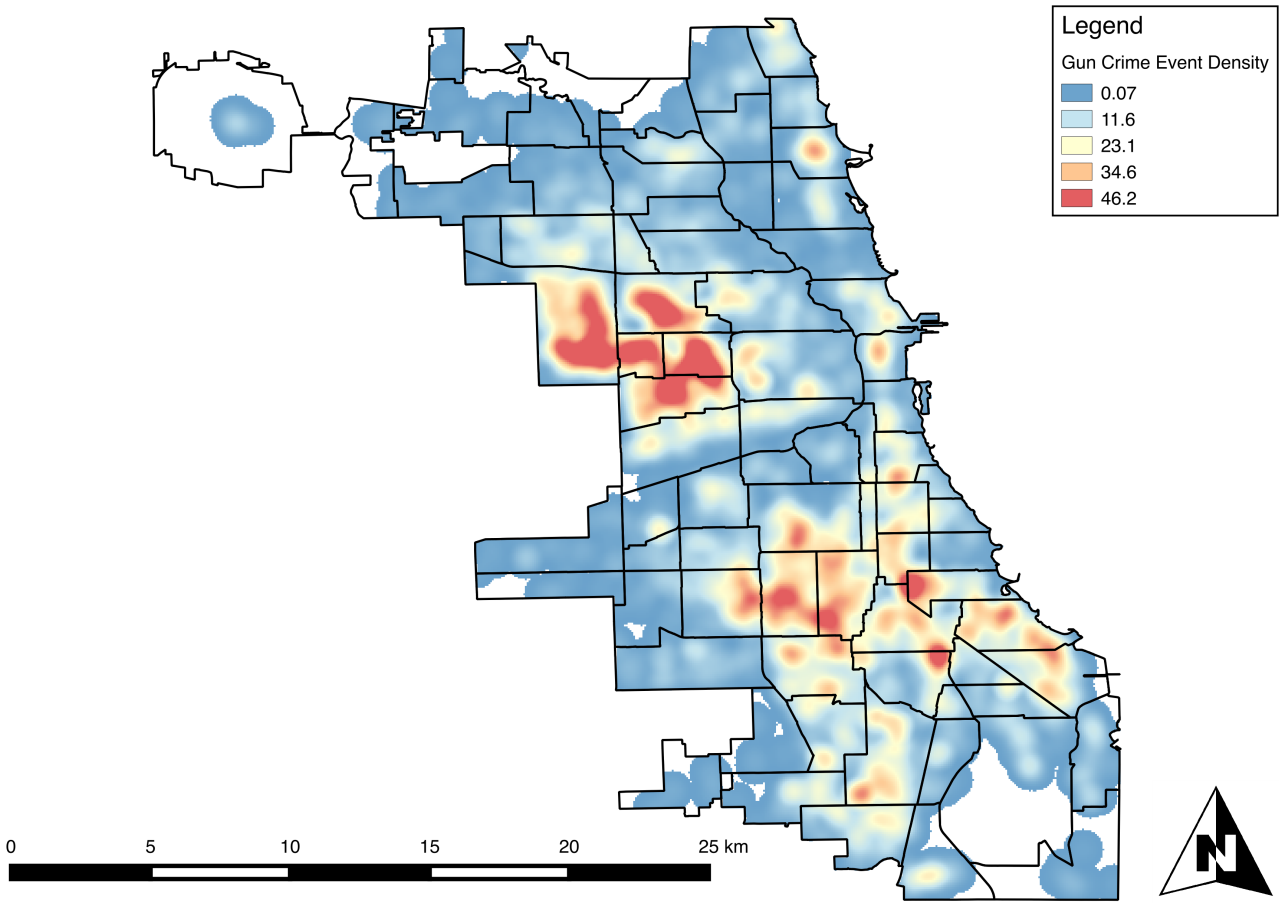
Cellular Automata Models

Rule 30



Applying Cellular Automata to Gun Crime in Chicago

- Spatial units $\rightarrow$ community areas of Chicago
- Temporal units $\rightarrow$ weeks
- Cell states $\rightarrow$ level of crime present
- Transition rules $\rightarrow$ depend on internal factors and on neighborhood influences



