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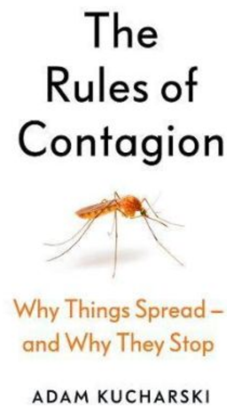

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The Rules of Contagion

Why Things Spread – and Why They Stop

Adam Kucharski • Profile Books © 2020 • 288 pages

Politics / Global Risks / Global Health Threats / Epidemics

Take-Aways

- Every outbreak is unique. While some outbreaks spread quickly, others ebb off just as fast.
- Mathematical models help show the growth of epidemics.
- Contagions can affect many industries, including the financial industry.
- Contagions can also spread through your social circle.
- Gun violence may be a type of behavior that’s socially contagious.
- Social behavior online may be different from real life. Abusive “trolling” behavior is common.
- Using big data can help with outbreak research but it’s not a panacea.

Recommendation

Despite the title, there are no real rules of contagion other than a basic pattern of growing, stabilizing and then declining. In this book, epidemiology professor and mathematician Adam Kucharski examines different types of outbreaks. Beyond infectious disease epidemics, other types of outbreaks include financial crises, viral online content, and the spreading of ideas and social behaviors such as obesity, yawning and even gun violence. Kucharski discusses traditional viral outbreaks such as Ebola and Zika, and the spread of malaria. But the more interesting chapters discuss how ideas and behaviors mushroom, from scientists who quote each other's work in academic journals to friends influencing friends. This book was published before the COVID-19 pandemic hit but it's appropriate reading during a quarantine.

Summary

Every outbreak is unique. While some outbreaks spread quickly, others ebb off just as fast.

What sparks an outbreak and causes it to spread? Can the past predict what the next pandemic will look like? It's easy to follow patterns and think the next outbreak will be similar to the one before it. Unfortunately, each individual outbreak is different. When researchers first hear of an outbreak, they draw a graph. An outbreak curve includes four stages – the spark, growth, peak and decline. A spark is only a start, and it's difficult to predict which contagions will spread like wildfire and which embers will flame out.

> *"In 1997, a group of epidemiologists proposed the '20/80 rule' to describe disease transmission. For diseases like HIV and malaria, they'd found that 20% of cases were responsible for 80% of transmission."*

In 2014, the Ebola epidemic in West Africa spread quickly from Guinea to Sierra Leone and Liberia. Cases were doubling every two weeks in the hardest hit areas, so 100 cases turned into 200 and 400 a month later. Other outbreaks move even faster, such as the WannaCry computer virus in May 2017. In the beginning, it was doubling in size almost *every hour* and hit 200,000 computers in 150 countries. Outbreaks affect many industries, including finance, politics, technology and health, and they're constantly evolving.

Mathematical models help show the growth of epidemics.

Mathematical models of outbreaks are now commonly used in public health and other fields. But the first mathematical modeling started in 1883 when Dr. Ronald Ross began observing mosquitos' behavior around water tanks. In September 1883, Ross moved to Bangalore to become Garrison Surgeon for the Indian Medical Service. After he tipped over a barrel of stagnant water, they disappeared. Ross tested his theory on whether mosquitos were transmitting malaria through their bites and found malaria parasites in the saliva glands of mosquitos after dissecting them. In 1902, Ross received only the second ever Nobel Prize in medicine for discovering how malaria spread. He was equally determined to find out how to stop it.

For malaria to continue in a population, infection and recovery rates have to balance out. In order to eradicate malaria (or any disease), recovery must outpace infection rates.

> *"As Ross saw it, there were two ways to approach disease analysis…'descriptive' and 'mechanistic' methods. In Ross's era, most studies used descriptive reasoning. This involved starting with real-life data and working backwards to identify predictable patterns."*

However, Ross used a mechanistic approach by discussing how transmission occurred between mosquitos and humans and how quickly humans recovered (or didn't). Then, he'd write an equation to show his model of thinking, which could be tweaked with new information.

With any outbreak, not everyone becomes infected. In an epidemic's early stages, there's rapid growth because there are more susceptible people than those recovering. Eventually, that equation flips over as the pool of susceptible people shrinks and the recovering pool starts growing. Herd immunity helps protect immune-compromised individuals from certain diseases. One small change over the herd immunity threshold can turn into an epidemic.

In the late 1970s, mathematician Klaus Dietz translated malaria researcher George MacDonald's theories to a wider audience in public health when he created a quantity known as R for "reproduction number." On average, a typical infectious person would generate R, which is a way of thinking about how many people are expected to pass on an infection. It can be used for any type of outbreak. In a disease outbreak, if R is two, an infected person will cause an average of two cases and then those will continue doubling. By the fifth generation, you'd expect, on average, 32 cases and 1,024 cases by the tenth.

