Modeling the Spread of Fear Caused by Terrorist Events and the Effects of Community Intervention

EECS 372 – Agent-Based Modeling – Northwestern University

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An Agent-Based Model of the Spread of Fear through a Community

I designed and implemented an agent-based model of the spread of fear after a terrorist event and how community intervention affects the level of fear within the community. My goal is to explore the dynamics of the severity of a terrorist event, its residual terror, and the community intervention and how these variables affect the change in fear after a terrorist event. The feeling of fear increases when an act of terror occurs. The feeling of fear also increases when people are made aware of terrorist events, whether it is through mediums such as the news and media or physically passing by the place where the event occurred. However, communities do not passively sit back as fear rises amongst themselves. Communities will take it upon themselves to help calm their members, by providing counseling and implementing measures that prevent these events from occurring in the future. This model will explore how the severity of the terrorist event and its residual effects contribute to the increase in fear and how the community intervention programs work to reduce these same issues.

Motivation

Terrorist events occur with the intention of creating fear and terror in the community. Terrorists want their targets to live in fear of being attacked, or that their friends and family will be hurt.

Terrorists can then exploit those in fear and bend to them their will. With the threat of one's life or their loved ones' lives, people are forced to cooperate with the terrorists.

In an ideal world, terrorist attacks would not occur. Resources should obviously be committed to preventing these events from ever occurring. This is evident in the United States of America (USA) after the events that occurred on September 11, 2001. Four airplanes were hijacked by terrorists and used as projectiles to fly into the World Trade Center and the Pentagon. In response to these events, the United States government scrambled to make changes and implement programs to prevent events like these from occurring again. These changes include the creation of the Department of Homeland Security (DHS) and moving the Transportation Security Agency (TSA) into this department. The TSA grew in both size and power to prevent such an occurrence from happening again. Security was ramped up all around the country.

However, still terrorist events occur, from shootings to the bombing of the Boston Marathon. Though these are not what we would imagine as a terrorist event, they are events that regardless spread terror. Despite all the resources put into preventing these events from occurring, they still happen. That is why it is important to not only seek ways to prevent these events but also to understand how they work and limit their effectiveness.

Terrorism is a detriment to the economy. The actual event drains resources in order to rebuild and restore the damaged areas. However, it is not just the physical damages but also the ramifications afterwards in terms of the economy. If an area is known to have had a history of a terrorist attack, then people are less likely to visit[1], which ends a stream of income.

[1] Sönmez, S. F., Apostolopoulos, Y., & Tarlow, P. (1999). Tourism in crisis: Managing the effects of terrorism. *Journal of Travel Research*, *38*(1), 13-18.

The spread of terror can be just as dangerous as the event itself. As seen in a study done in Pakistan, terrorism has a significant impact on mental health[2]. This study surveyed a diverse group of people with a wide range of ages and professions to see what exposure they had to terrorism and how it had affected their thoughts and behaviors. It was found that terrorism did have a significant impact on the mental health of individuals that had been exposed to it. The study found that "They became depressed, anxious, and worried. These psychological feelings also affected their behavior."

Limiting the spread of terror is essential to the mental health of people and subsequently the health of the community. Humans are inherently social and unhealthy individuals can tear a community apart. It is crucial to stop the spread of terror to maintain the integrity and healthiness of the people within a community.

The papers that study the negative effects of terrorism go on and on. It is a clearly an issue that must be addressed.

What can we learn?

I built this model to be as flexible as possible. There are very few instances where I hard coded any parameters into the model, allowing for almost all my parameters to be adjusted by the user. I did this so that it could be easy to explore all aspects of the model by having control over as many parameters as possible within the model. The adjustable parameters can be generally categorized under Network Parameters, Terror Parameters, and Community Intervention Parameters. For this report, we will be primarily focused on the Terror Parameters and the

[2] Hussain, J., Iqbal, S., Taj, R., & Khan, A. M. (2012). Impact of terrorism on mental health. *Ann. Pak. Inst. Med. Sci*, *8*(1), 46-49.

Community Intervention Parameters. The driving question behind this model is: what are the key factors in a terror event that produces the biggest increase in fear within a community and what factors can limit the effect of the terror event on the community the most?

With this question in mind, hopefully this model will allow us to gain a better understanding on how terror events work and what tactics work best to limit their effect. We will be able to see how terror spreads in the community under different circumstances and be able to identify the most important factors that cause and limit spread.