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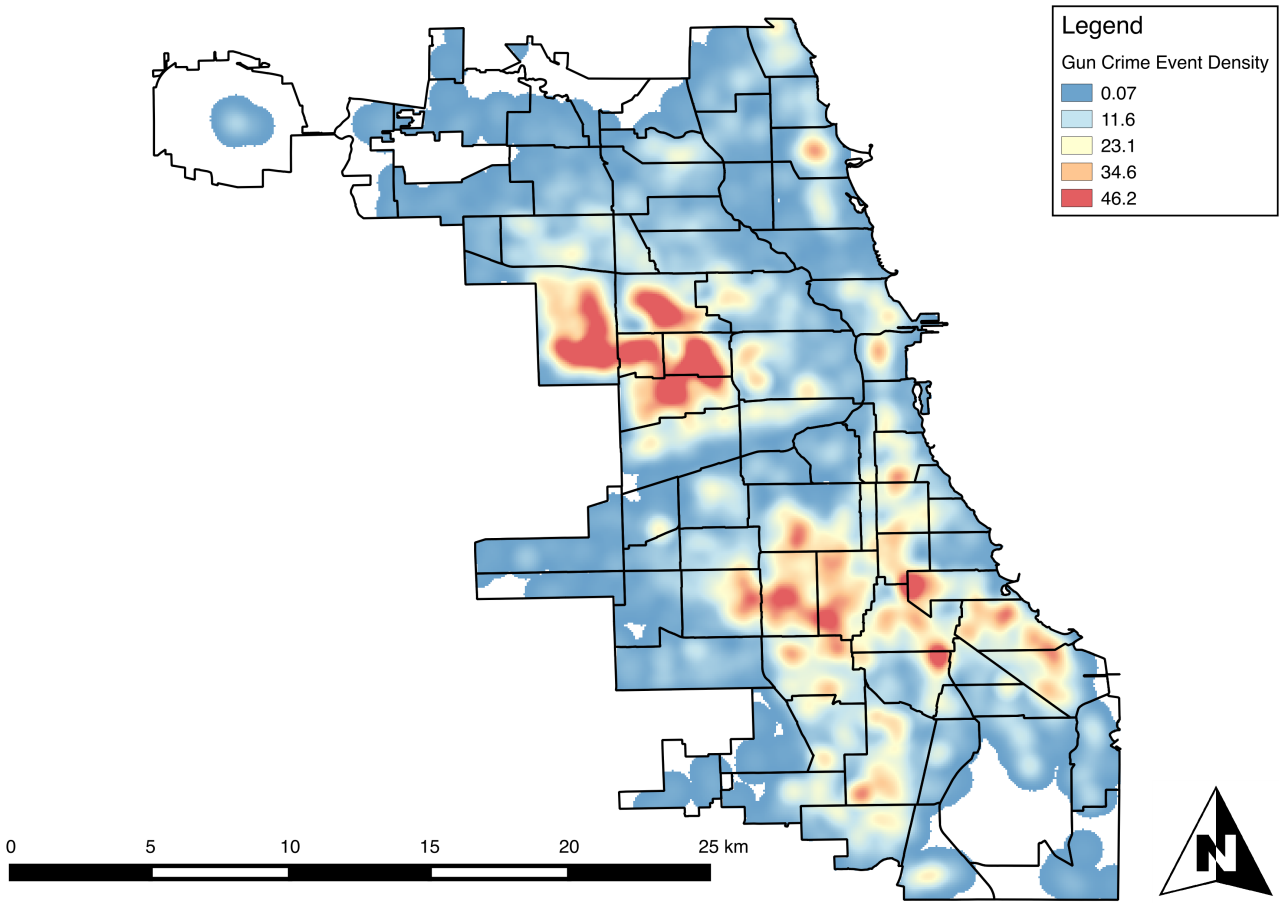

Which socio-economic conditions impact the number of gun crime events?

- 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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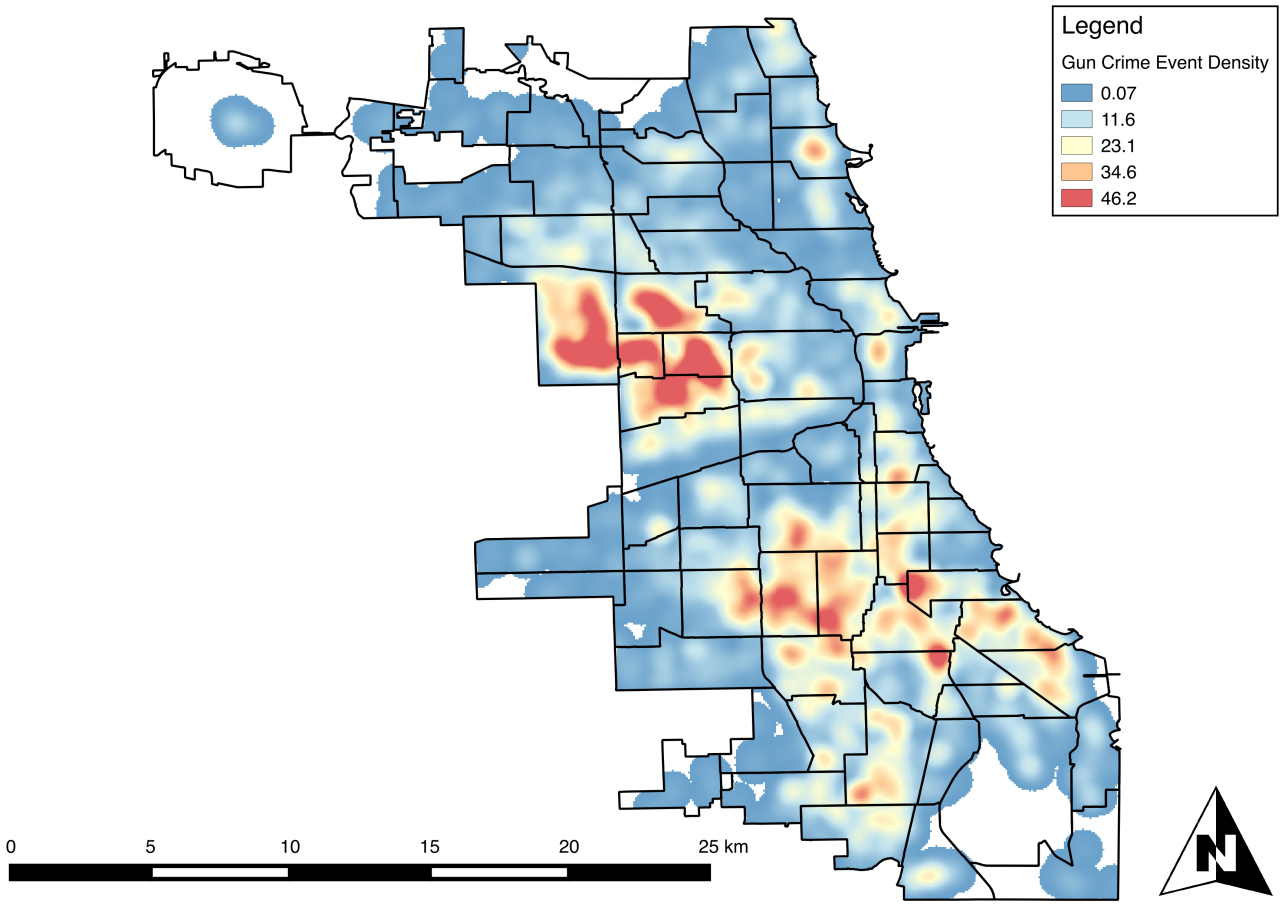


How far does gun crime spread in both space and time?

