THE VIRAL SPREAD OF A ZOMBIE MEDIA STORY

Robert Smith?

Abstract

This chapter uses the case study of a popular media story—the 2009 coverage of a mathematical model of zombies—to examine the viral-like properties of a story's propagation through the media. The coverage of the zombie story is examined and then a model for the spread of a media story is developed. Stability conditions are derived and the model is refined to include multiple secondary hooks, a series of additional pieces of information that may reignite an existing story. Sample scenarios are investigated, under a variety of suboptimal provisions. Conditions under which a story goes viral include initial newsworthiness, the natural lifespan of the story, durability after the fact and at least one secondary hook that occurs early in the story's lifespan.

1.1 Introduction

1.1.1 A Media Invasion of Zombies

Like any huge event, it started small. In August 2009, an online blog for a newspaper [1] and an article in *National Geographic* [2] triggered a tidal wave of reports: a group of Canadian researchers had created a mathematical model of zombies [3]. The story was reported in *Wired* [4], which acted as a hub for spreading it significantly further afield. It was picked up in Canada's *Globe and Mail* [5] and then spread to *The Toronto Star* [6], *The Wall Street Journal* [7] and *BBC News* [8], where it was the number one story in the world for 24 hours. Twitter was a-flutter, blogs went into overdrive and searches in Google spiked.

The story gathered even more steam when it was discovered that the lead researcher had a question mark in his name [9]. From here it spread worldwide: *The Daily Mail* [10], *The Melbourne Herald Sun* [11], Finnish news [12]. The authors made appearances on *National Public Radio* [13] and participated in episodes of TV programs devoted entirely to the subject [14].

Upon reaching Australia, the story gathered another boost: the senior author was Australian, so the Australian media became particularly interested in covering it, thus extending the lifespan of the story even further [11]. Agents came calling. Book deals were offered [15]. The Hollywood Science and Entertainment exchange arranged a panel at the Director's Guild of America, putting the senior author in a discussion with George Romero and Max Brooks [16].

In every sense of the word, this story went viral.

August 2009 was a slow news month, with no natural disasters or political scandals. It also fell in the northern summer, which is usually the period where lighter stories can gain traction. Hallowe'en occurred a few months later, resulting in a brief reinterest in the story and it was discussed at the year's end in the summary of stories for the year (and decade). Occasional reports surfaced intermittently thereafter and quotes continue to be solicited to this day.

The story's timeline is shown in Figure 1.1. This is an underestimation of the true number of stories but illustrates repeated spikes in interest that have continued since. Figure 1.2 shows the Google trends for the word "Smith?" in 2009, illustrating the relative spike in searches that occurred in mid-August. The figure also shows Google Trends "zombies" in 2009, indicating their consistent popularity. Note that searching for the word "Smith" produces different results than searches for the word "Smith?" (such as many reports of the death of celebrity Anna Nicole Smith earlier that year).

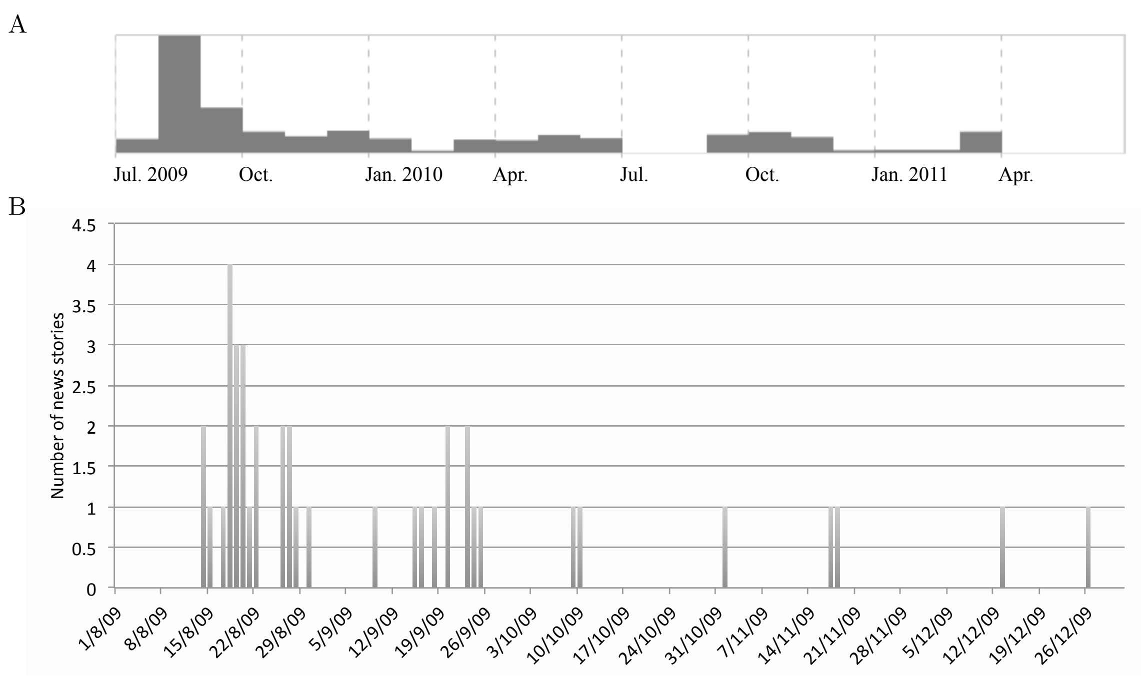

Figure 1.1: A: Timeline of stories in Google News archives featuring keywords "zombies" and "mathematics" since July 2009. B: Number of stories per day in Google News archives featuring keywords "zombies" and "mathematics" throughout the latter part of 2009.

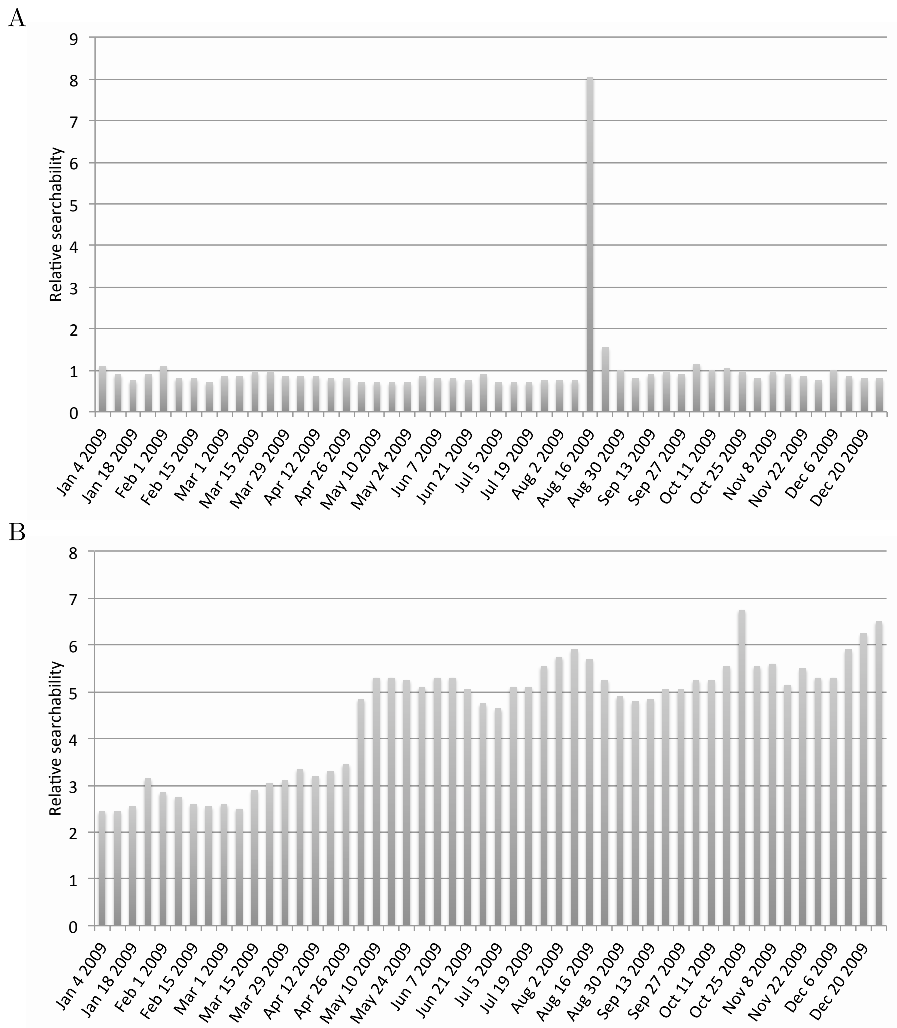

Figure 1.2: A: Google trends for the word "Smith?" in 2009. B: Google trends for the word "zombies" in 2009, as a comparison. Note that searches for "Smith?" produced different results than searches for "Smith."

