17. Complex contagions

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INTRODUCTION

Contemporary research on the spread of social contagions begins with a puzzle. The puzzle comes from a stark contradiction between the central claim of Malcolm Gladwell's (2000) best-selling book *The Tipping Point* and the answer to the question: How do innovative technologies—like Twitter, Facebook and Skype—and social movements—like the Arab Spring and Black Lives Matter—become successful? It is a puzzle that extends back many decades before Gladwell's book, to Mark Granovetter's (1973) famous study "*The Strength of Weak Ties*", and even further to Katz and Lazarsfeld's (1955) well-known study of "opinion leaders". Gladwell was only the most recent proponent of an influential idea that permeates the work of these important thinkers. The idea is that social innovations spread through networks by propagating just like a virus. The problem is that this widely accepted theory of social spreading does not match up with the most current data on how social innovations actually spread through social networks.

The solution to this puzzle comes from an overlooked theoretical distinction between simple contagions—like simple information and familiar ideas, which spread through single contact—and complex contagions, like changes in workplace culture or the adoption of innovative technologies, which typically require reinforcement from several peers before people are willing to adopt them (State and Adamic 2015; Steinert-Threkeld 2017; Sprague and House 2017; Mønsted et al. 2017; Traag 2016; Centola 2010, 2015). The hallmark of simple contagions is that they spread easily, like gossip or the measles. Mere exposure to an "activated" individual is typically sufficient for transmission. By contrast, complex contagions encounter resistance. Simply having contact with a single adopter is typically not enough to convince someone to adopt (Centola et al. 2007; Centola 2010, 2015).

There are four key sources of resistance that create complexity in the process of social spreading (Centola and Macy 2007; Centola 2018). Each one is a barrier to adoption. Identifying whether an innovation will encounter any or all of these barriers reveals whether an innovation will be simple or complex.

(1) Social coordination: If the value of an innovation or behavior depends on coordinating with other people who adopt it—i.e. the greater the number of adopters the more useful the innovation—then it requires social reinforcement to spread. Think of Twitter or Facebook.
(2) Legitimacy: For some behaviors, the more people who adopt them, the greater the expectation is that others will approve of the decision to adopt, and the lower the risk is of embarrassment or sanction. Think of wearing a new fashion.
(3) Credibility: It often happens that adopters act as sources of social proof for an innovation. The more people who adopt a behavior, the more likely it is that the behavior is worth the cost or the effort it takes to adopt it—and the lower the risk is of wasting time or resources on it. Think of the decision to adopt a new diet or an expensive new digital technology.

(4) Emotional excitement: Some innovations and behaviors are appealing only when people are emotionally energized by one another. Think of joining a protest like Black Lives Matter.

These four barriers to adoption may occur individually or together. However, all of them can be overcome by social reinforcement. For instance, innovative social media tools like Facebook and Twitter are transmitted through peer networks that provide sufficient social reinforcement to enable people to coordinate with their friends in their decisions to adopt (Ugander et al. 2012; Tool et al. 2011). The growth of political uprisings and social movements like the Arab Spring also spread via social reinforcement because people need to believe that a movement is legitimate before they will be willing to add their voice to the chorus (Steinert-Threkeld 2017). Similarly, the spread of new workplace gender norms typically requires sufficient social reinforcement to create a coordinated "critical mass" of peers that can trigger a tipping point for a new social norm (Kanter 1977; Dahlerup 1988; Centola et al. 2018). More generally, everything from the spread of memes like the Ice Bucket Challenge in the US (Sprague and House 2017) to the growth of environmental technologies like household solar panel installations in Europe (Rode and Weber 2016), are complex contagions that require social reinforcement in order to spread successfully.