- 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

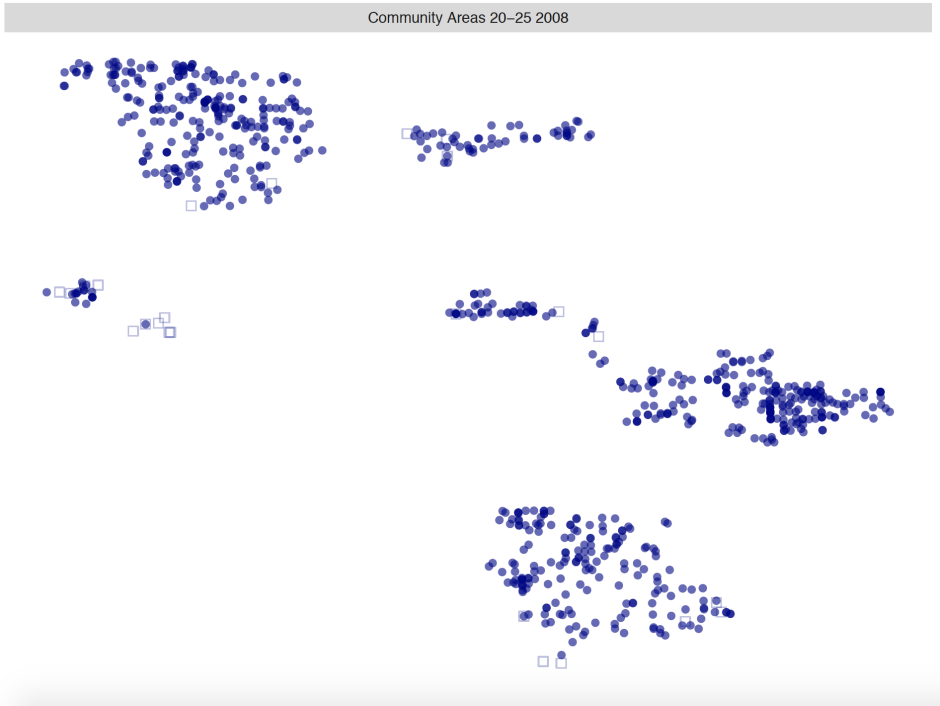
Conditional Intensity

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

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

Results of Point Process

Subset of Chicago data



- 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 caused by the initial 100 crimes
- We expect them to happen very soon after ($\sim$12 hours) and within a close geographic radius ($\sim$1.6 km).

Control for Spatio-Temporal Models

- There is no consensus on how to use optimal control in spatio-temporal models
- Analogous systems method
  - Convert the spatio-temporal model
  - Find the optimal solution for the analogous system
  - Use this solution for the original spatio-temporal model
  - Check for agreement of average behavior between the two
- Simulation method: add a control parameter to the spatio-temporal model and determine conditions that lead to an optimal solution

