Eli Ganz

CFS 392

Simulating the Spread of Gun Violence in Communities

1. Introduction

1.1 History

Gun violence has been a widespread issue in the United States, and around the world. While volumes of books have been written on the history of gun violence in the US, we will simply observe some important statistics here. The number of deaths due to gun violence is increasing in recent years; In 2001, 29,573 Americans were killed by firearms (Anderson,10), whereas 38,355 Americans were killed in 2019 due to firearms (BBC). According to a 2021 national survey, there are about 81.4 million adult gun owners in America (English, 7).

1.2 Significance of Gun Violence

Over 500 people die everyday from violence according to Amnesty International, a global organization dedicated to fighting for human rights. Gun violence has a significant effect on public health. Because it is often centralized in a small area, gun violence can be detrimental to a community's access to healthcare and to education (Amnesty). For the safety of their employees, healthcare facilities often will elect not to establish themselves in areas plagued by gun violence; this leads to trauma deserts in which individuals must travel great distances to reach lifesaving healthcare (Amnesty). Travel between one's home and the nearest hospital can also be dangerous due to a high concentration of gun violence in the area. In the same sense, it can be dangerous simply to go back and forth to school each day. Therefore, schools in areas of concentrated gun violence have a difficult time retaining teachers and high student attrition rates, leading to poor education for those who do stay in school and more uneducated individuals in the community. This perpetuates a cycle of gun violence in the community (Amnesty).

1.3 Population Impacted

Black communities are disproportionately impacted by gun violence. In 2017, 58.5% of victims of firearm homicides were Black (Amnesty). For reference, 13.4% of the US population is Black, according to the 2019 Census (USCB). In fact, Black Americans are more than 10 times more likely to die from gun violence than white Americans (Amnesty). Women and children are also disproportionately affected by gun violence, often in their own home due to domestic violence (Amnesty).

1.4 Proposed/Existing Solutions and Their Challenges

Since it is such a complex and multi-faceted issue, there are many proposed solutions to the gun violence epidemic in America, and every solution is, in some way, connected to another. We will explore three approaches. The one that is mainly in practice today is mass incarceration. As we have seen from class however, this is a dangerous solution with a plethora of negative public health impacts (Fullilove). Another approach is gun control. The hypothesis under which the philosophy of gun control operates is that if it becomes harder to obtain guns, less people will have guns, and then there will be less gun violence. Finally, the solution that I will be exploring in more depth in this paper is Gary Slutkin's approach: treating gun violence as an infectious disease and solving it with the same techniques used to curtail epidemics (Slutkin). I was inspired to develop a toy model of the spread of violence through a community.

2. Methods

2.1 The Model Community

The community in our model is built as a network. A network is a collection of nodes–in our case members of the community–and links between two nodes–in our case some sort of social or location-based connection. Each individual in the community has a set of others with which they can interact, we will call this the individual's "connections". Each individual's connections remain fixed throughout the simulation. Each individual is endowed with some propensity to be violent; this takes the form of a decimal probability, between 0 and 1, drawn from a normal distribution with a mean and standard deviation specified by the user. We will call this the individual's "probability". This probability will be updated throughout the simulation as described in the proceeding sections.

2.2 The Control

Our assumption for the control experiment is that there is no intervention in the spread of violence. We will now explain exactly how the simulation works. In each time-step, we start with a set of individuals who will have interactions with members of the community: let us call this set the "seekers" for the step. In the first time-step, the seekers are specified by the user. Each seeker chooses a node to interact with, randomly from it's connections. Each interaction will either be violent or friendly. This is decided by generating a random number between 0 and 1. If the number is less than one or both of the individuals' probabilities then the interaction will be violent, otherwise it will be friendly. If the interaction is violent then both individuals in the interaction will have their probabilities increased, and every member of their connections will also have their probability increased slightly. If the interaction is friendly, then both of the individuals will have their probability decreased, and every member of their connections will also have their probability decreased slightly. Since all of these parameters are variable, according to the user's preference, I will not talk about specific numbers. Once every interaction has occurred, all the individuals who took part in interactions, and were not seekers will become seekers for the next time-step. The process then repeats as many times as the user specifies.