Since the tail of Figure 1.1 is nonzero, it appears that the original zombie paper—or, specifically, its meme—may now have become endemic. This is fed by a constant recruitment of susceptible individuals who have not heard of the story because they were too young to be media savvy (or not born) at the time of the original outbreak. For example, there was a 2013 outbreak in the (relatively isolated) Canadian city of Kelowna, BC. The steady state prevalence will thus be nonzero, if low. As Andrew Cartmel said in the introduction to this book, zombies have invaded mathematics and appear to be here to stay.

1.1.2 The Effects of Media

The media influences individual behaviour, formation and implementation of public policy and perception of risk [17]. Media reporting plays a key role in the perception, management and even creation of crisis [18]. Since media reports are retrievable and because the messages are widely distributed, they gain authority as an intersubjective anchorage for personal recollection [19]. At times of crisis, non-state-controlled media thrive, while state-controlled media are usually rewarded for creating an illusion of normalcy [18]. Media exposure and attention partially mediate the effects of variables such as demographics and personal experience on risk judgments [20].

The original interpretation of media effects in communication theory was a "hypodermic needle" or "magic bullet" theory of the mass media. Early communication theorists [21, 22] imagined that a particular media message would be directly injected into the minds of media spectators. This theory of media effects, in which the mass media has a direct and rapid influence on everyday understanding, has been substantially revised. Contemporary media studies analyzes how media consumers might only partially accept a particular media message [23], how the media is shaped by dominant cultural norms [24, 25] and how media consumers resist dominant media messages [26, 27].

The choice of which stories receive coverage, and to what degree that coverage is emphasized, is a complex one, involving local, national and international concerns, perceptions of relevance and cultural effects embedded within the hierarchy of reporting. The adage "if it bleeds, it leads" is a journalistic shorthand for raising sensationalist stories (such as crime, accidents and disasters) to the top [28, 29]. A political story that does not dominate the day's news or fails to be the leading story from the capital has a diminished chance of reaching the public farther afield [30].

Journalistic practice includes the role of gatekeepers, who make decisions about which stories to cover, as well as which stories are worthy of the lead slot [31]. Access to media is access to influence [32], with the mass media serving the economic, social and political interests of the elite [33]. This involves persistent patterns of cognition, interpretation and presentation of selection, emphasis and exclusion through which symbol-handlers organize discourse [34]. For example, Canadian newspapers were three times as likely to have climate change or global warming stories as American ones [35]. Media coverage frequently conforms to cultural stereotypes involving gender and race [31, 29].

A handful of mathematical models have described the impact of media coverage on the transmission dynamics of infectious diseases. Cui et al. [36] showed that when the media impact is sufficiently strong, their model exhibits multiple positive equilibria. This poses a challenge to the prediction and control of the outbreaks of infectious diseases. Liu et al. [17] examined the potential for multiple outbreaks and sustained oscillations of emerging infectious diseases due to the psychological impact from reported numbers of infectious and hospitalized individuals. Liu and Cui [37] analyzed a compartment model that described the spread and control of an infectious disease under the influence of media coverage. Li and Cui [38] incorporated constant and pulse vaccination in SIS epidemic models with media coverage. Tchuenche et al. [39] examined the media impact on an influenza pandemic and showed that media overreactions could trigger a vaccinating panic and result in a significantly worse outcome than would occur without the media.

To examine the question of what makes a story go viral, this chapter will use the story of a mathematical model of zombies as a case study to determine the constituent elements of a media sensation. Although a story going viral is not a disease, it has the hallmarks of one and thus mathematical models for disease spread can be adapted to account for a story which is 'infecting' a variety of media outlets. The components of a media story (newsworthiness, durability, natural lifespan and hooks) are identified, in order to examine which aspects are most conducive to a story going viral and what the long-term outcome will be under a variety of suboptimal scenarios.

And, naturally, should you be a reporter reading this fine volume and discover that this meta-article on the spread of articles is itself so worthy of praise that it needs to be reported at once (perhaps under the headline, "Academic writes most egotistical article ever!!!"), then I welcome the chance to pen a future article discussing the spread of articles that discuss how other articles spread that you in turn can report on. If we do this right, we'll be on the gravy train for life...

1.2 The Model

A story that's currently running can be considered 'infectious,' in the sense that other media outlets may pick it up and run their own version. Stories that have recently run may also 'infect' susceptible media outlets, but this effect will lessen the more time passes. That is, unlike most diseases (with the possible exception of zombies!), susceptible media outlets can be infected by those who have already recovered from the infection. This is because journalists very often decide what to write about based on what their competitors have recently written about: not just what is hot right now, but what was recently hot.

Let S represent susceptible media, I represent media outlets that are currently running the story and R represent media outlets that have run the story. We define susceptible media to be those outlets (newspapers, television programs, radio programs, etc.) that have not yet run the story, but that have the potential to at some future time. Note that our active variables are media outlets, not news stories.

β measures how newsworthy the story is in the first place (based on the various criteria by which media outlets decide how 'interesting' a story is), α measures the durability of the story (driven in part by how good the interview subject was once the interview has run) and ν measures how quickly the story becomes old (so $1/\nu$ measures how long the story is news, or the story's natural lifespan). To capture the effect of distance from the story, α is time-dependent and eventually decreases to zero. We also assume that β could be time-dependent, although without the requirement that it necessarily approach zero.

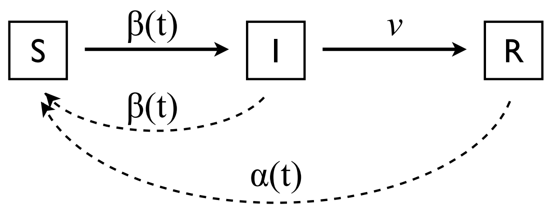

Figure 1.3: The model. Media outlets can be susceptible (S), can be currently running the story (I) or have run the story (R). The measure of a story's newsworthiness is β, the rate at which the story becomes old is ν (so that $1/\nu$ is the story's natural lifespan) and the story's durability is α.

The model is given by

$$\begin{aligned} S' &= -\beta(t)SI - \alpha(t)SR \\ I' &= \beta(t)SI + \alpha(t)SR - \nu I \\ R' &= \nu I. \end{aligned}$$

Mass-action transmission is assumed, since stories are easily accessible, thanks to the internet. The model is illustrated in Figure 1.3.

We say that a story goes viral if the infection rate initially rises, a classic epidemic wave appears and a majority of susceptible media outlets are infected.

1.2.1 The Durability of a Media Story

One technique for examining the dynamics of a model is the use of nullclines. These are places where one derivative is zero, but the others may not be (and usually aren't). In a two-dimensional phase plane representation, these would correspond to any time the tangent is either horizontal (the y derivative is zero at that moment) or vertical (the x derivative is zero at that moment). When the nullclines meet, we have an equilibrium.

The following conditions on the durability $\alpha(t)$ were assumed.

1. $\alpha(0) = 0$.
2. $\lim_{t\to\infty} \alpha(t) = 0$.
3. α is not uniformly zero.

If $\alpha \equiv 0$, then the S-nullclines are $S = 0$ and $I = 0$. The I-nullclines are $I = 0$ and $S = \frac{\nu}{\beta(t)}$. This suggests that, in the absence of a good interview subject, the story's peak would occur at $S = \frac{\nu}{\beta(t)}$ and then decrease until $I = 0$. See Figure 1.4.