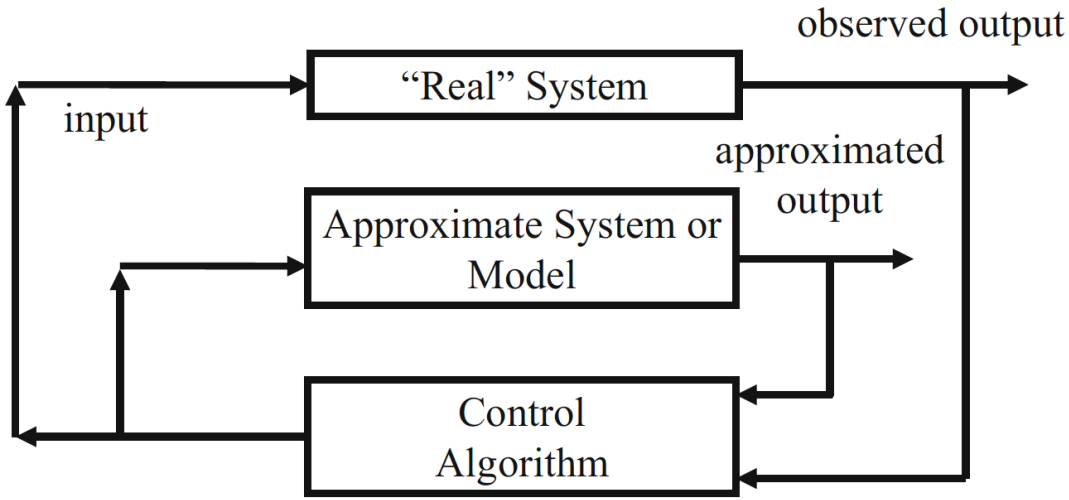


Fig. 2 Model-based control block diagram

Applying Cellular Automata to Gun Crime in Chicago

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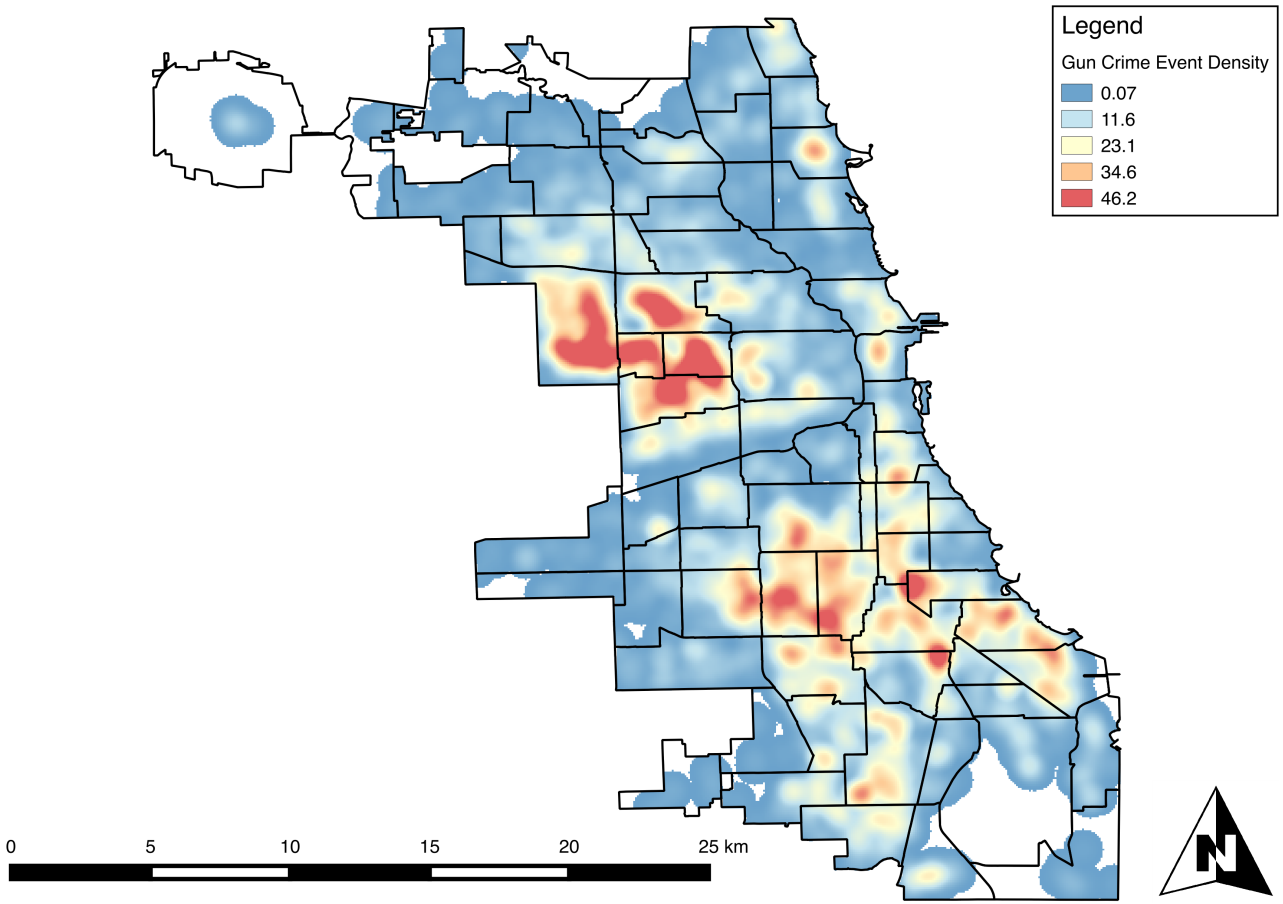
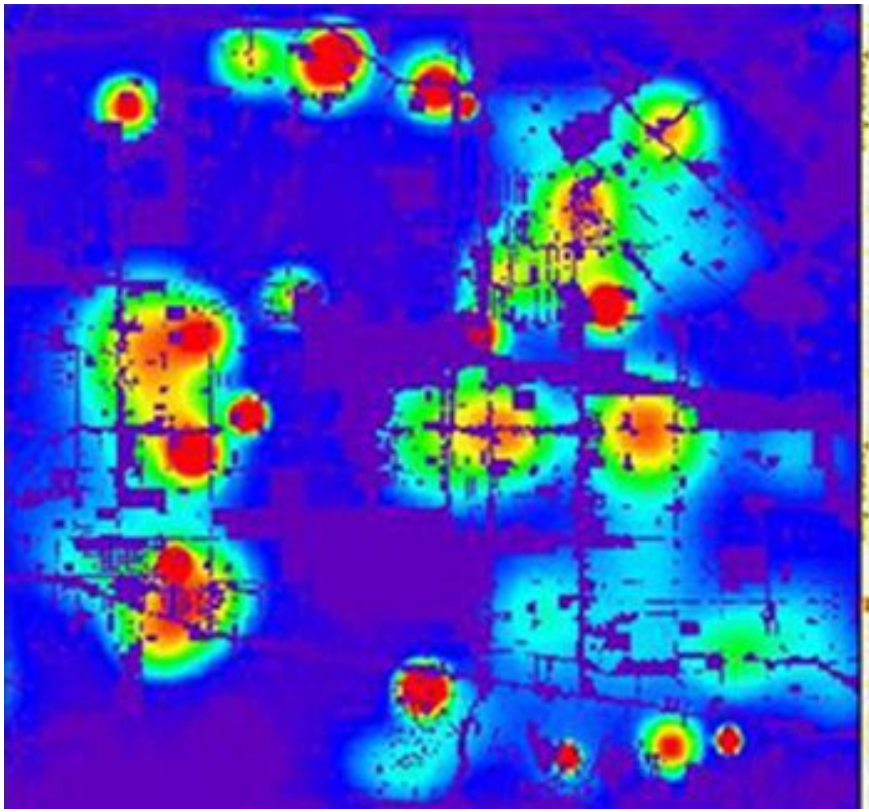