Implementation

Agents:

1. People
    a. Variables: fear-level, group, last-patch-residual
    b. Procedures: adjust-fear-levels, residual-fear-affect, move, update-color
2. Patches
    a. Variables: residual-fear

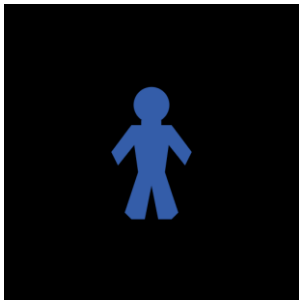


Figure 1: This is a person agent standing on a patch agent

This model has primarily two different types of agents, people and patches.

The people agents have three variables, fear-level, group, and last-patch-residual. Fear-level tracks what the current level of fear of each person. Group is used to help setup networks and links between the people. Last-patch-residual is a variable that keeps track of what the value of residual-fear was at the previous patch. Last-patch-residual is used so that a person will not be affected by an act of terror continuously; a person walking around on an area afflicted by terror will not see their level of fear go up with each step. However, if the person leaves the area and returns, they are thus reminded of the terror event and they are affected again.

The people agents also have four procedures that apply directly to them. The adjust-fear-levels function takes an argument of another person. This procedure looks at the fear-level of the other person and adjusts its own fear-level a little so that it is closer to the other person's.

The residual-fear-effect procedure increases the fear-level of the person by the amount of residual-fear on the current patch that was left over by a terror event.

The move procedure allows the person to move. There's a chance each turn that the person might face the closest other person and go towards them. The higher the person's fear-level is, the greater the chance that they go towards the closest person. The rationale behind this will be explained in the next section.

The update-color procedure changes the color of each person to reflect their level of fear. The higher their fear-level, the more red the person became, and the lower their fear-level, the more blue they became.

The patches have one variable, residual-fear, which keeps track of the amount of fear that is left on a patch after an event of terror has occurred.

System Parameters:

- Population –how many people are created in the community
- Network Parameters:
    - Network? – determines whether networks are on or off
    - Links-with-others –how many links the person should create with members of its group
    - Groups –how many network groups there should be
    - Network-communication-frequency – how frequently fear is diffused across the networks
- Terror Parameters:
    - Terror-radius – the size of the terror event, the number of patches out each direction that the terror event radiates out to
    - Terror-severity – the magnitude of terror events, how much a person's fear-level will increase if they are caught in the terror event
    - Initial-residual-fear – percentage of the severity that the residual-fear of the patches within the terror event should have
    - Residual-decay-rate – how much the residual-fear should decay per tick
    - Show-residual-fear? – on and off switch determining if the patches should show their residual-fear values or not
- Community Intervention Parameters:
    - Intervention-delay – number of ticks before community intervention occurs after a terror event
    - Number-of-interventions – number of people who will be affected by community intervention

- Level-of-intervention – the percentage decrease in fear-level of people affected by community intervention

System Procedures:

There are three system procedures, setup, go, and terror-event.

The setup procedure clears the previous simulation and sets up the new one with current system parameters.

The go procedure:

1. Have every person:
    a. Adjusts fear level if there is someone on the same patch as them
    b. Adjusts fear level based on those they are connected to in their network
    c. Adjusts fear level based on the residual-fear on the current patch
    d. Update the color
    e. Update their last-patch-residual to the value of the current residual-fear of the patch the person is on
    f. Move
2. Have every patch:
    a. Decrease residual-fear value if not zero
3. If a terror-event recently occurred, decrease the timer until community intervention by one

The terror-event procedure:

1. Checks for mouse click

2. When the mouse is clicked, increase the fear-level of those within the terror-radius by the terror-severity
3. Sets the residual-fear of the patches within the radius to initial-residual-fear percentage times the terror-severity
4. Start the timer until community intervention occurs.

This model also features a monitor and a few plots. The average level of fear of the entire community is shown in the monitor and one of the plots. The other two plots are histograms, showing the level of fear of each individual person in "fear of people" and the number of people at each level of fear in "fear distribution."