The most significant consequence of the distinction between simple and complex contagions is that it transforms our understanding of how the structure of social networks impacts the dynamics of social contagion. Granovetter's (1973) superb study of the strength of weak ties shows that "weak" acquaintanceship relations tend to link randomly across a network, bridging long social distances, while "strong" intimate friendship and family relations tend to be clustered together, creating many "triadic" friend-of-friend ties. Once Granovetter developed this strikingly clear conception of the large-scale structure of social networks, he inferred that long-distance acquaintanceship ties are more valuable for the process of social diffusion than trusted friendship ties. As he put it, "whatever is to be diffused can reach a larger number of people, and traverse a greater social distance (i.e. path length), when passed through weak ties rather than strong" (1973: 1366). The crucial concept in Granovetter's analysis is *path length*: the number of steps in the shortest path from one individual to another (Solomonoff and Rapoport 1951, Rapoport and Horvath 1961). Because weak ties span long social distances, they shorten the path length between everyone in the network. The more weak ties there are, the shorter the path length between people becomes—and the faster that new ideas, innovations and social movements can spread from one person to everyone else.

But, complex contagions change everything. For a complex contagion, a single link across a social network is not sufficient to spread an innovation from one person to another. The "bridge" across the social network created by a weak tie is narrow bridge—composed of a single link. Because the spread of complex contagions requires social reinforcement from multiple contacts, an effective bridge across the network must be a wide bridge—composed of multiple ties. Wide bridges are the essential network structure needed to spread complex contagions. And, they are typically associated with strong ties rather than weak.

Strong ties naturally create wide bridges because they are clustered together, creating stable pathways for spreading complex contagions from one community to another. This is why so many innovations (from farming equipment to Twitter memberships) have historically been found to spread "spatially" or "geographically"—because spatial and geographic networks are typically composed of strong ties that form wide bridges (Centola and Macy 2007;

Centola 2018; Hagerstrand 1968; Toole et al. 2012; Centola 2021). But, wide bridges need not be geographically constrained. They can also span long geographic distances. On social media sites like Facebook, the emergence of "virtual" wide bridges among vast networks of peers enables social reinforcement to propel the spread of complex contagions. As you will see, social movements ranging from the Arab Spring to the growth of support for same-sex marriage are complex contagions that have spread across social media networks by using reinforcing network pathways. Remarkably, these networks bear a stronger resemblance to the strong tie network pathways through which the Civil Rights Movement took hold (McAdam and Paulsen 1993) and pre-industrial technologies spread (Hagerstrand 1968), rather than the weak tie networks through which information and viruses typically expand (Centola 2018; Centola 2021; Guilbeault et al. 2018a).

For nearly a century, network concepts such as distance, influence and centrality have been developed under the assumption that social dynamics follow the principles of simple contagion, for which each weak tie constitutes a bridge across the network. But, a narrow bridge is not a viable path for a complex contagion, which means that the distance between people (the number of steps between them in the social graph) is different for a simple contagion than for a complex contagion. So, how do we measure a network's path length? And, what does it mean for predicting the spread of social innovations? This chapter will show you how the findings on complex contagions have changed our conception of social networks, impacting everything from how we measure social distance to how we develop strategies for social change.

In the last decade, research on complex contagions has produced several key advances in the science of social networks and diffusion, including:

(1) The role of countervailing influences in diffusion
(2) The failure of "influencers" to spread innovation and the power of the periphery for initiating social change
(3) Generalized network measures of centrality, bridge width and path length
(4) Social tipping strategies for triggering tipping points in social norms
(5) The role of network bias in the failure of vital innovations and what can be done about it
(6) The value of both similarity and diversity in social networks for the spread of new ideas and beliefs
(7) Unexpected backfire effects from product awareness campaigns

This chapter will explain each of these advances. To ground the discussion, I will begin with a recent example (from State and Adamic 2015) of the distinctive dynamics of complex contagion and how they can lead to rapid, population-wide cascades of collective behavior. I will then show the implications of these dynamics for a wide range of core concepts in the study of social networks and diffusion.

1. A SURPRISING EXAMPLE

On 25 March 2013, the civil rights organization Human Rights Campaign initiated one of the largest social movements in online history. It was the same week that the US Supreme Court was hearing two cases that would decide the fate of same-sex marriage in the United States.

The members of the Human Rights Campaign decided to work together in a coordinated effort to encourage citizens to change their Facebook profiles to an image—a red and pink "equals sign"—that would show support for same-sex marriage.