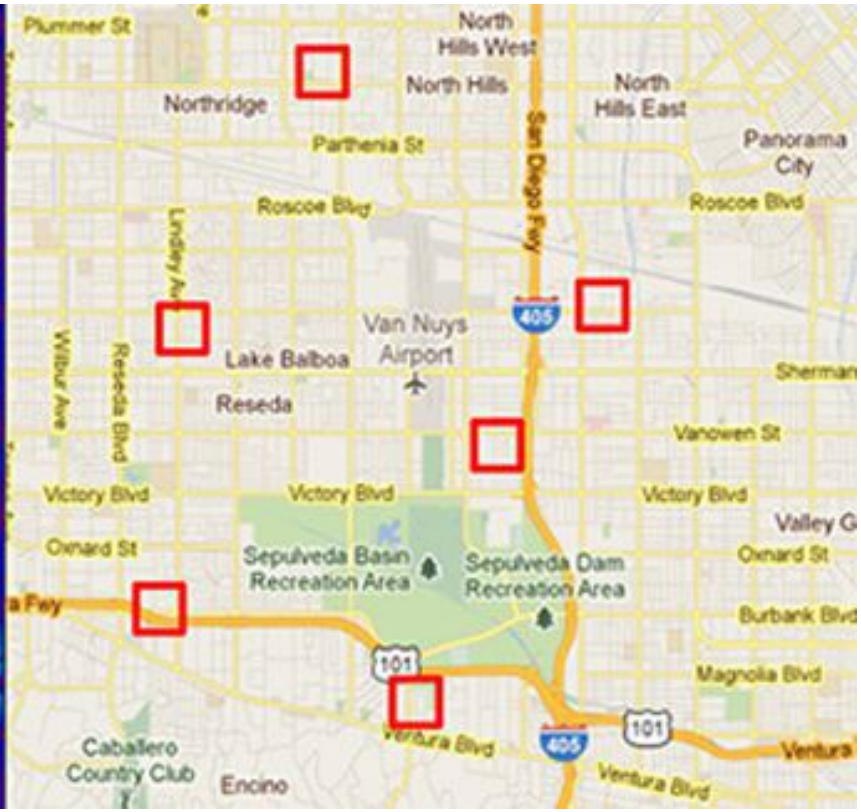
Adding Intervention Strategies

- Assess the impact of community-level interventions
- How does controlling each of the components in the model change the spread of gun crime?

Changing the level of crime present

- There are $\sim$14 levels of gun crime present in community areas of Chicago, Illinois
- What happens if we remove the highest level of crime?
- Implementation: Increased policing in high-crime community areas