Rationale for Implementation

The implementation and rules of this model are actually based on a paper about the diffusion of fear after a terrorist strike.[3] This paper actually used a system dynamics model which is the basis of the agent-based model that I built. In the system dynamics model, people within the proximity of a terror event are affected. This terrorist event causes official investigation and media coverage. The terror event itself, the official investigation, and media coverage all work to increase the level of fear in the community because it increases the community's awareness and perception of risk. As time passes, the official investigation slows down and media coverage turns to other stories, and so the effects of the terror event begin to die down. After the terrorist event, the community will eventually begin to address the increased level of fear and risk and seek to lower these values. The community intervention works to bring down the level of fear.

[3] Burns, W. J., & Slovic, P. (2007). The diffusion of fear: Modeling community response to a terrorist strike. *JDMS: The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology, 4*, 298–317.

The community will once again reach an equilibrium but with a higher level of fear than before the event.

The reason I chose to model this system dynamics model with an agent-based model is because the agent-based model allows us to better see what is happening on an individual basis, to see the interactions between each individual person, as opposed to merely observing the system as a whole. It provides more randomness and uncertainty as opposed the homogeneity of a system dynamics model.

My agent-based model seeks to recreate the system dynamics model though I have made a few simplifications. I have merged the idea of official investigation and media coverage into the parameter residual-fear within the patches. When people encounter official investigations and media coverage, their fear increases as they become aware or are reminded of the terror event. This is simulated in my agent-based model by the residual-fear found in the patches of the terror event. When people happen upon these patches, their fear increases as they become aware or are reminded of the terror event that had occurred there, emulating the official investigations and media coverage.

In terms of individual behavior, people with a higher level of fear are more vocal about their fear, according to Burns. To reflect this, I have given people with a higher level of fear a higher probability of going towards other people to spread their ideas.

In the original system dynamics model, only the delay of the community intervention could be adjusted. I have extended the options with community intervention in my model by allowing the user to not only manipulate the delay in community intervention but also control the quality and

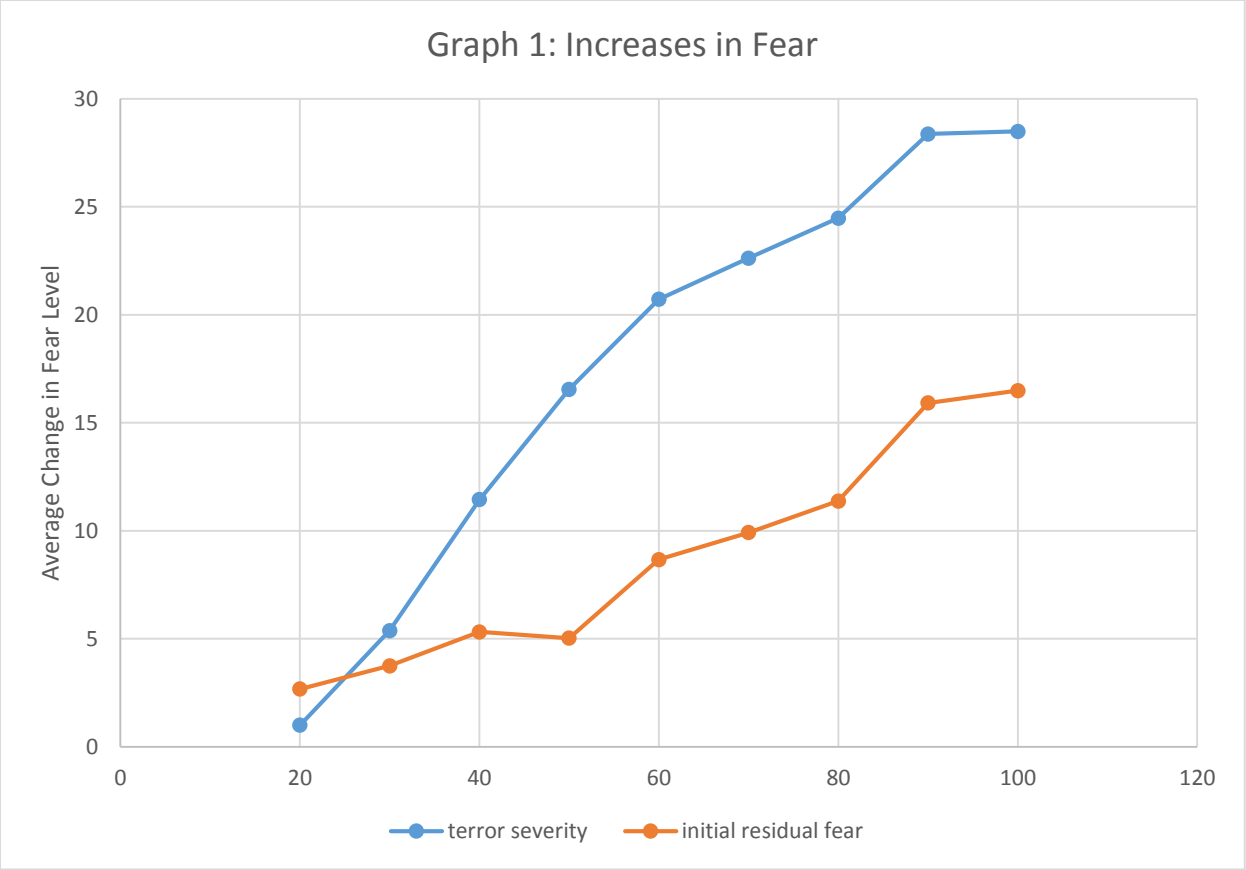
quantity of community intervention, through the system parameters of number-of-interventions and level-of-intervention.