> *"Because outbreaks often grow exponentially at first, a small change in R can have a big effect on the expected number of cases after a few generations."*

In the above example, if R had been three instead of two, you'd get 243 cases in the fifth generation. You can use R to compare transmission rates of any disease.

When R is below one, you have a population where most individuals are vaccinated, and they'd generate about one or two cases on average. But in a very susceptible population where R is five, you'd need to vaccinate four out of five people to contain the spread of disease. Disease outbreaks don't always grow neatly by doubling each generation or in some other identifiable pattern. However, as with any other rule, there are always exceptions. While sexually transmitted infections and mosquito-borne infections seemed to follow the 20/80 rule, other outbreaks such as SARS and the infamous food poisoning case of Mary Mallon, aka "Typhoid Mary," did not.

Contagions can affect many industries, including the financial industry.

Contagions don't only apply to disease. During the mid-1990s, "financial contagion" became a popular term to describe the spread of economic problems across countries. Ten years later, a global financial crisis would hit. Banks had bundled mortgages and other loans together in "collateralized debt obligations" or CDOs. Although some predicted the housing market bubble would burst, bankers lent more money than customers could afford to pay back. Mortgage products stayed popular even when housing prices started falling.

Just like an infection, the faster a financial bubble grows, the faster it will pop. But unlike disease outbreaks where individuals can be tested for immunity, there's no way to test for susceptibility in finance. People don't always make rational decisions when it comes to their money. Economist Jean-Paul Rodrigue acknowledges there's a shift in thinking during the growth phase of a bubble. As more money becomes available, average investors get greedy. While enthusiasm strikes in the beginning, fear strikes in later bubble stages.

Contagions can also spread through your social circle.

Social contagion, such as the spreading of ideas, is another type of outbreak. Richard Feynman first introduced his physics diagrams in 1948, and scientists have been quoting them ever since then. In 2005, physicist Luís Bettencourt, historian David Kaiser and their colleagues decided to count the number of times Feynman's diagrams were quoted in scientific papers. They also decided to measure how contagious Feynman's ideas were, which they called the reproduction number, R. As R, Feynman's ideas were very contagious – about 15 in the United States and up to 75 in Japan.

> *"It was one of the first times that researchers had tried to measure the reproduction number of an idea, putting a number on what had previously been a vague notion of contagiousness."*

Other examples of social contagions include obesity, smoking, happiness, loneliness and even yawning. There was a controversial study in 2007 suggesting obesity could be spread among social networks. Dr. Nicholas Christakis and social scientist James Fowler based their paper on the famous Framingham Heart Study from Framingham, Massachusetts. Their research suggested friends could influence unhealthy eating behaviors. Although their paper was cited more than 4,000 times, they had their critics. The *British Medical Journal* and mathematician Russell Lyons said their study had "fundamental errors" and exaggerated claims.

Christakis and Fowler thought about analyzing smoking before obesity but it's more subjective, and obesity is objectively measured. However, it's hard to separate out whether you end up sharing the behaviors of your friends because of their influence or whether you're choosing your friends because you share common interests or characteristics. They tried to rule out "homophily" (aka "birds of a feather flock together") in their research by including a lag time. If obesity is spread through social contagion, then a friend couldn't have started out obese. Environmental factors were harder to isolate. Here they looked at influence; if I listed you as a friend on a survey but you didn't list me, this could mean that I'm more influenced by you than vice versa. But if we share a mutual love for fast food restaurants, that's more of an environmental factor.

Gun violence may be a type of behavior that's socially contagious.

Researchers have questioned whether violence is contagious. In the mid-1990s, World Health Organization (WHO) epidemiologist Charlotte Watts set up one of the first major studies on domestic violence against women. Watts wanted to identify common factors of domestic violence. Within the WHO study, at least one out of four women had been previously abused by a partner in what's called the "dose-response effect." This applies to diseases whereby the risk of getting sick depends on how much of pathogen's dose one receives.

> *"If a man or woman has a history involving violence, it increases the chance of domestic violence in their future relationships. And if both members of the relationship have a history of violence, this risk increases even further."*

A history of violence won't always lead to violence but it is a risk factor.

Violence such as suicides or homicides can potentially cluster together. Media coverage of suicides in American and British newspapers led to an increase in area suicides immediately afterwards, according to research by David Phillips in 1974. After that, WHO published guidelines for ethical reporting of suicides, which should stress where to get help and avoid sensational headlines or discussion of the suicide method used.

> *"There can be a similar effect with mass shootings: One study estimated that for every 10 US mass shootings, there are two additional shootings as a result of social contagion."*

Suicides can happen within a few days or weeks, as a 1989 outbreak in Pennsylvania showed. After one suicide at a Pennsylvania high school, there were nine attempts in the next 18 days.