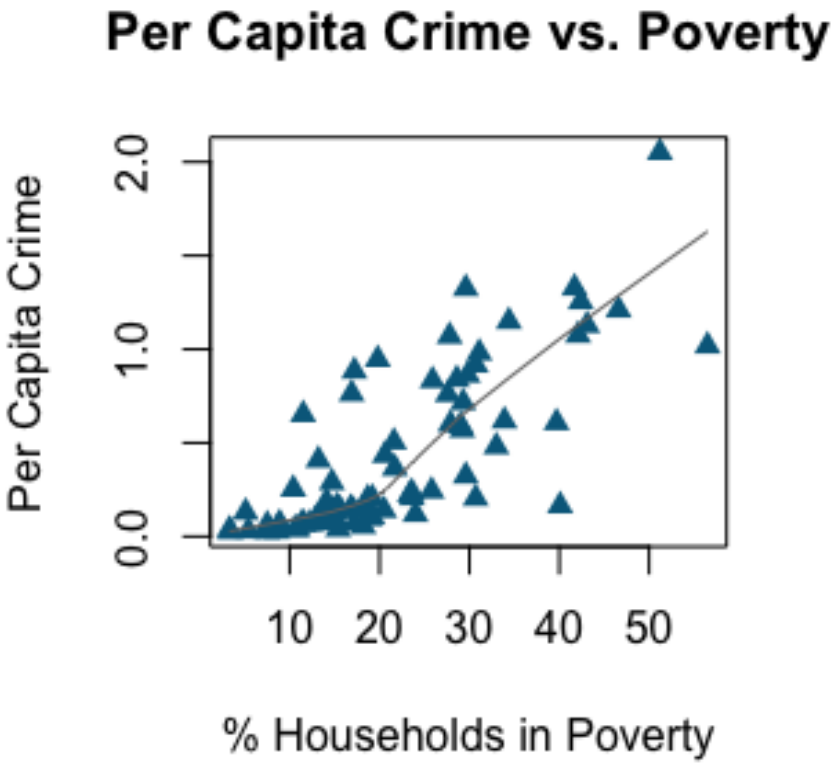




PredPol

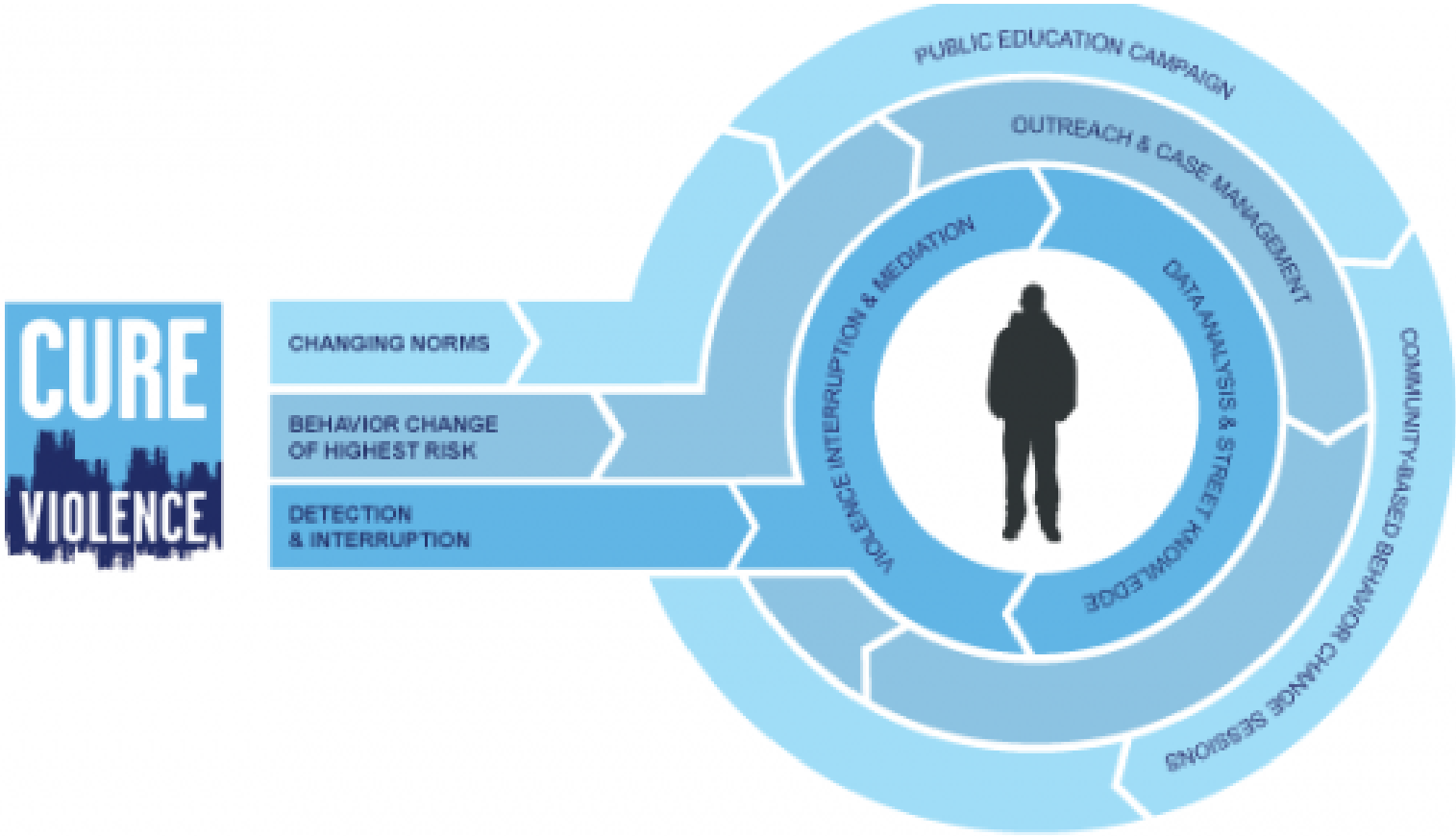
Changing the Internal Factors Present in Communities

- Socio-economic indicators affect gun crime in Chicago
- If we can reduce the impact of some of these factors, how can we change the spread of crime?
- Implementation: poverty and unemployment reduction programs



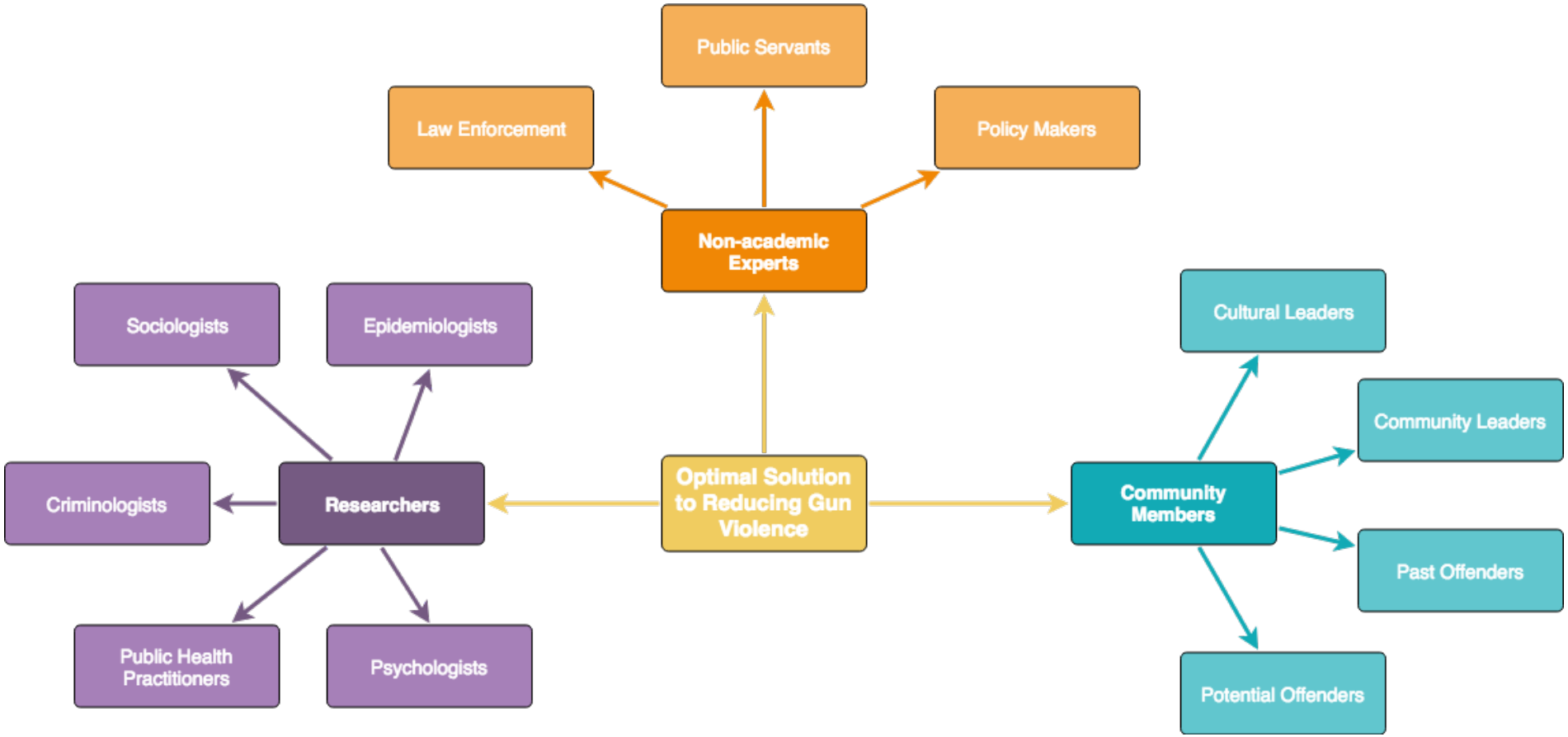
Changing the Impact of Neighborhood Influences