A reasonable form for $\alpha(t)$ might be

$$\alpha(t) = \begin{cases} 0 & 0 < t < t_0 \\ \bar{\alpha} & t_0 < t < t_f \\ 0 & t > t_f, \end{cases}$$

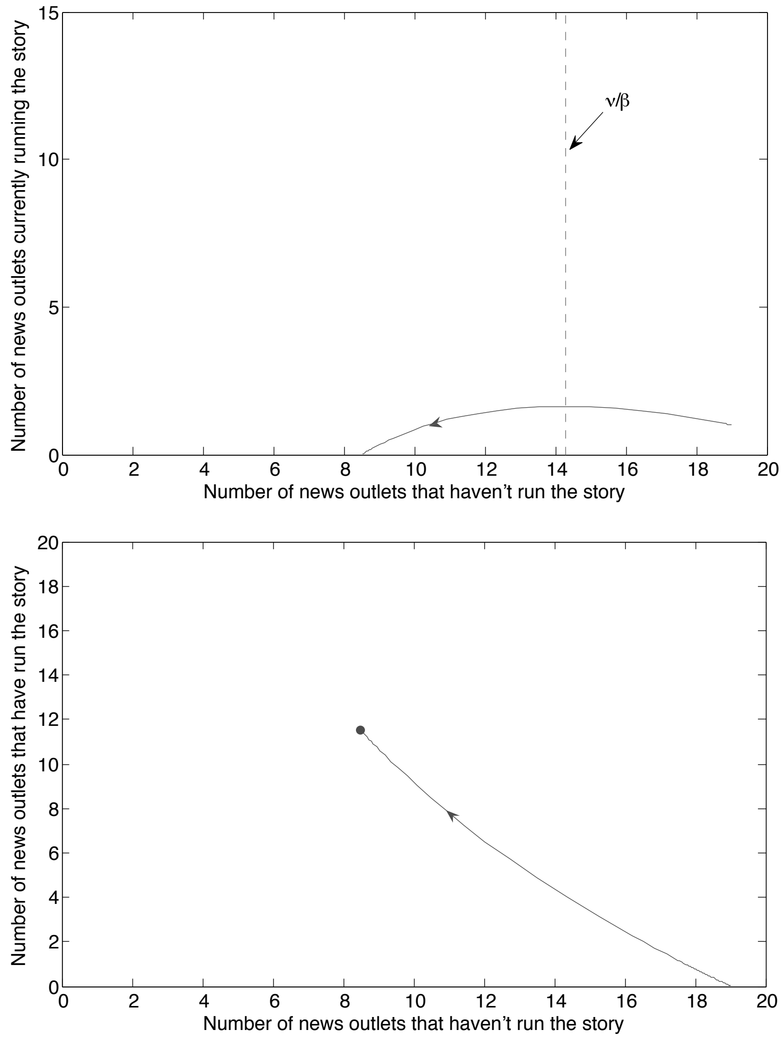

Figure 1.4: Nullclines and trajectories in the case $\alpha = 0$. Other parameters were $\beta = 0.01$, $\nu = 1/7$, $N = 20$, $S(0) = 19$ and $I(0) = 1$. In this case, the story has an initial rise, but does not go viral, since there is no significant epidemic wave.

where the interval $[t_0, t_f]$ is the time during which the interviewee provides added value to the story. That is, when the story breaks, a good interviewee initially adds no effect. However, at time t_0, the time of the first interview, the interviewee's skills are discovered. The interviewee remains a 'hot property' until time t_f, after which their interview skills are irrelevant. This is of course not the only form that such a function can take, but it's the example we'll consider.

In this case, the story receives an extra boost, as media outlets that have already run the story become infectious, since the interview subject has demonstrated a flair for interviews. As a result, more outlets run the story and the peak number of stories is higher. See Figure 1.5.

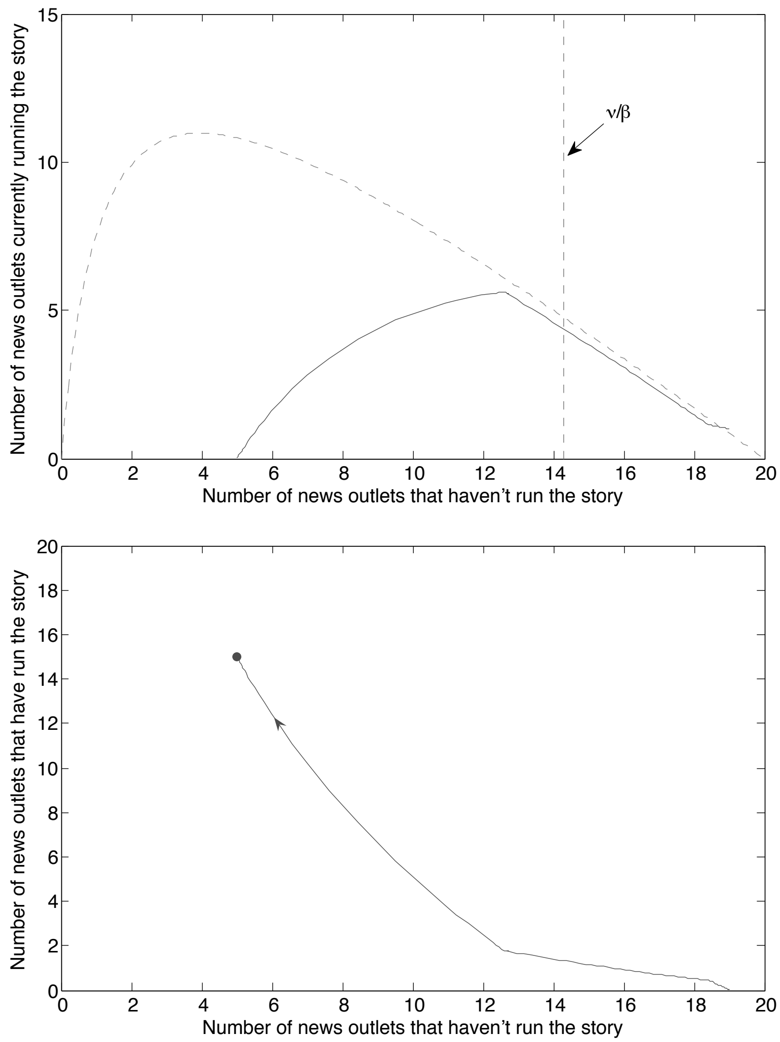

Figure 1.5: Nullclines and trajectories in the case $\alpha \neq 0$. Here, $\alpha = 0.1$ for $3 < t < 6$; otherwise, $\alpha = 0$. All other parameters are as in Figure 1.4. The dashed curve is the nullcline for $\alpha \neq 0$, which only applies in the region $S(t_f) < S(t) < S(t_0)$. The line $S = \frac{\nu}{\beta}$ is not a nullcline in this case, but is included for comparison. Having an interview subject who is 'hot' can significantly increase the number of media outlets that run the story. In this case, there is an initial rise and the majority of susceptible outlets are infected, but the epidemic wave is not significant so the story does not go viral.

1.2.2 The Newsworthiness of a Media Story

The following conditions on the newsworthiness $\beta(t)$ were assumed.

1. $\beta(0) > 0$.

2. $\lim_{t\to\infty} \beta(t) = \bar{\beta} \geq 0$.

Unlike durability, newsworthiness starts at $t = 0$ (whereas $\alpha(t) = 0$ for $0 \le t < t_0$), so $\beta(0) > 0$. As we shall see, the form of β is less important as time varies, since β is primarily a parameter that applies at the start of an epidemic. Thus $\beta(t) = \bar{\beta}$ (i.e., β is constant) may be a reasonable form. This simply suggests that a story is newsworthy if anyone is currently reporting it.

1.2.3 The Natural Lifespan of a Media Story

Our third parameter is ν, a measure of how quickly a story becomes old, which we assume to be time-independent. The inverse, $1/\nu$, measures the natural lifespan of a story. This takes into account other news stories that may compete for a finite number of susceptible media outlets. For example, a sports story that would have been quite popular may have a significantly shorter lifespan if a tsunami has hit.

1.3 Analysis

1.3.1 Final Size Populations

One important concept in disease modelling is determining the final size of an epidemic: the number of noninfected outlets who are left when the disease has passed and the infection has done its damage.

First we demonstrate that solutions are bounded for large time. Define S_∞, I_∞ and R_∞ to be the final size populations of the susceptible, infected and removed outlets, respectively.

Suppose $t > t_f$. Then the model becomes

$$\begin{aligned} S' &= -\beta(t)SI \\ I' &= \beta(t)SI - \nu I \\ R' &= \nu I. \end{aligned}$$

Note that $I = 0$ is an equilibrium. Let $\Sigma = S + I + R$. Then $\Sigma' = 0$, so Σ is constant. In particular, since $R' = \nu I$, it is important to establish that R cannot blow up to infinity.

Next, notice that the R equation decouples from the system, so we can analyze the two-dimensional system in S and I. Since $S' \le 0$, there are no limit cycles. If $S_\infty > 0$, then $I_\infty = 0$ and hence $R_\infty = \Sigma - S_\infty$ is finite.

Now consider the case when $S_\infty = 0$. In this case, every susceptible media outlet has run the story. Suppose $I(t) \neq 0$ for any t. Then the second equation can be divided by the first to derive

$$\frac{dI}{dS} = -1 + \frac{\nu}{\beta(t)S}.$$

Since we are interested in long-term dynamics, let $\beta(t) = \bar{\beta}$. Then, integrating, we have, for t large,

$$\begin{aligned} I(t) &= I(0) + S(0) - S(t) + \frac{\nu}{\bar{\beta}} \ln\left(\frac{S}{S(0)}\right) \\ I_\infty &= I(0) + S(0) - S_\infty + \frac{\nu}{\bar{\beta}} \ln\left(\frac{S_\infty}{S(0)}\right). \end{aligned}$$

Since $S_\infty = 0$, this implies that $I_\infty = -\infty$. However, since $I(0) > 0$, there must exist a finite time t_a such that $I(t_a) = 0$, which is a contradiction. It follows that the assumption that $I(t) \neq 0$ is incorrect and hence $I_\infty = 0$ (since $I = 0$ is an equilibrium).