Within a week, nearly three million people had adopted the innovation, showing unprecedented nationwide support for the initiative. If you were on Facebook at the time, you probably saw this. You may have even been part of it. The social contagion spread so quickly that magazines like the *Huffington Post* and *Adweek* wrote articles not just about HRC's campaign, but also about how quickly it was spreading. Clearly, if anything it was a case of viral diffusion, this was.

Facebook researchers Lada Adamic and Bogdan State decided to take a closer look. Poring over millions of shares, comments and likes, the scientists looked at not just the spread of the equal sign movement, but at dozens of social memes that had spread across Facebook—from "viral" photos that were widely shared and liked to "contagious" behaviors, like changing your profile to support same-sex marriage. They found something striking. While photo sharing was a simple contagion that spread very quickly through weak ties—on average spreading from person to person after only a single contact—the equality sign required more social reinforcement in order for people to adopt it. The equal sign was a complex contagion.

What was the difference between sharing a popular photo and adopting a popular profile change? While both kinds of contagions spread effectively through Facebook, and both kinds of contagions were relatively easy to adopt, they were spreading in very different ways.

State and Adamic (2015) discovered that the key to explaining the spread of the equal sign was that people needed social confirmation from multiple peers before they would believe that the movement was legitimate enough, and widely accepted enough, to support it. Unlike photo sharing, the equal sign movement spread through social reinforcement, cascading across clustered ties in the Facebook network. As State and Adamic (2015: 1741) put it:

> It is easy to see why social proof obtained from multiple sources would be necessary for many individuals to show their support for a cause they believe in. Engaging in a behavior that challenges the status quo carries inherent risks, from the minute—a quarrel with one's otherwise-thinking friends—to the life-threatening, as experienced by activists in a political movement challenging a repressive regime … [S]howing support for same-sex marriage still carries a level of perceived risk … [because] it was also likely that at least some friends and acquaintances of potential supporters of same-sex marriage held the opposing view … [Consequently,] most individuals would only change their profile picture after observing several others do it.

2. COUNTERVAILING INFLUENCES

State and Adamic's (2015) findings highlight one of the principal differences between simple and complex contagions: the influence of non-adopters. For a simple contagion, non-adopters are irrelevant. Contact with a single person who has the measles will transmit the disease regardless of how many people you know who don't have the measles. Similarly, a single person can spread information about which team won the championship game, regardless of how many people haven't found out yet.

It's different for most complex contagions.

Whether the decision to adopt requires coordination, credibility, legitimacy or emotional excitement, a potential adopter will not be swayed by a single adopter if everyone else they know has failed to adopt. The nonadopters are countervailing influences. They send a silent but distinct signal to potential adopters: the new behavior is not widely accepted. While some complex contagions (like establishing the credibility of a new rumor) may rely solely on having a sufficient number of contacts activated, whenever adopting a behavior requires establishing its legitimacy or coordinating with those around you, then people typically require a significant fraction of their contacts to adopt before they will. As Doug McAdam and Ronelle Paulson remarked in their study of participation in the Civil Rights Movement, "the fact that we are embedded in many relationships means that any major decision we are contemplating will likely be mediated by a significant subset of those relationships" (1993). The more non-adopter contacts that a potential adopter has, the more countervailing influences the person will confront. And, the more social reinforcement from activated peers will be needed to trigger their adoption.

3. INFLUENCERS

Countervailing influences have surprising consequences for the well-known idea of "influencers"—highly connected social stars who are able to influence lots of people simultaneously. For simple contagions, influencers can transform a small outbreak into a massive epidemic. Think of COVID-19. The disease spreads easily from person to person. If a highly connected "social star" becomes infected, that person can single-handedly spread the disease to hundreds of others (Liljeros et al. 2001; Newman et al. 2006). An influencer's remarkably large number of social contacts can make them into "super-spreaders" who can single-handedly trigger the epidemic spread of a viral contagion. This insight from epidemiology has often been generalized from the spread of viruses to the growth of social epidemics, such as the contagious spread of ideas, innovations and political movements. The journalist Malcolm Gladwell referred to the power of highly connected individuals to accelerate the spread of social contagions as "the law of the few".