Another extension that I have made in my model is the introduction of networks. We live in a day in age where we are constantly connected to our friends and family, whether it is through our phones by a simple text or call or via the Internet, with social media and emails. I chose to incorporate networks because it is a more accurate representation of how ideas travel today. Ideas are no longer limited by physical distance. I created the system parameter network-communication-frequency because although we are connected with our network, we are not constantly connected, so the frequency with which the people communicate over their network can be controlled.

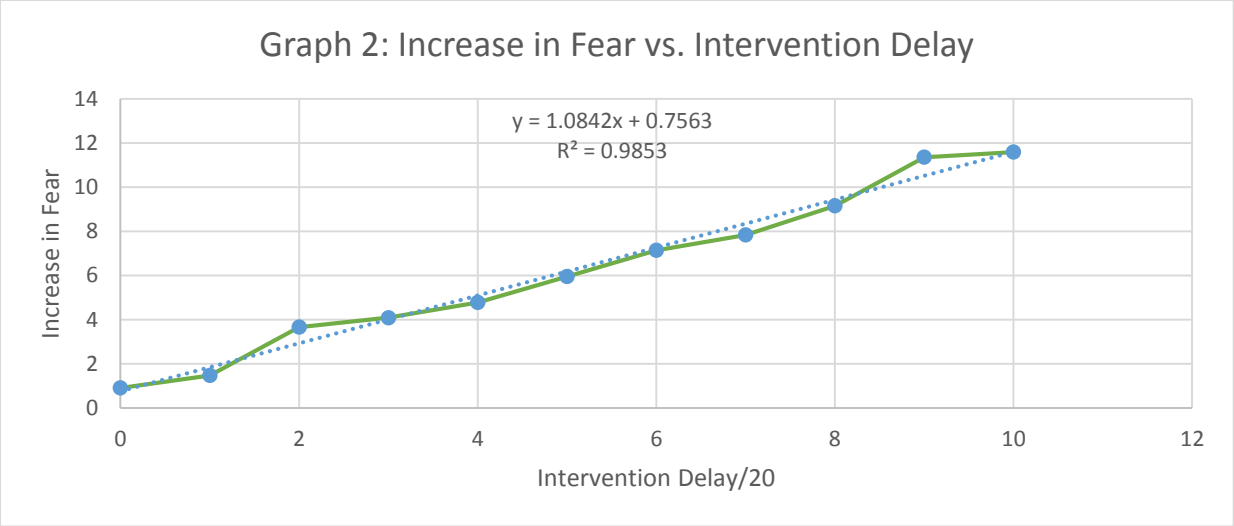
Analysis

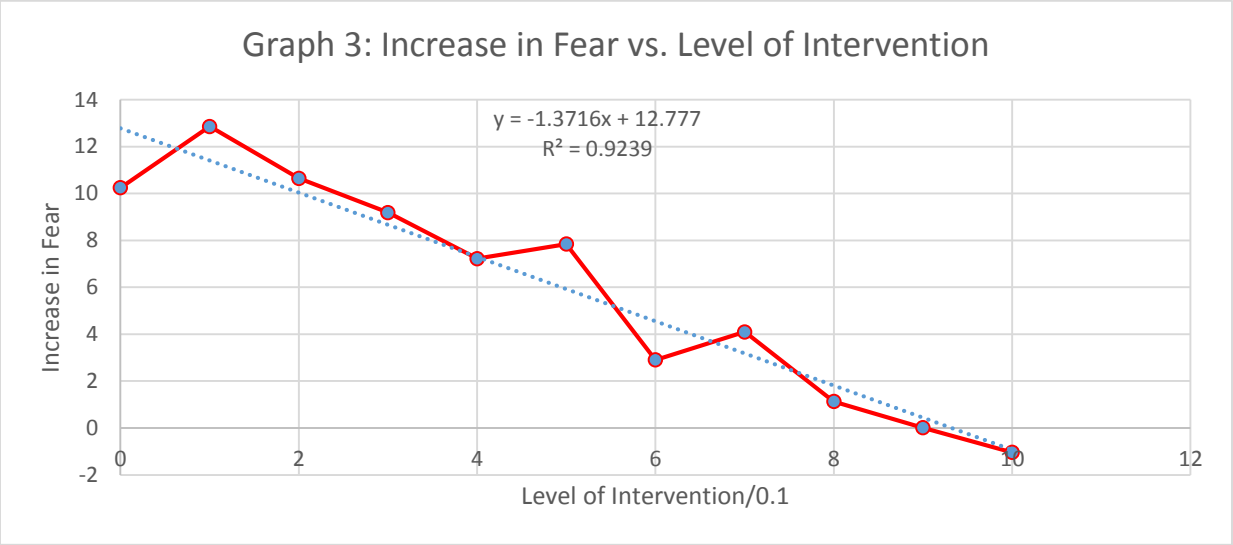
To tackle the driving questions of what factors increase fear level the most and what factors limit them the most, I used a slightly modified