Thus, whether all media outlets run the story or not, the eventual outcome is that I reaches zero in finite time. Hence R cannot blow up.

1.3.2 Stability

Stability is an enormously useful concept in disease modelling (and beyond). If an equilibrium is stable, it means that small perturbations away from that equilibrium will return to it, or at least not stray far away. And equilibrium is unstable if small perturbations move away from it. So if you're sitting in a classroom with no zombies, you're at a disease-free equilibrium. If a single zombie enters the room and starts an epidemic, then that equilibrium is unstable. If, however, you and your classmates manage to hack the zombie to death before it infects anyone, then congratulations: not only have you saved your fellow students from becoming the living dead, you've also experienced a stable equilibrium.

Equilibria are of the form $(S, I, R) = (\hat{S}, 0, \hat{R})$. The Jacobian matrix is

$$J(S, I, R) = \begin{bmatrix} -\beta(t)I - \alpha(t)R & -\beta(t)S & -\alpha(t)S \\ \beta(t)I + \alpha(t)R & \beta(t)S - \nu & \alpha(t)S \\ 0 & \nu & 0 \end{bmatrix}.$$

We are interested in the stability of the disease-free equilibrium, where perturbations are applied at $t = 0$. Thus the Jacobian matrix is evaluated at $\alpha(0) = 0$ and $\beta(0)$. We thus have

$$\begin{aligned} \det(J(\hat{S}, 0, \hat{R}) - \lambda I) &= \det \begin{bmatrix} -\lambda & -\beta(0)S & 0 \\ 0 & \beta(0)S - \nu - \lambda & 0 \\ 0 & \nu & -\lambda \end{bmatrix} \\ &= \lambda^2(\beta(0)\hat{S} - \nu - \lambda) = 0. \end{aligned}$$

It follows that equilibria with $\hat{S} > \frac{\nu}{\beta(0)}$ will be unstable. That is, stories that are particularly newsworthy (high $\beta(0)$) or which have the potential to run for a long time (low ν) have the potential to go viral, since this condition predicts an initial rise in infections, which is a necessary (but not sufficient) characteristic of the viral spread of a story.

Stories with $\hat{S} > \frac{\nu}{\beta(0)}$ will have an initial rise in the number of infections, although it remains to be seen whether they will display the classic infection wave or whether a majority of susceptible media outlets can be infected. However, we can conclude that stories with $\hat{S} < \frac{\nu}{\beta(0)}$ cannot go viral.

Note in particular that this threshold only depends on the initial value of β. We could thus assume $\beta(t) = \bar{\beta}$ (as we will in numerical simulations).

1.3.3 A Competing Story

Next, we examine the case where two stories may compete for the resource of susceptible media outlets. Consider the example posed earlier, of a sports story versus a tsunami. For simplicity, suppose $\alpha = 0$ since we are only interested in the initial viral properties of the story.

The model thus becomes

$$\begin{aligned} S' &= -\beta_1(t)SI_1 - \beta_2(t)SI_2 \\ I_1' &= \beta_1(t)SI_1 - \nu_1 I_1 \\ I_2 &= \beta_2(t)SI_2 - \nu_2 I_2. \end{aligned}$$

The Jacobian is

$$J(S, I, R) = \begin{bmatrix} -\beta_1(t)I - \beta_2 I & -\beta_1(t)S & -\beta_2(t)S \\ \beta_1(t)I & \beta_1(t)S - \nu_1 & 0 \\ \beta_2(t)I & 0 & \beta_2(t)S - \nu_2 \end{bmatrix}.$$

At equilibrium, we have

$$J(\hat{S}, 0, 0) = \begin{bmatrix} 0 & -\beta_1(0)\hat{S} & -\beta_2(0)\hat{S} \\ 0 & \beta_1(0)\hat{S} - \nu_1 & 0 \\ 0 & 0 & \beta_2(0)\hat{S} - \nu_2 \end{bmatrix}.$$

Thus eigenvalues are $\lambda = 0$, $\beta_1(0)\hat{S} - \nu_1$ and $\beta_2(0)\hat{S} - \nu_2$. The disease-free equilibrium is unstable if $\max\{\beta_1(0)\hat{S} - \nu_1, \beta_2(0)\hat{S} - \nu_2\} > 0$.

Suppose that, independently, both stories are equally newsworthy. That is, the media is interested in each story. However, where they will differ is in their natural lifespan. Thus we assume $\beta_1(0) = \beta_2(0) = \bar{\beta}$ but $\nu_1 > \nu_2$ (so that Story 2, the tsunami, has a longer natural lifespan). It follows that $\bar{\beta}\hat{S} - \nu_1 < \bar{\beta}\hat{S} - \nu_2$.

In this case, if $\hat{S} > \nu_2/\bar{\beta}$ but $\hat{S} < \nu_1/\bar{\beta}$, then Story 2 can go viral, but Story 1 cannot. Thus Story 2 (the tsunami) would eat up the oxygen that might otherwise allow Story 1 (the sports game) to go viral.

1.4 The Power of a Right Hook

When a subsequent 'hook' appears (more information that makes the story more appealing), the effect is a near-instantaneous transformation in the number of susceptible media outlets: those that may not have thought the story newsworthy before, and were thus impervious to infection, may suddenly decide the story is newsworthy with the presence of the further hook. Alternatively, media outlets that ran the original story now have a new story to run. This may happen a number of times throughout the life of a story.

Such near-instantaneous changes to the system can be described using impulsive differential equations. These are equations that allow a rapid change to be approximated by an instantaneous one at certain impulse times. Applications include the rapid infusion of drugs in the body after taking a pill [40], the effect of spraying pesticides [41] or a pulsed vaccination strategy [42]. The interested reader is referred to [43, 44, 45, 46] for more details on the theory of impulsive differential equations.

The model then becomes

$$\begin{aligned}
S' &= -\beta(t)SI - \alpha(t)SR && t \neq t_k \\
I' &= \beta(t)SI + \alpha(t)SR - \nu I && t \neq t_k \\
R' &= \nu I && t \neq t_k \\
\Delta S &= S_k && t = t_k,
\end{aligned}$$

where t_k ($k = 1, 2, \ldots, n$) are the times at which the hooks occur and S_k is the strength of the kth hook. We assume there are only finitely many hooks. In particular, note that we do not assume the t_k's are fixed, nor that each S_k is equal for different k's.

Although a hook may increase a story's attractiveness, the net effect is that the initial conditions are reset. Since all trajectories are attracted to an equilibrium with $I = 0$, the result is that the story will still once again begin to die out. However, a series of hooks may prolong the story's lifespan and result in a significantly larger number of media outlets covering it than would otherwise be the case. Compare Figure 1.6 to Figure 1.7. Note that we chose fixed times for illustration, but that this is not required. We also chose the first hook to be significantly stronger than subsequent hooks.

1.5 Sample Scenarios

The model can now be used to examine a number of potential scenarios. News stories do not occur in isolation; they exist in the context of other stories happening at the same time, they have a degree of newsworthiness that media outlets determine and additional information may surface. While a combination of factors is clearly favourable to the viral spread of a story, cases where one or more factor is limited are examined.

