

The Maths of Going Viral: When Small Sparks Become Cascades

Ideas do not spread evenly. Most just fade away quietly. But every now and then, something catches fire in a way that feels almost impossible. I have seen it happen so many times. A random video pops up once, then twice, and suddenly it is on everyone's phone. A song that has been forgotten for years suddenly takes over the entire internet. It always feels magical and completely random. Yet after looking closer, I have realised there is a beautiful mathematical story hiding underneath all that chaos.

It all starts with the network. Think of every person as a node and every follow, share, or chat as an edge connecting them. Some people are like quiet corners with just a handful of connections. Others are massive hubs with thousands of links. The network basically sets the rules before the idea even gets a chance.

But connections by themselves are not enough. The real drama is in people's heads. Mark Granovetter's idea of thresholds changed how I think about this. Each of us has our own personal threshold. It is the number of people who need to do something before we join in.

Let us make this real. Imagine ten friends in a WhatsApp group. Person A has a threshold of zero and shares every funny reel instantly. Person B needs just one friend to share before they join. Person C waits for two, Person D for three, and so on, up to Person J, who only joins when at least six others have already shared. At the beginning, nothing much happens. Share a new dance video. B sees it and joins in. Now two people have shared. C sees two and also shares. Then D crosses their threshold of three. Suddenly, the group chat lights up. Within minutes, six or seven people are sharing the same video, tagging others, and adding their own versions. What started as two quiet shares became a flood. That sudden jump from slow, hesitant spreading to rapid adoption is the tipping point. It is the magical moment when the system flips.

Mathematics lets us capture this moment precisely. Suppose each time you see a friend share something, there is a probability p that it convinces you to join in. If k of your friends have already adopted the idea, the probability that you resist all of them is $(1-p)^k$. Therefore, the probability that you adopt it is:

$$P(\text{adopt}) = 1 - (1-p)^k$$

This innocent-looking equation hides something surprisingly powerful. Let us see how it actually behaves when p equals 0.2, which is a realistic chance that one exposure influences you:

- When k is 1, the probability is about 20 per cent
- When k is 2, the probability is about 36 per cent
- When k is 3, the probability is about 49 per cent
- When k is 5, the probability is about 67 per cent
- When k is 10, the probability is about 89 per cent

Notice how the probability does not increase in a straight line. It starts slowly and then accelerates sharply as k grows. This nonlinear behaviour is the mathematical heart of virality. Early on, when very few people shared the idea struggles to gain momentum. But once k crosses a certain level, each new adopter adds significantly more pressure than the previous one. The curve bends upward, and that upward bend creates tipping points.

When this individual behaviour plays out across a large real network, the effects become breathtaking. Duncan J. Watts studied exactly this phenomenon in 2002 and discovered something remarkable. Large global cascades only occur inside a narrow window of conditions. If the network is too sparse, ideas stay trapped in small local clusters and die out. If the network is too dense and most people have high thresholds, the idea also fails to spread because no one sees enough adopters to cross their personal threshold. But in that special middle zone, where connectivity is moderate, and enough people have relatively low thresholds, a tiny initial spark can trigger a cascade that eventually reaches almost everyone in the network. Watts showed that the fate of an idea often depends less on its quality and more on whether the network's average degree and threshold distribution sit inside this delicate cascade window.

Real-world examples begin to make much more sense through this lens. The #MeToo movement in 2017 started as quiet personal stories shared by survivors. For a long time, it stayed below most people's thresholds. Then a few highly visible women spoke out. Suddenly, thousands found that the number of people they saw participating had jumped. Threshold after threshold was crossed in rapid succession. What looked like an overnight explosion was actually a network that had quietly reached its critical tipping point.

The same story repeats on modern platforms, often with old content. In 2022, Kate Bush's song *Running Up That Hill*, which was released in 1985, shot back to the top of the charts after appearing in *Stranger Things*. The song had not changed in thirty-seven years. What changed was the network. Millions of viewers were exposed to it at once. This dramatically raised k for people across countless friendship circles. Algorithms noticed the rising engagement and began pushing it even harder, creating a powerful feedback loop. The music was old. The mathematics of the cascade was timeless.

Of course, this understanding has its limits. Even with perfect knowledge of the network and thresholds, exact prediction remains incredibly difficult. Tiny differences in who shares first, the exact timing of a post, or a small algorithmic tweak can completely flip the outcome. This sensitivity echoes the butterfly effect discovered by Edward Lorenz in weather systems. The smallest change in starting conditions can produce wildly different results. Laplace once dreamed of a perfectly predictable universe, but human networks refuse to cooperate.

In the end, mathematics does not give us complete control over the spread of ideas. It cannot tell us exactly which video will go viral tomorrow or which hashtag will spark the next global movement. Yet it reveals both the patterns that govern their growth and the limits of our ability to predict them. It shows us why some ideas stay hidden while others cross a tipping point and sweep through the network like wildfire. It teaches us that virality is not pure randomness, even if it is not perfectly predictable.

The next time something appears everywhere at once, remember that beneath the surface chaos, mathematics is quietly at work. It illuminates the hidden architecture that makes such extraordinary moments possible.