version of my model that was built for use with Behavior Space. This modified model saved and outputted the average fear before and after the terror event occurred, after the average fear had reached equilibrium. It also was set up so that instead of clicking to produce a terror event, it consistently produced a terror event centered on the origin. Once the average fear level has reached an equilibrium, the value is saved and then the terror event occurs. Once the average fear level has once again reached an equilibrium after the terror event, the average fear level is once again saved and the model stops.

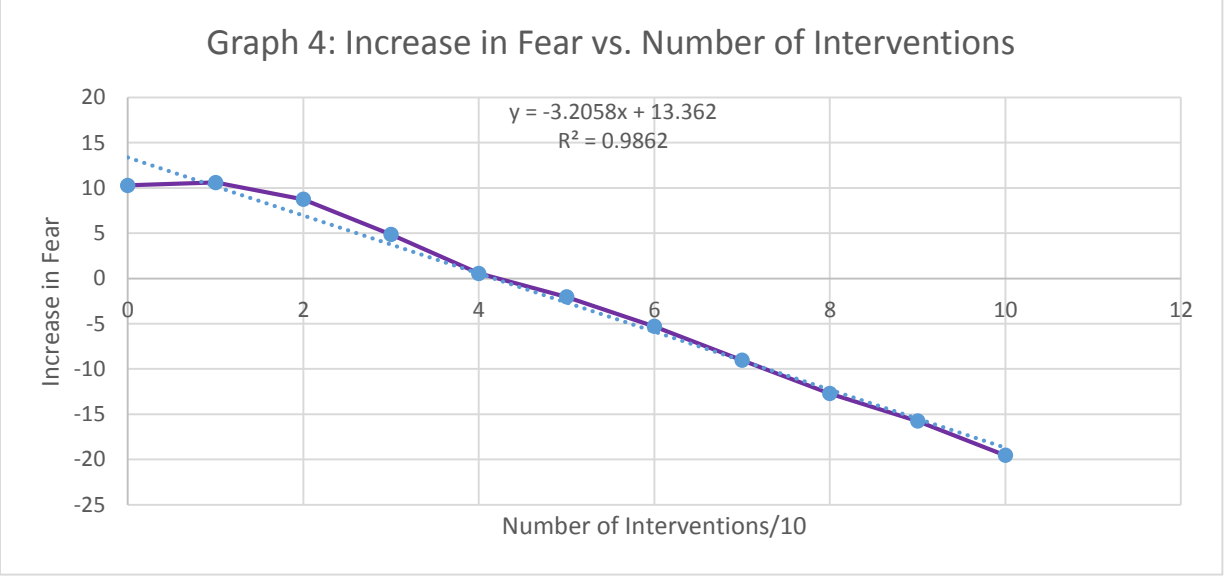
For my analysis, I would use Behavior Space to run experiments where everything was fixed except for the parameter I was testing. For each interval within the parameter, I had ten trials. I then plotted the average of these ten trials.