A

B

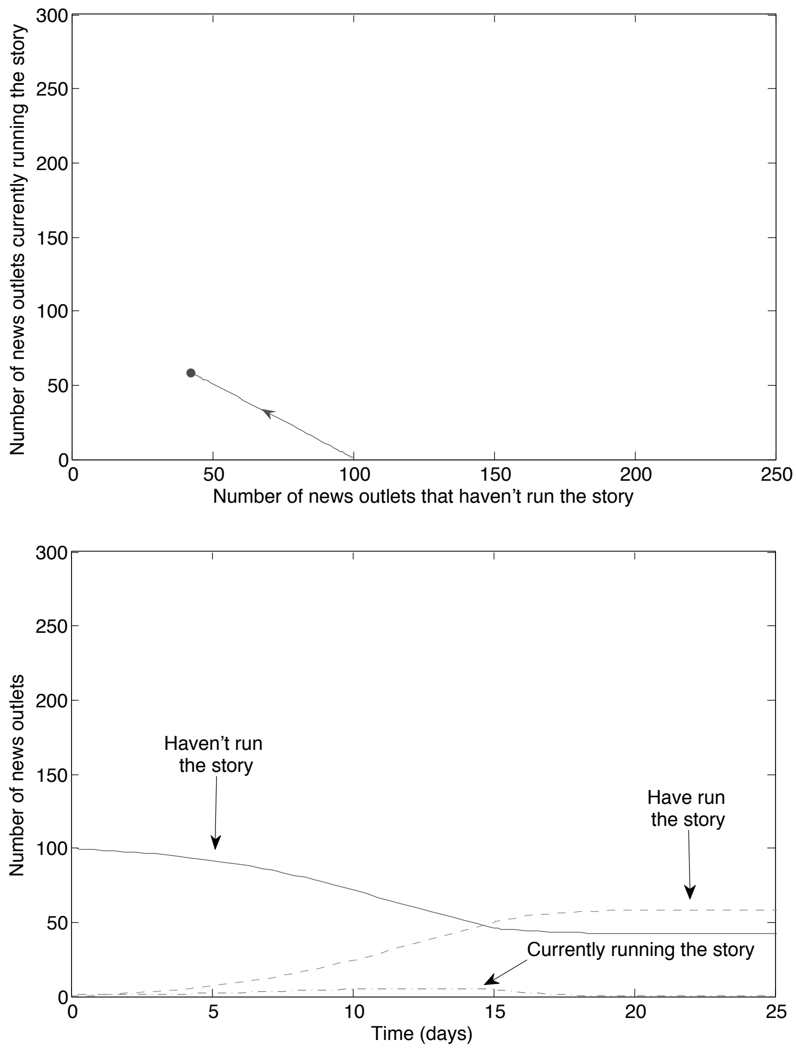

Figure 1.6: Behaviour of media outlets in the absence of a secondary hook. The story proceeds through its natural cycle in an orderly fashion. A: The phase plane (a representation where time is implicit) illustrating the tradeoff between media outlets that have run (or are currently running) the story versus those that have not. B: The time course of the story through the media. Parameters were as in Figure 1.4, except that $S(0) = 100$. This story does not go viral.

1. *Non-newsworthy story, good interview subject*

   In this case, the story never gets off the ground, regardless of the skills of the interviewee. This illustrates the power of the media to shape the cultural narrative, by determining what is or is not newsworthy. See Figure 1.8.

2. *Slow news week*

   In this case, the story remains in the infectious class for significantly longer than it otherwise would, allowing it to be sustained. The story can reap close

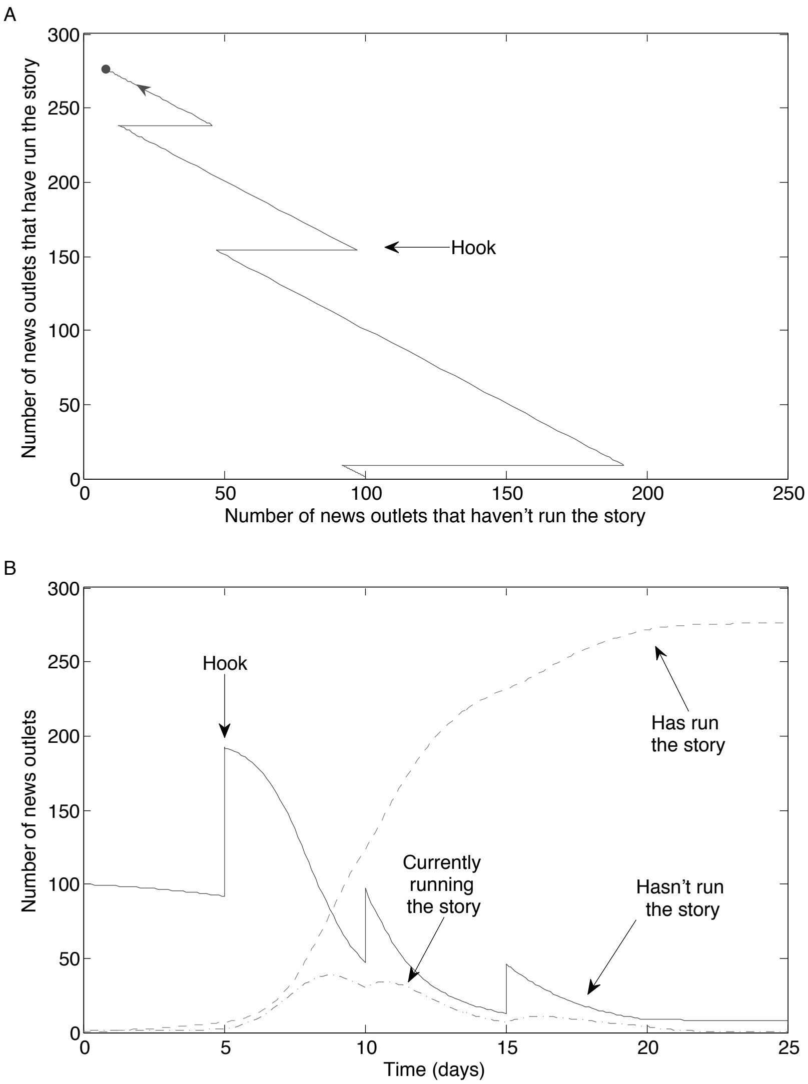

Figure 1.7: Behaviour of media outlets in the presence of multiple hooks. The story can be kept alive for significantly longer and be picked up by many more media outlets when successive hooks revive interest. A: The phase plane illustrating the trade-off between media outlets that have run (or are currently running) the story versus those that have not. B: The time course of the story through the media. Parameters were as in Figure 1.6, except that hooks of decreasing strength were added at regular intervals. In this case, there is a classic epidemic wave (double-peaked due to the impulses) and the majority of susceptible media outlets are infected, meaning that the story has gone viral.

to its maximum potential, with almost all susceptible media outlets running the story. See Figure 1.9.

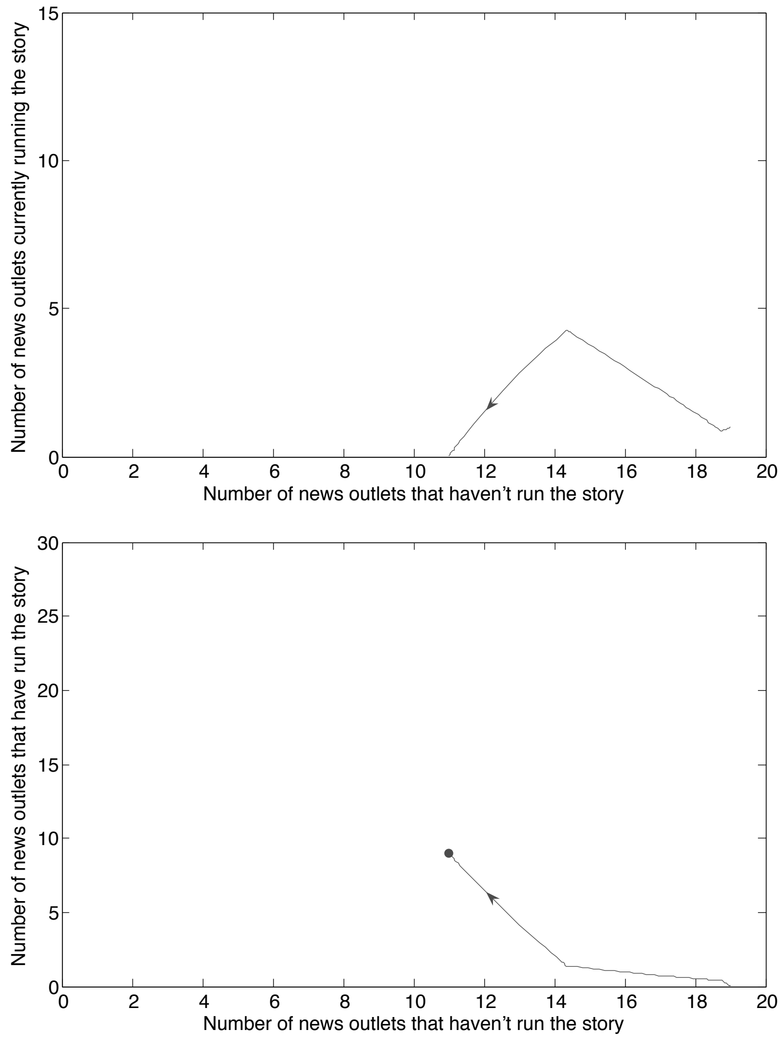

Figure 1.8: A good interviewee cannot compensate for a story not deemed newsworthy, resulting in the story barely registering in the media. Parameters were as in Figure 1.5 except that $\beta = 0.005$.

3. *Good topic, bad interview subject*

   If the the story has sufficient initial interest, then it can reap close to its maximum potential, with almost all susceptible media outlets running the story, even if it has no durability. See Figure 1.10.

4. *Secondary hooks, bad interview subject*

   In this case, secondary hooks mean that a story on its way out can receive new life. If a hook occurs early enough, this may result in a significant revival of the story, even in the absence of any long-term durability. See Figure 1.11.