However, complex contagions break this "law". When a social contagion is not merely a piece of gossip or a familiar product, but a social innovation, highly connected social stars can be roadblocks for diffusion rather than accelerants (Centola 2021b). This is because the more connected someone is, the more countervailing influences they face. For an innovation that is unpopular, contentious or socially risky—like changing your Facebook profile to support same-sex marriage—highly connected people are likely to look carefully at what others are doing before adopting the change themselves. Unlike highly connected social stars, at the "center" of the social network, people in the network periphery have only a modest number of social contacts. But, this is precisely why they are the key to social change.

In the network periphery, people do not need to contend with a sea of countervailing influences. Even a modest amount of social reinforcement from their peers can be sufficient to convince them to join a protest, since these positive signals do not need to contend with a sea of countervailing influences. In the network periphery, clusters of social change can grow—and spread—through chains of wide bridges linking moderately connected individuals. As a social movement gains momentum, it can reach a critical mass in the network periphery, at which point even highly connected social stars will be convinced to join. This is how the

Arab Spring protests took hold of Egypt. While there were many highly connected activists who joined the movement, the events that triggered the eruption in Egypt's Tahrir Square originated with moderately connected people who collectively mobilized to grow a revolution (Steinert-Threkeld 2017).

And it's not just social movements. The same dynamics of countervailing influences affect the spread of novel technologies. From technologies like Twitter (Toole et al. 2012) to memes like the Ice Bucket Challenge (Sprage and House 2017, these innovations are complex contagions (Centola 2021) that spread much more effectively through reinforcement in the network periphery than from highly connected influencers.

Why are influencers so reluctant early on?

Because highly connected influencers didn't become social stars by ignoring their social connections, but by paying attention to them. Influencers are keenly aware of how their behaviors are perceived, and one of the best signs of whether a contentious new idea or social movement is widely accepted is how many countervailing influences they observe in their social networks. It's the same for coordinating on a new social technology, like Twitter. For someone in the network periphery, it only takes a handful of adopters to make coordination on a new technology seem worthwhile. However, for a highly connected influencer, it takes a significant number of adopters to convince them that an unusual and unknown technology will have any coordination value for them.

For all of these reasons, social movements and novel innovations typically do not spread from highly connected influencers out to the periphery. Rather, it is the opposite. Social innovations first take hold in the network periphery and spread from there to take over the center.

4. STRUCTURE IS DYNAMICS: COMPLEX PATH LENGTH AND COMPLEX CENTRALITY

It makes intuitive sense that if a highly connected person at the center of the network adopts a new behavior, then that behavior should spread quickly and effectively to everyone else. But we just saw that this intuitive notion of spreading does not work when it comes to spreading complex contagions.

Why? Why is the periphery suddenly so important just because a social contagion is more complex? If there's more resistance to an innovation or idea, shouldn't that make influencers more important for spreading social change, rather than less? Countervailing influences are part of the explanation. But there's more to it than that.

The answer to these questions—the reason why complex contagions spread from the periphery to the center, rather than from the center to the periphery—comes from measures of network structure that reveal that the "center" of the network changes with the contagion (Guilbeault and Centola 2021).

Traditionally, the most common methods for identifying central individuals in a social network are (i) "degree centrality" (individuals with the most connections); (ii) "betweenness centrality" (individuals through which most paths must travel, going from one part of a network to another); and (iii) "eigenvector centrality" (individuals whose neighbors are highly connected). But all of these assume that a single tie between people constitutes a step in the network. It turns out that these measures of centrality—in fact all of the common measures of network topology—assume that contagions are simple. One of the most valuable findings

on complex contagions (from a practical point of view) has been that all these measures of network structure are defined by the complexity of the social contagion that is spreading across them.

This insight takes us back to Granovetter's observation about path length. Path length is the default measure of distance between nodes in a network used for characterizing the dynamical properties of networks. For nearly three quarters of a century, dating back at least to Somolonoff and Rapoport (1951) and Erdos and Renyi (1960), the assumption has been that a single link in a graph—for instance, a tie from A to B—is equivalent to a path between A and B. But that's only for simple contagions.