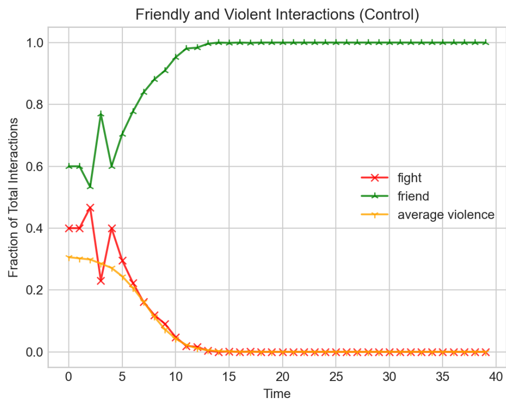
2.3 The Experiment

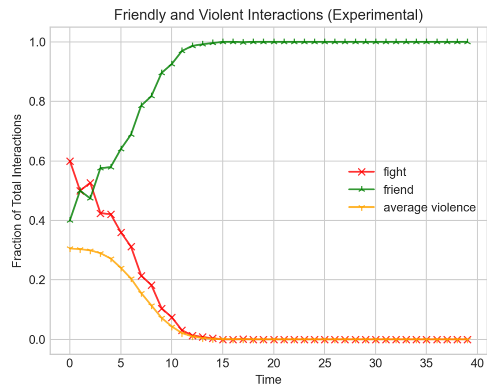
In the experimental simulation, the process is nearly identical to the control, however we modify it to take into account the three steps that Slutkin cited in his Ted Talk. First, we interrupt transmission. This means finding the most violent people and trying to help them become less violent. We implement this in the simulation by putting an upper limit on individuals' probabilities. Second, we prevent future spread. This means intervening in the community and helping individuals who might end up becoming violent. We do this by adding a group of workers to the community who are designated "helpers", endowed with a probability of being helpful, which we will label "helpfulness". If an individual interacts with a helper, they will have a "conversation". This conversation will either be successful or not, based on the helpfulness of the helper. If it is successful then the individual's probability will be decreased as well as their connections' probabilities, and the helper's helpfulness will increase. If it is a failure then the individual is not affected by it and the helper's helpfulness will still increase, as they learned something from the conversation. Thirdly, we change social norms. This is implemented implicitly during successful conversations when an individual's connections' probabilities are decreased.

3. Results

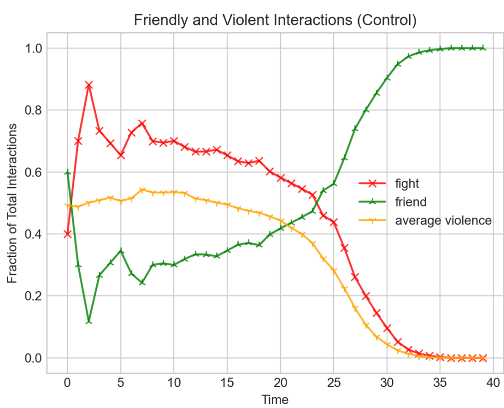
3.1 Community Dynamics

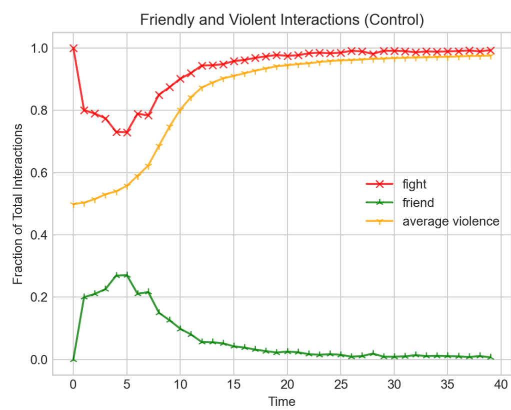
For both the control and experimental simulations, the communities behaved similarly. Depending on the initial average violence of the community (IAV), we might see some interplay between majority friendly, and majority violent interactions in the initial time steps, but in the long term, communities would all end up either completely friendly or completely violent.