It follows that a story can reap its original potential if the topic is sufficiently newsworthy or the story occurs during a slow news week. A good interview subject

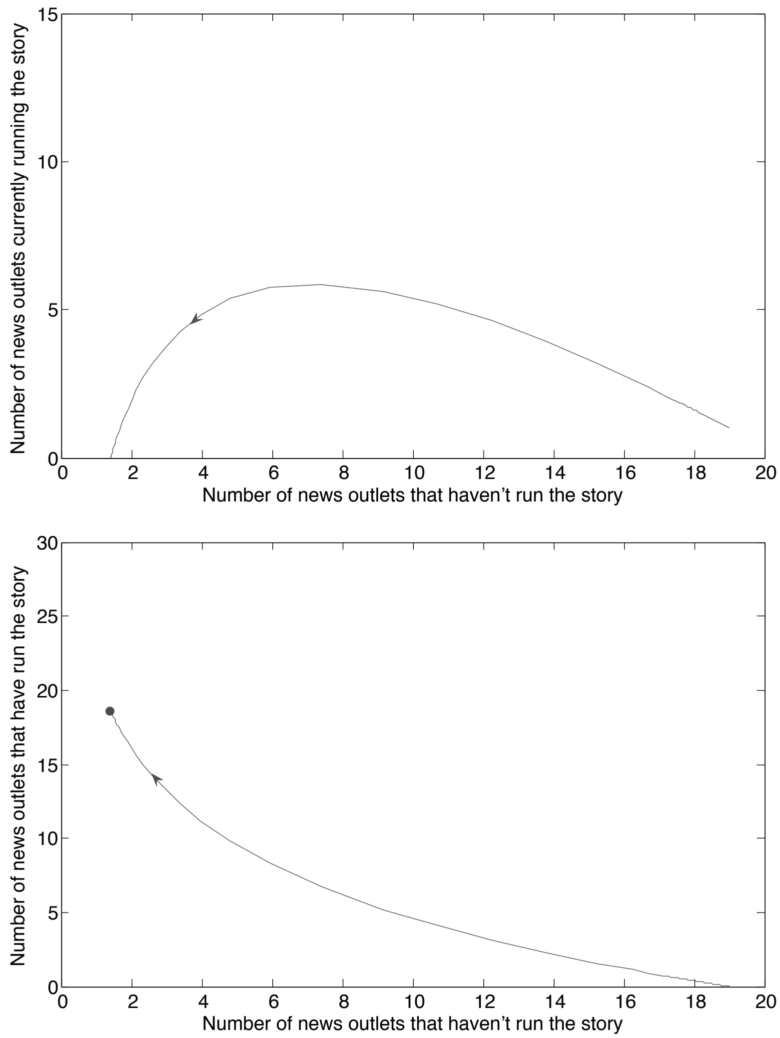

Figure 1.9: A slow news week can sustain a story, even in the absence of good interview subject. Parameters were as in Figure 1.4 except that $\frac{1}{\nu}$ was doubled.

can increase the power of a story. However, a series of secondary hooks, occurring at discrete times, can significantly expand a story's appeal beyond its original potential. This is especially true if the hooks occur early in the story's life.

1.6 Discussion

Just like zombies themselves, articles about zombies are the gifts that keep on giving: every time you think they're finally dead, they seem to come back to life.

Ultimately, the story of a mathematical model of zombies going viral was a confluence of circumstances: a diverting topic that happened to occur in a slow news week, which came with media-savvy interview subjects and had a major secondary

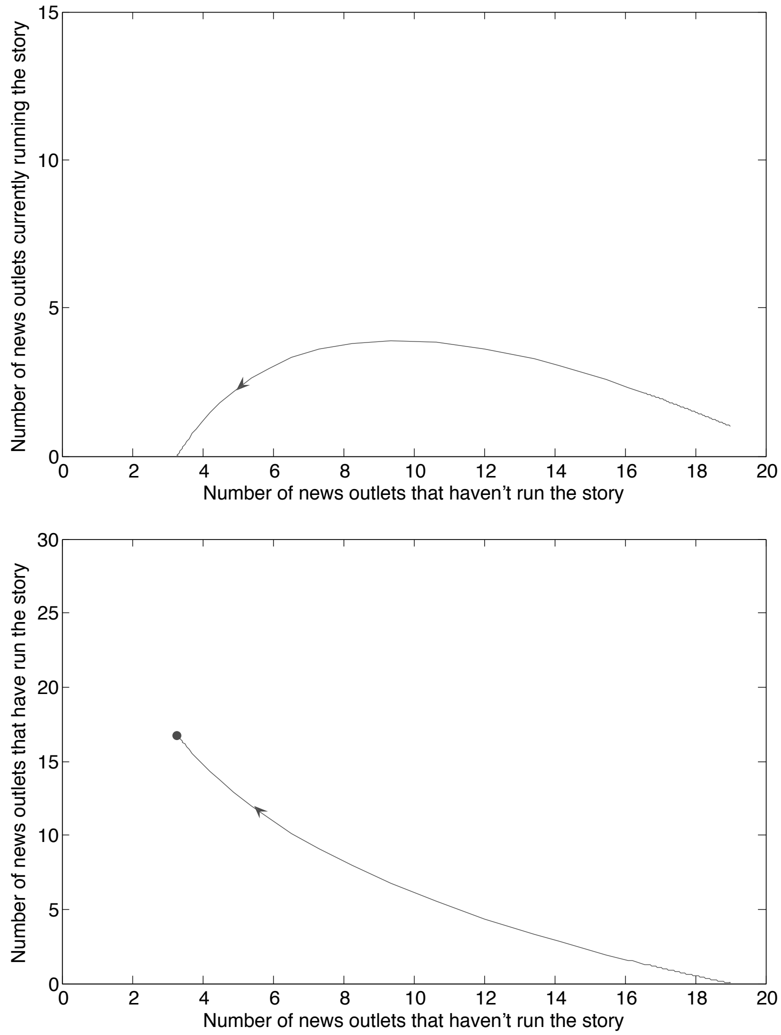

Figure 1.10: A fascinating topic can overcome a poor or nonexistent interview subject. Parameters were as in Figure 1.4 except that β was increased by 50%.

hook that occurred early in the story's lifespan. Furthermore, since it was a fairly self-contained phenomenon, it forms a useful case study for the effects of media.

For a story to go viral, it needs to be newsworthy and needs to have a long natural lifespan. Once a story is under way, a good interview subject can extend the lifespan of a story. However, a series of further hooks that increase a story's appeal have the potential to breathe new life into the story by creating new outlets for it to appear in. The effect is particularly significant if such a hook appears early in the news cycle. These hooks may occur randomly and may have different strengths when they do occur.

As an example of a story that did not go viral, but was studied intensely, consider Jensen's 1977 account of the lack of focus on lead in the blood of children living

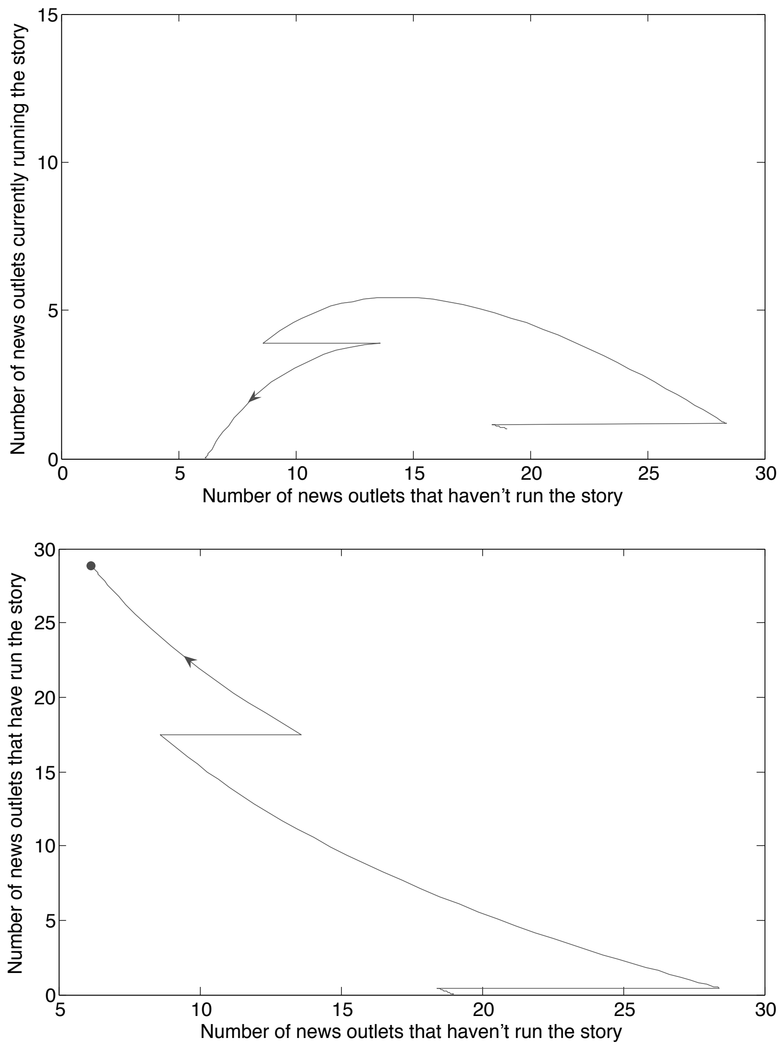

Figure 1.11: A series of hooks can sustain the story beyond its original lifespan, even in the absence of a good interview subject. However, hooks that occur early in the story's lifespan can breathe significant new life into the story, whereas those that occur late will not. Parameters were as in Figure 1.4 except that two hooks were added. Note that, despite an initial rise and the majority of susceptible media outlets being infected, there is no significant epidemic wave, despite the presence of secondary hooks. Thus this story does not go viral.