For a complex contagion, a path between A and B requires multiple ties—a wide bridge. This means that the number of "steps" in the network (or the "degrees of separation" between people) is based on the kind of contagion that is being transmitted between them. For a simple contagion, like gossip, a single tie from A to B is sufficient for transmission. For a complex contagion, like signing up for Twitter or joining the Arab Spring protests, a weak tie from A to B is not a path for transmission. For the spread of a complex contagion, the existence of a path from A to B must be composed of wide bridges at each step. Thus, even though a single weak tie may exist between A and B, the actual network path to travel from A to B may, in fact, have a path length of nine "steps", as shown in Figure 17.1.

Guilbeault and Centola (2021) refer to the classic definition of "path length" used by Granovetter and others as "simple path length", or PLs, indicating that it measures social distance in a graph based on the propagation of simple contagions. They then introduce an alternative way to measure the distance between nodes in a graph based on the propagation of complex contagions, called "complex path length", or PLc.

Complex path length measures the "steps" between nodes A and B in terms of the number of wide bridges that must be traversed to travel from A to B. This new measure of path length explains why the dynamics of social change often spread from the periphery to the center. According to this measure of social distance, the locations in the network that are most

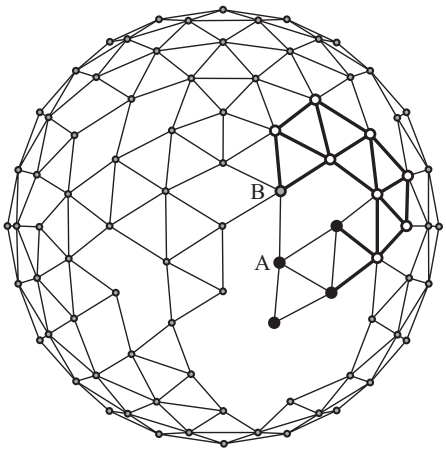

Figure 17.1 Example of a simple path from node A to node B (single tie) and a complex path from node A to node B (white nodes)

"central" in the network—from which complex contagions will spread most effectively—are located in the network periphery.

Based on the classic notion of simple path length, the traditional centrality measures of degree centrality, betweenness centrality and eigenvector centrality all assume that a single tie between people constitutes a step in the network. If, instead, each step in the network requires a wide bridge, the general measure (for both simple and complex contagions) of "complex centrality" identifies the neighborhoods in a social network that are most highly connected to every other neighborhood. The people in these neighborhoods are located at the intersection of more wide bridges than any other individuals in the network. Strikingly, these individuals are not very central according to standard centrality measures (Guilbeault and Centola 2021). However, when it comes to complex contagions, these network locations consistently outperform every other network location for spreading the adoption of social innovations across large and complex populations (Wang et al. 2019; Centola 2019; see also Becker 1970 and Bakshy et al. 2009).

5. SOCIAL TIPPING POINTS

Once we appreciate that measures of network centrality depend on network dynamics—that is, a person's centrality in a social diffusion process depends on whether the contagion that is spreading is simple or complex—it has enormous strategic implications. Complex centrality not only explains the apparent puzzle of why social movements spread from the periphery to the core, but also identify the particular network locations from which new social initiatives will spread most effectively. One way to apply this idea is to use complex centrality for identifying the locations in a social network that can be used to trigger tipping points.

The theory of "tipping points" in social change dates back to the 1950s when it was first used to explain emergent patterns of residential segregation. In the 1970s, Mark Granovetter (1978) and Thomas Schelling (1978) generalized these ideas to study critical mass dynamics in collective behavior—from the rapid growth of social movements to the surprising dominance of new intellectual traditions. Simultaneously, Rosabeth Moss Kanter (1977) discovered that the logic of tipping points also applied to the dynamics of changing gender norms in organizations. Today, tipping dynamics have been found among across a wide variety of social change events (Centola et al. 2018). For instance, the Black Lives Matter movement was supported by well below 50 per cent of Americans in 2014, but it jumped to above 75 per cent of Americans by 2020 (Cohn and Quealy 2020).