- If we can reduce the infectious aspects of gun crime, can we control the spread?
- Implementation: Community intervention efforts



Conclusions

- Which socio-economic conditions impact the number of gun crime events?
  - Poverty $(+)$
  - Unemployment $(+)$
  - Dependents $(-)$
- Does crime diffuse in both space and time?
  - **Yes**
  - A majority of crimes are triggered by past crimes and future crimes occur relatively close to past crimes
- Control measures can be added to cellular automata models to determine where and when interventions should be deployed


Public Servants
Law Enforcement
Policy Makers
Non-academic Experts
Sociologists
Epidemiologists
Criminologists
Researchers
Public Health Practitioners
Psychologists
Optimal Solution to Reducing Gun Violence
Cultural Leaders
Community Leaders
Community Members
Past Offenders
Potential Offenders

Future Work

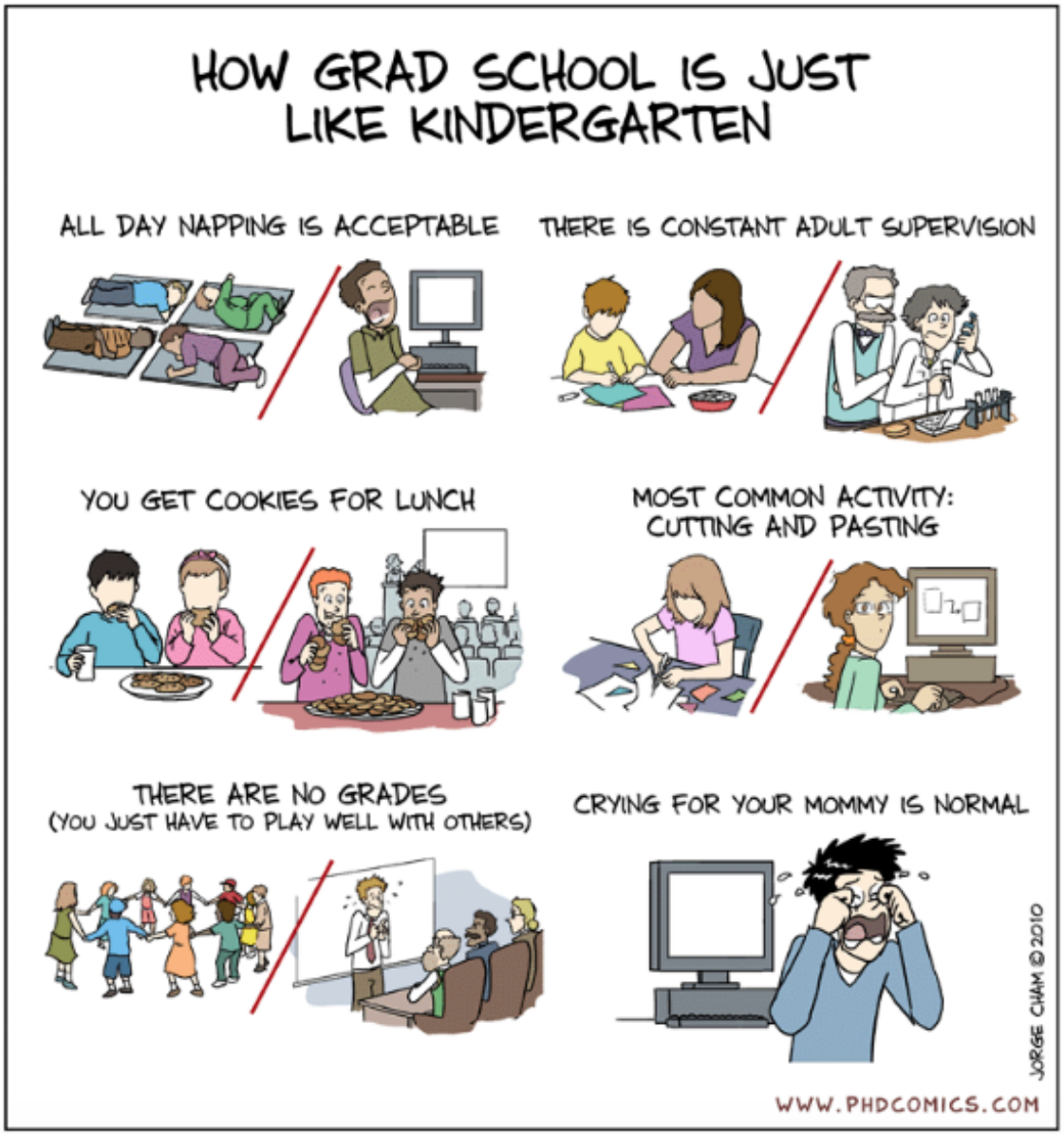
- Incorporate statistical results into cellular automata model
- Apply methods of control to cellular automata - any ideas?
- Create evidence-based policy recommendations of how to best combat gun crime in Chicago
- Extend these ideas to other cities and countries to reduce the burden of firearm-induced violence

NIMBioS

National Institute for Mathematical and Biological Synthesis

Questions?