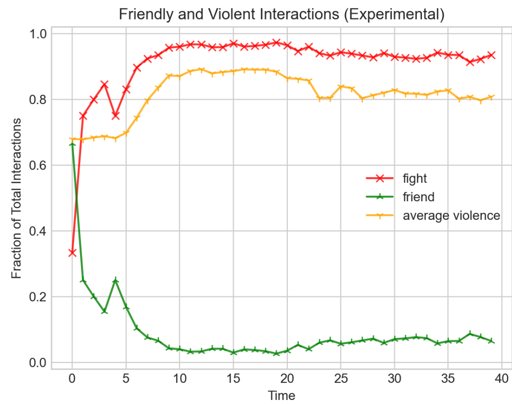


Left: fig. (a) Control Simulation with IAV = 0.3. Right: fig. (b) Experimental simulation with IAV = 0.3. We notice they have very similar behavior.





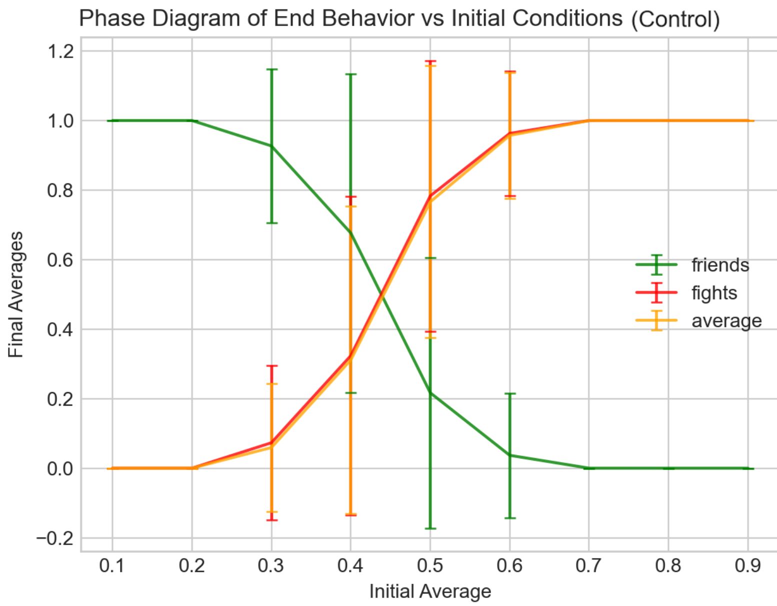
Left: Fig. (c) and Right: Fig. (d) Two control simulations with IAV = 0.5. We see that even if the community ends up being friendly, it takes a significant amount of time to reach a steady state as compared to the lower IAV examples.



Left: Fig. (e) Control with IAV = 0.7, Right: Fig. (f) Experimental with IAV = 0.7. We remark again, that these are simply two examples of the behavior with this IAV. In fact either could end up being entirely friendly, with varying likelihoods.

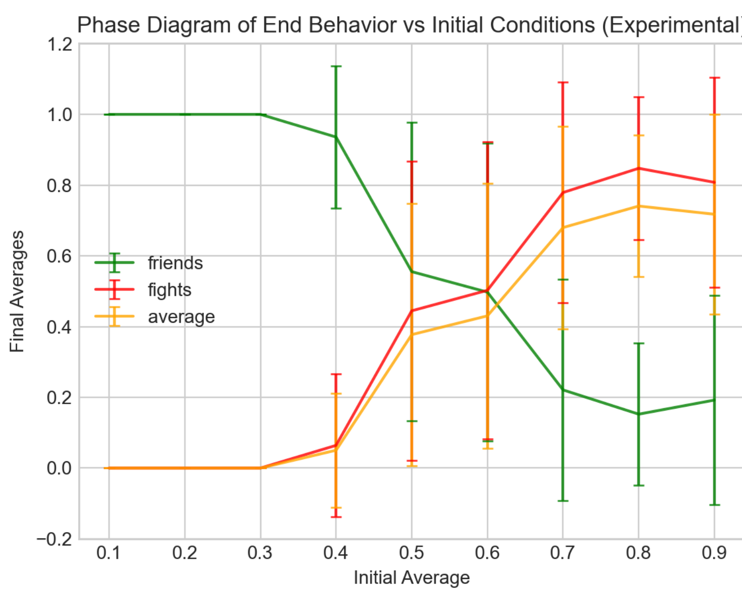
3.2 Phase Transitions in Long Term Behavior

While looking at the dynamics of individual communities is interesting, it tells us only the overall trends. In particular it tells us that over a long period of time, the community in this model will either be entirely friendly or entirely violent. However, it does not tell us much about the success or failure of the experiment. In order to see this, we will analyze the long term behavior of the community as a function of IAV. For both the control and the experimental, we will run 30 simulations from IAV of 0.1 to 0.9, increasing by steps of 0.1. We will then plot the average end behavior of these thirty simulations along with error bars that represent the standard deviation of the sample.