To answer the first half of our question, what factors lead to larger increases in fear levels, it is clear for our Behavior Space results that the severity in terror event leads to much larger increases in fear than the amount of initial residual fear afterwards. This means that media coverage and official investigations are smaller factors in fear within a community than the event itself's severity though they still do contribute to the increase in fear. Something interesting to take note is that in the interval 60 to 100, both terror severity and initial residual fear change at the same rate. I think this occurs because both values are beginning to converge since there is a limit to how much the level of fear can increase by.


Graph 2: Increase in Fear vs. Intervention Delay
y = 1.0842x + 0.7563
R² = 0.9853
Increase in Fear
Intervention Delay/20
0
2
4
6
8
10
12
14


Graph 3: Increase in Fear vs. Level of Intervention
y = -1.3716x + 12.777
R² = 0.9239
Increase in Fear
Level of Intervention/0.1
-2
0
2
4
6
8
10
12
14


Graph 4: Increase in Fear vs. Number of Interventions
y = -3.2058x + 13.362
R² = 0.9862
Increase in Fear
Number of Interventions/10
-25
-20
-15
-10
-5
0
5
10
15
20

In the original system dynamics model[3], the only parameter of community intervention that could be adjusted was the intervention delay. In that model, the longer the delay, the greater the increase in fear after equilibrium is reached. We see this is the case as well in Graph 2. I normalized all these graphs so that the magnitude of the slopes could be compared. It appears that Graph 4, the number of interventions is the biggest factor in terms of limiting the spread of fear. This means the more people the community intervention is able to reach at first, the more the fear is limited. However, this is misleading and a limit to the model. In reality, it would be impossible or extremely difficult to lower the fear level to less than what it was before short of brainwashing and propaganda. Additionally, this graph is misleading because the number of interventions physically changes the level of fear of a person. This is fine with smaller numbers of intervention because the level of fear is still dispersed naturally, only with some calmer people injected into the community. However, with the larger numbers of intervention, the 'intervention' is simply changing everyone's attitude instead of allowing for a natural spread. Though I do think that community intervention outreach is important, in terms of this model and its rules, it is difficult to justifiably say that the number of interventions would be the greatest limiting factor for the spread of fear. Comparing the other two parameters, intervention delay and level of intervention, it seems like the level of intervention performs slightly better. This would indicate that the quality of the intervention limit the spread of fear a little better than the timeliness of the intervention. I was unable to find any literature regarding these results so I can not say whether it is an accurate result or not.

Extending the Model

The focus of the model right now is how the different parameters affect the spread and change in the levels of fear. A logical next step would be to extend the model so that it can also measure how fast fear spreads. This could be potentially done by measuring the time it takes for a community at equilibrium to reach equilibrium again after the terror event. Another possible measure would be how long it takes for the average person to be affected by the terror event from when the event occurred.

An idea I was not able to implement was including people with different attributes that made them behave differently under different conditions. Perhaps there could people who refused to interact with others or only interacted with certain groups. There could be people who tried to spread their ideas regardless of their level of fear. There are many options to pursue this path.

Quarantining is a possible effect of bioterrorism and would be interesting to implement in the model. Groups would be separated by walls and people would only be able to interact with those physically in the same quarantine. It would be interesting to see how fear spreads on either side of the quarantine. Furthermore, networks could be introduced so that people could possibly be connected to those on the other side of the quarantine.

These were all ideas that I did not have the chance to pursue in this project and may do so in the future.

Another area for improvement is doing more research and reading more literature to support the model.

Conclusion

What are the key factors in a terror event that produces the biggest increase in fear within a community and what factors can limit the effect of the terror event on the community the most?

In the end, the only definitive conclusion was that the severity of a terror event was more influential to spreading fear than the residual effects of the event, from media coverage and official investigations. It was difficult to draw conclusions with the community intervention due to limitations of the model, especially with the number of interventions parameter. It did appear that the quality of an intervention was more important to limiting the spread of fear than the timeliness of the intervention.

This experience of coming up with an idea and actually pursuing it, building and creating the project from start to finish, was a learning experience unlike any other. This course melded curiosity, learning, and computer science in a way that challenged me to think differently every day. Building this model from scratch has helped me develop not just technical skills but a new way of thinking.