This rapid change in public opinion can be understood by the dynamics of complex contagions. The reason the movement was initially resisted is also the reason it grew so rapidly. In 2014, people needed to believe in the legitimacy of the movement before they would join in. The movement initially took hold in the periphery, expanding through networks of wide bridges. But, once it grew large enough to establish its broad legitimacy, a tipping point was triggered that quickly saw the mushrooming of public support.

So, how should an activist target a social network to trigger a tipping point?

The most popular strategy has been to target the influencers. Following the metaphor of a virus, the assumption has been that the most highly connected people—that is, the most "central" actors based on traditional measures of centrality—are the most effective individuals for spreading social innovations. But, countervailing influences, complex path length and

complex centrality show otherwise. The network locations with the greatest complex centrality are within the network periphery by classical standards, but they are the most central locations for activing a critical mass that can trigger a tipping point for social change.

6. NETWORK BIAS

An unexpected implication of these findings on centrality is what they reveal about how bias takes hold in social networks, and what it means for spreading social innovations. It has become customary to think of bias as a feature of individuals: some people are highly biased and others less so. A common assumption is that information is the cure. All that is required is to give people access to correct information and their biases will be eliminated.

But this dream of reason did not take social networks into account.

Decades of failed policy efforts—from public health initiatives like promoting MMR vaccinations and COVID-19 precautions, to scientific initiatives to spread warnings about climate change—have found that simply disseminating accurate scientific information is insufficient to change people's beliefs and behaviors. The problem is not that people don't have access to information. Rather, it's that new information is filtered through people's social networks—which shape how they interpret it and what they ultimately believe.

The mistake is to think of social networks merely as pipes—conduits for the passage of diseases and information. That may be true for simple contagions, but not for complex ones. For complex contagions, social networks are also prisms. Depending on how we receive new information, who we hear it from, and how the community around us perceives it, we may either become readily convinced by a new idea or staunchly opposed to it. The networks around us can trigger motivated reasoning (Festinger 1957) that reduces important new scientific information about public health or climate change to nothing more than a "hoax", while misinformation that confirms a community's biases spreads effectively and is widely believed.

The reason for this frustrating asymmetry between accurate information and misinformation is that ideas that reinforce a community's existing beliefs are simple contagions. They are easy to understand and easy to spread. Within communities that share a set of beliefs, highly connected influencers at the center of the conversation can easily spread misinformation that plays to a group's biases (Becker et al. 2017; Becker et al. 2019; Guilbeault et al. 2018b; Guilbeault and Centola 2020b). By contrast, contentious or novel ideas that challenge a group's biases are complex contagions. These kinds of opinions face strong opposition, and thus are not likely to emerge from highly connected individuals facing a sea of countervailing influences (Samuelson and Zeckhauser 1988; Steinert-Threkeld 2017; Centola 2018, 2021).

When COVID-19 hit the US in the spring of 2020, public health officials used the media to disseminate information about new health behaviors that could slow the spread of the deadly new virus. Chief among them were wearing face masks and practicing social distancing. At first, it appeared as if these new behaviors would spread like the virus—reaching everyone and becoming a worldwide phenomenon just like the novel coronavirus. But, as the months progressed, and the weather warmed, some communities embraced the new practices while others actively opposed them. Invisible lines of social distinction (such as party affiliation) were visibly reflected in people's behavior. Some groups followed the social norms of wearing face masks and social distancing—and even tried to enforce them—while other groups aggressively flouted these norms. Face masks became ground zero for a new kind of epidemiological culture war.

Why would something as basic as protecting yourself (and others) from the spread of a deadly virus become so socially complex and politically divisive? The answer comes from the simplicity and complexity of these social contagions. In communities in which there was widespread distrust of government propaganda, public health interventions were viewed as an infringement on personal rights. Public health advice was not seen as credible, and was resisted. People instead coordinated on a set of behaviors that reinforced their beliefs about the virus (and the precautions it required) being a "hoax". Misinformation that confirmed these beliefs was a simple contagion and spread effectively in these communities. By contrast, COVID-19 precautions (and, on the horizon, COVID-19 vaccinations) were complex contagions, which encountered staunch opposition.