Graduate School Explained



Things to do in Undergrad: Academic Edition

- Get involved with research:
  - Summer REU Programs
  - Internships and externships
  - Informal experiences
- Attend conferences
- Develop valuable skills:
  - LaTeX
  - Effective Oral and Poster Presentation
  - Coding
  - Teamwork
- Publish (if possible)
- Enroll in classes outside of STEM

Things to do in Undergrad: Non-Academic Edition

- Determine your work style
- Find an extra-curricular (or a few)
- Start to develop work-life balance

- Explore Lexington
- Establish a mentor/mentee relationship
- Develop a support system

Applying for Graduate School

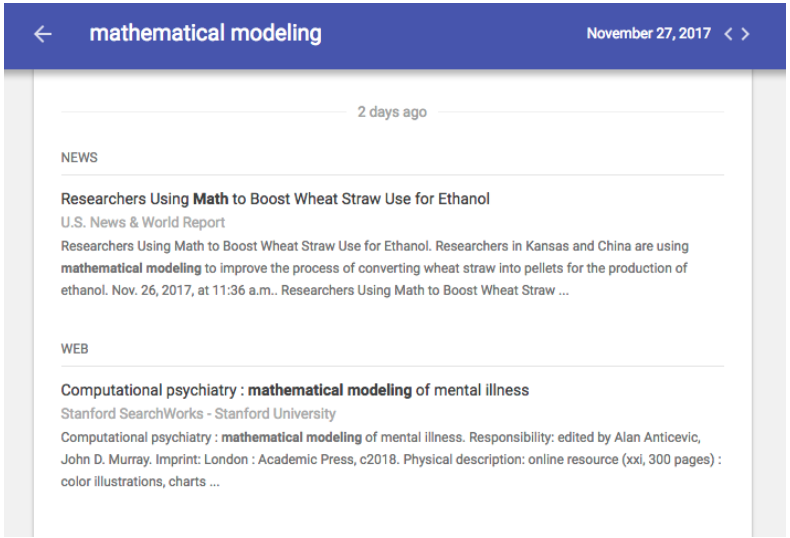
- Step 1: Decide if graduate school is the right path
- Step 2: Question your conclusions from Step 1
- Step 3: Decide that graduate school is the right path
- Step 4: Look for graduate programs

Item #	Date	Time	Recs		Subject
009926	03/02/04	19:18	57		PhD student - Ecological Modeling and Spatial Statistics; Germany
009545	02/12/18	16:24	51		PhD opportunity in Microbial Ecology
009526	02/12/17	11:12	26		PhD graduate assistantship in aquatic and quantitative ecology
009402	02/11/27	09:50	36		PhD assistantship
009331	02/11/19	08:39	42		PhD assistantships in Plant Ecophysiology
009328	02/11/18	14:12	64		PhD Fellowship
009320	02/11/17	15:25	38		PHD Assistantships - announcement
009043	02/10/10	11:18	42		Environmental Sciences PhD program
008965	02/09/27	10:33	59		PhD assistantships in aquatic and/or quantitative ecology, MSU
008863	02/09/11	13:23	33		PhD Graduate Research Assistantship
008785	02/08/30	09:46	37		PhD position in Landscape Modelling
008774	02/08/28	17:35	33		PhD Inquiry
008711	02/08/15	15:34	54		PhD assistantship in tallgrass prairie
008377	02/06/13	16:49	25		Postdoc, Technician, PhD Assistantships in Stream Ecology
008125	02/05/06	17:03	59		PhD assistantships
008126	02/05/05	23:14	92		
007988	02/04/23	20:16	82		Temporary fellowship for European PhD students
007853	02/04/09	12:37	32		Graduate Research Assistantship (PhD) in Land Cover Change
007498	02/03/11	10:50	39		Job posting: PhD Research Fellowship - Coyote Ecology

- Once you have narrowed down your program options:
  - Check for any outstanding course work
  - Find professors you want to work under (and contact them)
  - Ask current graduate students their perspective
  - Look up career trajectories of past students
  - Determine funding
- Take the GRE (if necessary)
- Start working on applications ASAP

The Interim

- Following the application process:
  - Recruitment Weekend
  - Advisor interviews
  - Decision
- Second-semester senior slump
- Graduation



- Apply for external fellowships
- Prevent burnout
- Stay engaged in the field

How to Succeed in Graduate School

How to Survive in Graduate School: Academic Edition

- Stay organized
- Manage your time
- Establish mentor/mentee relationships
- Apply for fellowships
- Go to seminars
- Read, write, read some more, write some more

NDSEG

How to Survive in Graduate School: Non-Academic Edition

- Schedule in time to step away from your work
- Pick up a hobby (or a few)
- Fall in love with your new city

- Work socialization into your self care routine: your dissertation may be an individual event, but thriving in grad school is a team sport
- Use the resources available to you

Questions?

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