near a lead and zinc smelter in Kellogg, Idaho [47]. This story was featured briefly on national television, but thereafter had no national followup. A reporter for an independent local newspaper, Cassandra Tate, followed the story for two years, writing 175 articles on the subject. However, the story never received much attention beyond her direct employer, despite the presence of several hooks: the lead poisoning was not limited to Idaho and lead was later found in the newspaper-publishing industry. Jensen concluded with a general summary he called Cassandra's Law: the odds against comprehensive coverage of an environmental story are high, and are increased by complexity, proximity and distance. These effects are aggravated by the more recent dominance of corporate media.

In the context of our model, this story was somewhat newsworthy to begin with, but had no durability, further hooks failed to take hold and it was swamped by coverage of Evel Knievel's September 1974 motorcycle leap across Snake River Canyon, which was covered by hundreds of reporters. Thus, although β was relatively high, α was low (or zero), $\frac{1}{\nu}$ was low and there were no substantial secondary hooks.

A major difference that arises in this model, as compared to other epidemic models, is a counterpoint to cross-immunity. Many diseases provide some immunity to further infection, but in this model previous infection actually primes some media outlets for secondary outbreaks. Thus 'removed' media outlets are still infectious. However, since this form of infection decreases with time, the results are highly dependent on the speed of the epidemic. That is, if a story isn't going to go viral immediately, then it is much harder for it to take off later.

The model has several limitations, which should be acknowledged. Media 'infection' may focus more on an outlet's specific competitors than general reports, making the mass-action transmission factors less accurate. It would be instructive to generalize the model to include more details about the factors that determine 'newsworthiness,' in all its complication. Furthermore, the negative effects of media were not considered; if an interview subject was particularly off-putting, so that $\bar{\alpha} < 0$, then this could stop even a potentially fascinating story in its tracks.

Other effects that could be considered include the effects of unofficial media, such as blogs or Twitter (which were a factor in gaining initial attention in the zombie story and then sustaining a 'buzz' for it throughout its intense phase). However, while these may sustain a story that is under way, they do not, as yet, have the sheer reach that official media has and lack some of the factors that have been identified here, such as an interview subject. Furthermore, the lifespan of stories in these incarnations is significantly shorter, suggesting that stories would pass through their natural life cycle at an accelerated rate in the absence of traditional media.

It should also be noted that the factors affecting a story's newsworthiness, durability and natural lifespan are culturally specific. Thus what makes a story newsworthy in one media market may not in another. Media may also be limited in some places by government restrictions, the need to sell ads, etc.

This media model was informed by the news story of the zombie model going viral. Data from that story was used to inform and parameterize the media model and also to compare this news story with other news stories that did not go viral. Thus the zombie news story gives insights into how the media works, while also quantifying several factors.

In summary, a story can go viral, but it needs a perfect storm of events to do so. It must be deemed newsworthy in the first place and it needs room to breathe, a good interview subject and at least one hook. Given an arbitrary topic, the only factors external to the media itself that are potentially controllable are the skills of the interviewee (through media training) and perhaps the timed release of further information that acts as a secondary hook. Otherwise, the viral nature of a story is at the mercy of the randomness inherent in the media.

Appendices

A Acknowledgements

The author is grateful to Graeme Burk, Shoshana Magnet, Penelope Ironstone-Catterall, Sandra Robinson, Seth Sazant and Anna Kwik for technical discussions. The author also acknowledges two anonymous reviewers, whose comments greatly improved the manuscript. Handling editor for this chapter was Jane Heffernan. The author is supported by an NSERC Discovery Grant, an Early Researcher Award and funding from MITACS. For citation purposes, note that the question mark in "Smith?" is part of his name.

B Glossary

Durability. The essence of a media story's staying power, largely driven by how fascinating and insightful the interview subject is. For anyone wishing to interview me in greater, but entertaining, depth about this topic, I am easily contactable at rsmith43@uottawa.ca or by telephone after a quick google search of my now-quickly-identifiable name.

Epidemic wave. A steep rise in infections that reaches a peak and then starts to dissipate, eradicating the epidemic but leaving a trail of devastation and horror in its wake. A bit similar to the emotions you'd feel if you walked in on your parents in the act.

Equilibria. A state where all dynamic forces are balanced so that the net effect is no change in the system. A bit like being high, really.

Final size. The number of survivors of an epidemic. Finally, a mathematical definition that sounds suitably zombie-like!

Hook. Further information that increases a story's appeal, either to media outlets that were not previously interested or that causes those that have already run the story to run it again. They also use these things to catch fish, you know.

Impulsive differential equations. A fairly new type of mathematical model that contains continuous solutions punctuated by short, sharp shocks. These reset the system so that it starts again at new initial conditions that are related to the final conditions from the previous cycle. You know, before I was the first person to apply this theory to infectious diseases, I used it to examine sewage treatment for my Ph.D. That's right, my thesis was shit.

Infectious. A media outlet is infectious if it is currently running the viral story and has the potential to infect other media outlets by virtue of its cutting-edge insights, sheer depth of coverage and fascinating reporting. So Fox News is quite safe, then.

Jacobian. Just about the most massively useful thing that mathematics has ever invented. It combines multivariable calculus with linear algebra to create a matrix of partial derivatives whose eigenvalues almost completely determine the stability properties of an equilibrium. Okay, I realize this doesn't tell you what the Jacobian actually is, but some things defy a pithy one-paragraph summary, you know.

Mass-action transmission. A form of infection modelling that assumes every infected media outlet has equal chance of infecting every susceptible outlet. Mass action means that your cohort has to be either small or very well connected. So if you're modelling a serious disease in Africa, you'd have to restrict yourself to a small village where—Oh, I'm sorry, was I boring you? Oh look, here are some imaginary zombies!

Media. The collective apparatus for reporting the news. Mainstream media consist of newspapers, television, radio, etc., while other media include blogs, Twitter, tumblr and so forth. Between the writing and publication of this article, six entirely new media propagation vehicles have undoubtedly been invented.

Natural lifespan. The length of time that a story remains newsworthy, in the absence of further disturbances. Thus the inverse of this parameter is the rate at which a story becomes old. See also: Grandpa, and the precise point at which he stopped being sexy.

Newsworthiness. That mystical and capricious property that assigns some media stories value over others, seemingly at random, to the complete bafflement of anyone who has ever thought about it. Rupert Murdoch, you have a lot to answer for.

Nullcline. The place where just one variable is constant, although the others can usually change. Why my first-year calculus class can never grasp this simple concept, I'll never know.

Perturbations. Small changes to a system that might destabilize it. Either that or kinky sexual practices, I forget which.

Removed. A media outlet is removed/recovered if it has already run the story but may be capable of still infecting susceptible outlets. Any resemblance to zombies is purely coincidental.

Slow news week. Those rare times when nothing is taking the editor-in-chief's fancy. There you are, in the whiskey-filled back room, chain-smoking your way through packs of cigarettes, while the typewriters lie idle and your fedora with the word "press" stuck in it hangs sullenly on the hatstand. I think you know what I'm talking about.

Stable. A place where you keep a horse. No, wait, that's not right. It's when small perturbations away from an equilibrium return you to that equilibrium. Nothing to do with horses. Except for that one type of equilibrium that's called a saddle. But that type of equilibrium is never stable, so I really don't know why I brought it up.

Susceptible. A media outlet is susceptible if it is not infected but has the potential to be at some point in the future, regardless of whether that eventually happens. Also, one that is prone to jumping on the bandwagon of whatever the cool kids are doing. I'd tell you to see CNN, but I'm not that cruel.