However, in communities that viewed government advice as a public service designed to protect people, there was widespread conformity with face masks and social distancing. Public health advisories were carefully followed, and anger grew over other people's willing disregard for safety protocols while grocery shopping, walking in public parks and standing in line for ice cream.

Public spaces became battlegrounds for conflicting social norms. A public health behavior that was a simple contagion for one community was a complex contagion for others. The problem that was preventing the new behavior from spreading was that community belonging and social (and political) identity played an important part in determining who was seen a relevant source of social influence, and who was not.

7. THE POWER OF SIMILARITY AND DIVERSITY

When people come into contact with a new idea or behavior they don't simply observe the number of people adopting. They also see who those people are. Are they like me or different? Are they like each other or diverse? When people were deciding whether to wear face masks, they were keenly aware of whether the people who were wearing them were part of their social group, or not. The more conspicuous the differences, the more clearly the behavior became viewed as an "out-group" behavior—not just different, but oppositional.

The spread of new ideas, innovations and beliefs from one group to another depends on wide bridges between the groups. But it also depends on people seeing the adopters as relevant. For many sociologists, it has been common to think of similarity as the defining feature of relevance (Granovetter and Soong 1988; McPherson et al. 2001; Lazarsfeld and Merton 1954; Centola 2011). That is true in some cases, but there are also situations in which diversity can be more effective than similarity for creating relevance.

The explanation for whether similarity or diversity creates relevance brings us back to the four key barriers to adoption: social coordination, legitimacy, credibility and emotional excitement. Determining which of these factors are the primary barriers to adoption reveals which features of the adopters—similarity or diversity—will be effective for creating relevant sources of social influence.

When credibility is required—for instance regarding the accuracy of new public health information about COVID-19, the safety of vaccinations or new scientific reports about the dangers of global warming—people look for social proof from similar peers. Social reinforcement from adopters is most effective when it indicates that the new behavior or idea is accepted by your "in-group" (Davis and Greve 1997; Centola and van de Rijt 2015; Howe and Monin 2017).

Similarly, when emotional excitement is required—for instance in recruitment to join the Arab Spring revolution, or in joining in to run the streets in celebration of victory by your home town sports team—once again, similarity with the adopters increases their ability to provide effective social reinforcement. Seeing others "like you" join in the excitement is how social effervescence grows (Centola 2021).

However, when it comes to establishing the broad legitimacy of an activity or social movement—for instance changing your Facebook profile to show support for same-sex marriage—then diverse sources of social reinforcement will be more effective. In State and Adamic's (2015) study of the spread of the equal sign, they found that people's sense of social risk could only be overcome when they saw multiple adopters from diverse social groups.

It's easy to see why. On Facebook in 2013, people were connected to their friends from high school and college, their colleagues at work, their parents, their grandparents and their neighbors. Showing support for a contentious political movement could trigger aggressive commentary on your Facebook page, and potentially even alienate or offend members of your community. However, once people saw that support for the movement was being taken up by people from diverse social quarters—their grandparents, their high school friends and their colleagues—they were convinced of the broad legitimacy of the movement, which reduced the social risk of joining and triggered widespread adoption.

8. BACKFIRE EFFECTS

For people who are interested not only in understanding the dynamics of social contagions, but also in spreading social innovations of their own, they need a way to navigate all of these subtleties of social diffusion—simple and complex contagions; simple and complex path length; various notions of centrality; asymmetry in the influence of the influencers; network bias; and varying roles similarity and diversity in creating relevance. One of the most common solutions to this problem is to take a "kitchen sink" approach.

Instead of trying to get too specific, why not just do everything? Hire influencers and target the periphery. Buy television advertisements and try to create a critical mass. Build narrow bridges and wide ones. Foster influence from similar peers and diverse ones. Surely, more is better. Even if an innovation is complex, using the strategies of simple contagion can't hurt, right?

Wrong.

I call this the *kitchen sink fallacy*. The fallacy is that any solution, even if it's not quite the right one for your particular problem, is better than no solution. Unfortunately, that's not what the science of complex contagions shows us. To the contrary, aggressively applying strategies that are effective for spreading simple contagions can backfire, actively preventing the uptake of complex contagions (Centola 2021).

Take Google+.