Left; Fig. (g) Long term behavior as a function of IAV for the control simulation. We notice that between IAV = 0.4 and 0.5 it becomes more likely for the community to end up violent rather than friendly.

Right; Fig. (h): The long term behavior of the experimental community. We notice that only at IAV = 0.6 does it become more likely that the community will end up violent rather than friendly.



Observation of figures (g) and (h), will show that there is indeed a critical point at which a phase transition occurs. Communities with IAV above 0.45 will most likely end up violent in the control, but until IAV of 0.6, they have a good chance of ending up friendly in the experiment. This is clear evidence that this experiment has some degree of success in our simulation.

In the control simulation, in the violence-dominated regime and of IAV ≥ 0.7 we notice that the error bars disappear, meaning in thirty simulations, an insignificant amount of communities were anything but completely violent. In the experimental simulation, however, in the violence-dominated regime of IAV > 0.6 there are still large error bars. This means that communities still ended up friendly, even when the odds would have been completely against them in the control.

4. Discussion

4.1 Errors and Shortcoming of the Model

While this is an interesting model, there are certainly many things that make it unrealistic. In the following section, we will outline the main shortcomings, explain the thought process behind each, and detail the consequences as well as some potential solutions.

Firstly, the simulation does not necessarily start with a very violent person, as an infectious disease model might suggest. The user specifies the seekers to begin the model. This decision was made in case we wanted to explore how certain properties of the topology of the network came into play, which we will discuss in Section 4.2.

Next, there was no real spectrum of violent interactions. In reality, not all fights involve guns and they have varying degrees of severity, from a heated argument to a shooting. This model simplifies all violent interactions to non-fatal acts of gun violence, which is unrealistic. This decision was made to encompass violent interaction in general and its effects on the community as a whole.

Another shortcoming is that all the probabilities and parameters of the network structure were set arbitrarily. They are easily tunable but they are not representative of real statistics. This was due to the lack of availability of certain statistics, and to create a simple comparison of the two situations: a control and an experiment. As long as the parameters are held fixed between the two, we get a sense of how the experimental setup affects the community. With real statistics, we could certainly build a more accurate model.

Along the same lines as the last comment, it is not necessarily realistic that every connection gets updated after every interaction. Furthermore, it is not necessarily realistic that those updates have the same polarity (increasing or decreasing) for an individual's connections. For example, if my enemy becomes more friendly, I might become more violent. More evidence of this being a drawback is that the community will inevitably end up completely violent or completely friendly. Clearly, this is almost never the case. One possible solution to this could be having smaller communities within the community, which we will explore further in Section 4.2.

Finally, the simulation has an arbitrary and fixed number of helpers. In reality the group of helpers would likely grow as they conduct more community outreach. Further, in the experiment, there is a hard upper limit for an individual's probability. What might be more realistic is having some chance of decreasing the probability, and some chance of it increasing. This may even be a low chance because the individual is already very violent.

4.2 Further Ideas to Explore

As alluded to in the previous section, there are many interesting paths that we could explore even with this simple model. For example, it might be interesting to see if individual nodes that are extremely well connected or extremely central in the community are good proxies for the state of the community as a whole. It would also be interesting to exploit the network's topology by using helpers to interfere with nodes based on their betweenness (G. d'A University) or other attributes. Similarly, we used a Barabasi-Albert Network Model (Barabasi, 5.3) to build this community. It might be interesting to use a Stochastic Block Model (Wikipedia) which captures community structure. If individuals are more likely to have friendly interactions within their community and violent interactions outside of their community, the dynamics might be completely different. These certainly are not the only ideas we could explore but they are indeed the most interesting and potentially influential ones to me.

5. Conclusion

Gun violence is clearly a complex public health crisis that does not have any sort of simple solution. Although it is a simplistic model of reality, we see that Slutkin's idea for limiting gun violence, by treating it as an infectious disease, is in fact effective in changing the trajectory of some initially violent communities into ultimately friendly ones.

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