Threshold. A definitive line between one thing and another. Not just the airy-fairy sense that today you're in the mood for waffles when yesterday you liked pancakes, but a real, honest-to-goodness change, like losing an arm and not being able to play the guitar any more. Don't mix these things up, because mathematicians take them very seriously indeed. Indeed, somebody once took something that wasn't a threshold and called it "the reinfection threshold." Much merriment was had in academia as a result.

Viral. A media story is viral if it is able to expand its reach significantly, with a virtual explosion of reports across multiple media outlets and types. Unless it uses a condom, of course.

Zombies. Hideous inhuman creatures who exist in a state of half-existence, shambling from location to location with outstretched hands and moaning audible pain, despite not feeling any. Or do I mean politicians?

References

[1] J. Gardy. Science tackles zombie attacks. *Globe Campus*, 10 August 2009.

[2] B. Scriber. What Can Zombies Teach Us About Swine Flu? *National Geographic*, 12 August 2009. http://blogs.ngm.com/blog_central/2009/08/what-can-zombies-teach-us-about-swine-flu.html

[3] P. Munz, I. Hudea, J. Imad, R.J. Smith?. When zombies attack!: Mathematical modelling of an outbreak of zombie infection. In *Infectious Disease Modelling Research Progress*, J.M. Tchuenche and C. Chiyaka, eds., Nova Science, Happuage, NY 2009, pp. 133–156.

[4] B. Mason. Mathematical Model for Surviving a Zombie Attack. *Wired Science*, 14 August 2009. http://www.wired.com/wiredscience/2009/08/zombies/

[5] S. Chase. Scholars put braaaaains together to thwart zombies. *The Globe and Mail*, 15 August 2009. http://www.theglobeandmail.com/news/national/scholars-put-braaaaains-together-to-thwart-zombies/article1253006/

[6] K. Wallace. Mathematicians use zombies to learn about swine flu. *The Toronto Star*, 18 August 2009. http://www.thestar.com/article/682691

[7] J. Goldstein. What's the Best Way to Fight Zombies? Someone Did the Math. *The Wall Street Journal*, 18 August 2009. http://blogs.wsj.com/health/2009/08/18/whats-the-best-way-to-fight-zombies-someone-did-the-math/

[8] P. Ghosh. Science ponders 'zombie attack.' *BBC News*, 18 August 2009. http://news.bbc.co.uk/2/hi/science/nature/8206280.stm

[9] K. English. The man in question is Smith? *The Toronto Star*, 22 August 2009. http://www.thestar.com/comment/article/684873

[10] M. Hanlon. Forget swine flu—could we cope with a plague of the Undead? Scientists ponder the threat of a zombie attack. *The Daily Mail*, 26 August 2009. http://www.dailymail.co.uk/sciencetech/article-1209052/Forget-swine-flu--cope-plague-Undead-Scientists-ponder-threat-zombie-attack.html

[11] K. Rose. Professor Robert J Smith? does maths on surviving oubreak of zombies. *Melbourne Herald Sun*, 20 August 2009. http://www.heraldsun.com.au/news/professor-robert-j-smith-does-maths-on-surviving-oubreak-of-zombies/story-e6frf7jo-1225764287719

[12] S. Leppänen. Tiedemiehet pohtivat zombien hyökkäystä. *Iltalehti*, 18 August 2009. http://www.iltalehti.fi/ulkomaat/2009081810098216_ul.shtml

[13] Who Will Win in Human, Zombie War? *All Things Considered*, National Public Radio, 20 August 2009. http://www.npr.org/templates/story/story.php?storyId=112075098

[14] N. Hayden. Zombies. *ABC TV*, December 2, 2009. https://www.youtube.com/watch?v=AjBxxKR5Uvg

[15] R. Smith?, ed. *Braaaiiinnnsss!: From Academics to Zombies*. University of Ottawa Press, Ottawa, 2011.

[16] Science of the Living Dead. *The Science and Entertainment Exchange*, 23 October 2009. http://blog.scienceandentertainmentexchange.org/2009/10/science-of-living-dead.html

[17] R. Liu, J. Wu, H. Zhu. Media/psychological impact on multiple outbreaks of emerging infectious disease. *Comp. Math. Meth. Med.*, 8(3):153–164, 2007.

[18] R. Ma. Media, Crisis, and SARS: An Introduction. *Asian J. Comm.*, 15(3):241–246, 2005.

[19] C.R. Simpson. Nature as News: Science Reporting in *The New York Times* 1898 to 1983. *Internat. J. Polit. Cult. Soc.*, 1(2):218–241, 1987.

[20] M.D. Slater, K.A. Rasinski. Media Exposure and Attention as Mediating Variables Influencing Social Risk Judgments. *J. Comm.*, 55(4):810–827, 2005.

[21] H. Lasswell. *Propaganda Technique in the World War*. MIT Press, Cambridge, MA, 1971.

[22] P. Lazarsfeld. *Radio and the Printed Page: An Introduction to the Study of Radio and Its Role in the Communication of Ideas*. Duell, Sloan and Pearce, New York, NY, 1940.

[23] J. Radway. *Reading the Romance*. University of North Carolina Press, Chapel Hill, NC, 1984.

[24] S. Hall. *Cultural Representations and Signifying Practices*. Sage Publications, London, UK, 1997.

[25] R. Williams. *Television: Technology and Cultural Form*. Fontana, London, UK, 1974.

[26] D. Hebdige. *Subculture: The meaning of style*. Methuen & Co., London, UK, 1979.

[27] P. Treichler. *How to Have Theory in an Epidemic*. Duke University Press, Durham, NC, 1999.

[28] L.C. Owens. International Accident, Disaster Stories Generate Greater Interest Among Students. *Newspaper Research J.* 28(2):107–113, 2007.

[29] T.C. Trautman. Concerns about Crime and Local Television News. *Comm. Research Reports* 21(3):310–315, 2004.

[30] F. Kuhn et al. What the readers see: How a sample of newspapers treats Washington news. *Columbia Journalism Rev.* 1:21–23, 1962.

[31] C. Burke, S.R. Mazzarella. "A Slightly New Shade of Lipstick": Gendered Mediation in Internet News Stories. *Women's Stud. Comm.* 31(3):395–418, 2008.

[32] K. Ross. The journalist, the housewife, the citizen and the press: Women and men as sources in local news narratives. *Journalism* 8(4):449–473, 2007.

[33] E. Herman, N. Chomsky. *Manufacturing consent: The political economy of the mass media*. Pantheon, New York, NY, 1988.

[34] T. Gitlin. *The whole world is watching: Mass media in the making and unmaking of the new left.* University of California Press, Los Angeles, CA, 1980.

[35] J.E. Good. The Framing of Climate Change in Canadian, American, and International Newspapers: A Media Propaganda Model Analysis. *Canad. J. Comm.* 33:233–255, 2008.

[36] J. Cui, Y. Sun, H. Zhu. The impact of media on the spreading and control of infectious disease. *J. Dynam. Differential Equations*, 20:31–53, 2003.

[37] Y. Liu, J. Cui. The impact of media coverage on the dynamics of infectious disease. *Int. J. Biomath.*, 1:65–74, 2008.

[38] Y. Li, J. Cui. The effect of constant and pulse vaccination on SIS epidemic models incorporating media coverage. *Commun. Nonlinear Sci. Numer. Simul.*, 14:2353–2365, 2009.

[39] J.M. Tchuenche et al. The impact of media coverage on the transmission dynamics of human influenza. *BMC Public Health* 11(Suppl 1):S5, 2011.

[40] O. Krakovska, L.M. Wahl. Optimal drug treatment regimens for HIV depend on adherence. *J. Theoret. Biol.* 246(3):499–509, 2007.

[41] B. Liu, Z. Teng, L. Chen. The effect of impulsive spraying pesticide on stage-structured population models with birth pulse. *J. Biol. Systems* 13(1):31–44, 2005.

[42] A. d'Onofrio. On pulse vaccination strategy in the SIR epidemic model with vertical transmission. *Appl. Math. Lett.* 18(7):729–732, 2005.

[43] V. Lakshmikantham, D.D. Bainov, P.S. Simeonov. *Theory of Impulsive Differential Equations*. World Scientific, Singapore, 1989.

[44] D.D. Bainov, P.S. Simeonov. *Systems with Impulsive Effect.* Ellis Horwood Ltd, Chichester, UK, 1989.

[45] D.D. Bainov, P.S. Simeonov. *Impulsive differential equations: Periodic solutions and applications*. Longman Scientific and Technical, Burnt Mill, UK, 1993.

[46] D.D. Bainov, P.S. Simeonov. *Impulsive Differential Equations: Asymptotic Properties of the Solutions*. World Scientific, Singapore, 1995.

[47] D. Jensen. The loneliness of the environmental reporter. *Columbia Journalism Rev.*, 15(5):40–43, 1977.