In 2011, Google launched Google+, its fourth and final foray in the social media market. Their strategy was to spread their social technology through a massive awareness campaign. Google's search engine had already dominated the market for nearly a decade, and Google's webmail service, Gmail, had recently overtaken AOL as the dominant webmail service worldwide. They had also acquired the world's most popular video-sharing site, You Tube.

They wanted to use each of these services to spread worldwide adoption of Google+. It would be the epitome of "cross-promotion". Done right, they could create widespread acceptance of their new social technology and mount a serious challenge to the established industry leader, Facebook. That's exactly what they set out to do. By 2013, every person who used a Google service was automatically (in many cases involuntarily) associated with a Google+ account. Almost instantly, everyone had Google+, and everyone knew that everyone had it. Google had achieved worldwide spread of awareness: everyone knew what Google+ was.

But, the problem was that no one was using it. People were still using Facebook. And, this caused a backfire effect. Google's massive informational awareness campaign—forcibly associating many millions of people with Google+ accounts—inadvertently created worldwide social proof against their own technology (Centola 2021). By 2016, it was clear that Google+ had failed. By 2019, Google+ closed its doors permanently. The explanation for Google's backfire effect takes us all the way back to where we started: the problem of countervailing influences.

It's one thing for a technology not to be adopted because people don't know about it yet. In that case, non-adopters are not a very strong signal about the product itself. They simply indicate that it's not popular and therefore not yet easy to coordinate on. These are the kind of countervailing influences that can prevent adoption early on. However, this can change, and the product can easily become more attractive if more people start using it.

The situation with Google+ was different. Because of Google's enormously successful awareness campaign, everyone not only knew about Google+, they also knew that everyone else knew about it. The lack of use of Google+ was incredibly conspicuous. It meant that every person who continued to use Facebook was offering an explicit rejection of Google+; these were significant countervailing influences. People were left with the need to explain why no one was using the new technology and, very soon, people concluded that the product's lack of use must be due to some flaw in the technology.

What Google overlooked in its remarkably successful awareness campaign is that a social networking platform—unlike a search engine portal or a webmail client—requires social coordination. People need to adopt together. The challenge of moving people from a powerful incumbent like Facebook to a new platform cannot be bested simply by spreading informational awareness. Success requires spreading the complex contagion of coordinated social action. In this sense, spreading a new social media technology is more like the spread of the Arab Spring than it is like the spread of gossip.

CONCLUSION

Since the 1950s (Lazarsfeld and Merton 1954; Katz and Lazarsfeld 1955) sociologists have appreciated that social networks are the crucial link between individual behavior and social outcomes, with Granovetter's (1973, 1978) groundbreaking work in the 1970s establishing the prototype for the later development of network science as a field of sustained inquiry in analytical sociology. Building on this tradition, the study of complex contagions has deepened and broadened the exploration of the micro-macro dynamics of social behavior—from new findings on innovation diffusion in the archeological record (Manzo et al. 2018) to new insights into how consolidation and homophily affect social integration and inequality (Blau and Schwartz 1984; Centola 2015; Zhao and Garip *forthcoming*). The study of complex

contagions has uncovered new terrain in social networks research that includes not just the structure of interpersonal interactions and social influence, but also the ways in which social networks mediate the expansion of different kinds of social innovations, as well as how differing kinds of social contagions interact with each other, often producing highly counterintuitive collective outcomes (Zhang and Centola 2019; Campbell and Salathe 2013; Su et al. 2016).

The success of a new scientific area can be measured by its intellectual productivity. How many existing puzzles does it solve and how many new ones does it uncover? How many new insights and conceptual advances does it produce, and how much new scientific exploration does it foster? By these lights, the study of complex contagions is a highly productive field of inquiry, with researchers currently exploring new applications to substantive topics, such as political influence, bullying, gender relations and immigration, as well as new theoretical studies exploring the role of influencers, the relevance of diversity, the meaning of centrality, the emergence of bias, the dynamics of inequality and the possibility of backfire effects. New research on how simple and complex contagions spread through society continues to reveal the hidden pathways through which social networks and personal influences give rise to unanticipated collective behavior.

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