Gun violence murders can also happen in clusters. Epidemiologist Gary Slutkin and colleagues decided to tackle the problem of gun violence in neighborhoods. The "CeaseFire" program evolved into Cure Violence, which started in West Garfield Park in Chicago in 2000. Slutkin said it "was the most violent police district in the country at the time." The Cure Violence program's goals are to intervene and prevent further violence, identify who's most at risk for violence and try to change attitudes, behavior and social norms around guns. They hired workers called "violence interrupters" who were part of that community and had possibly experienced gun violence themselves. Violence in West Garfield Park dropped by about two-thirds a year after Cure Violence started. However, critics say some violence interrupters don't work well with police, and some have even committed crimes themselves.

Social behavior online may be different from real life. Abusive "trolling" behavior is common.

The Facebook data science team decided to examine political opinions among Americans from 2014 to 2015. They found that Facebook users tend to be more exposed to political views like their own. Facebook's algorithm filtered out five to eight percent of opposing political views after users' friends' content was posted. Users were less likely to click on articles with opposing political views and more likely to click on posts at the top of their news feeds. Sociologists from Duke University tried a similar experiment on Twitter. They recruited Americans to follow Twitter accounts of people with opposing political views and discovered that people tended to retreat back into their ideological hole.

> *"It does imply that reducing political polarization isn't as simple as creating new online connections. As in real life, we may resent being exposed to views we disagree with."*

Context is what's missing from social interactions online. Many people exploit this missing context by behaving badly online compared to how they'd interact in person. Harassing or abusive behavior online is called "trolling" (after mischievous trolls). Trolling is effective because casual onlookers don't understand the full context.

> *"Many trolls – of both the prankster and abuser kinds – wouldn't behave this way in real life. Psychologists refer to it as the 'online distribution effect:' shielded from face-to-face responses and real-life identities, people's personalities may adopt a very different form."*

Anyone can act like a troll given the right circumstances, such as when they pile on to an existing argument, or they take their frustration out on others unnecessarily. Trolls in online forums often spread misinformation, some of which gets picked up by legitimate media sources. Spreading misinformation is like "information laundering." While drug dealers will use legitimate businesses to launder money, trolls will use mainstream media outlets or celebrities to spread their message. It's easy and cheap to create fake bots, which is why online manipulation is so widespread. Virtual outbreaks can't spread far without amplification.

Using big data can help with outbreak research but it's not a panacea.

In the mid-2000s, researchers created Google Flu Trends (GFT) as a "big data" project to track the flu in real time by analyzing Google search functions for the flu. However, GFT had three major flaws. First, their predictions were off: While GFT had shown the winter seasonal flu peaks in the United States between 2003 and 2008, it underestimated the pandemic that sparked in spring 2009. Second, Google didn't share their algorithms so it was hard for researchers to analyze when GFT performed well versus poorly. Finally, GFT wasn't ambitious enough because the flu virus is constantly evolving every winter, which makes vaccines less effective.

> *"Similarly, the main reason governments are so worried about a future pandemic flu virus is that we won't have an effective vaccine against the new strain. In the event of a pandemic, it would take six months to develop one, by which time the virus will have spread widely."*

Basically, GFT gave scientists the opportunity to track flu trends a week or so earlier than usual but not much useful information after that. Big data often holds more promise than real solutions.

Technology helps scientists and researchers analyze outbreaks but not necessarily control them. Mathematical models can be used to create control measures, smartphones collect data from patients and computers can use sequences to track how pathogens spread. But logistical problems remain as researchers struggle to keep up with new outbreaks. In 2015 and 2016, when researchers were ready to start vaccines against Zika, it suddenly stopped spreading.

> *"This is a common frustration in outbreak research; by the time the infections end, fundamental questions about contagion can remain unanswered. That's why building long-term research capacity is essential."*

Obtaining data is only part of the problem. Contagion is messy in real life. In order to study outbreaks, researchers must move quickly and be as adaptable as what they're studying.

Infectious diseases are decreasing worldwide because our knowledge of contagions have grown. The global death rate for infectious diseases has been cut in half in the past 20 years. Unfortunately, other diseases can become contagions depending on environmental and societal factors. Researchers are taking their knowledge of contagions and applying them to other types of outbreaks, such as social, financial or technological outbreaks. Using R helps researchers quantify and track data on any type of outbreak. Only by being open to new challenges regarding outbreaks will scientists and others continue to learn.

About the Author

Adam Kucharski is a mathematician who has worked on global outbreaks including the Ebola epidemic and Zika virus. Kucharski is also an associate professor at the London School of Hygiene & Tropical Medicine.

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