

FAUX REVIEW

A report on the zombie outbreak of 2009: how mathematics can save us (no, really)

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ABSTRACT

An outbreak of zombification wreaked havoc recently in Canada and the rest of the world. Mathematical models were created to establish the speed of zombie infection and evaluate potential scenarios for intervention, mainly because mathematicians don't have anything better to do with their time. We review the development of these models and their effect on the undead.

In August 2009, a new disease emerged in North America and quickly made its way around the world.¹ Media reports suggest the outbreak began in Ottawa² but rapidly spread across Canada^{3,4} and was transported thereafter to the United States⁵ and the United Kingdom.^{6,7}

The infection resulted in a new species of human, classified as *nonmortuus contagio*, but known in the popular press as “zombie”, from the Congolese *nzambi*, meaning “spirit of a dead person.” As the name implies, the outbreak resulted in a resurgence of the previously deceased. Clinical signs included discoloration around the eyes, open wounds and rotting flesh, with organs and bodily functions operating at minimal levels.

Initial studies reported that the zombies did not feel pain, but these findings could not be verified because of the zombification of the researchers in question. When asked for comment, the lead author of one such study said, “Grrrrnn, aaarghhh, huuuuuungry!” When questioned in more detail, he replied, “Braaaaaiiiiiinnssss!” No further information is available from the interview.

The cause of the virus remains unknown. Anecdotal evidence suggests that zombies can be defeated by guns, the army, eventual starvation or Dire Straits records.

New diseases are generally investigated using experiments on infected people, clinical trials or medical observation. Unfortunately, because of the rapid zombification of scientists, epidemiologists and doctors, society was left with only one group of technocrats who remained uninfected: mathematicians. Fortunately, during the time at which the outbreak occurred, members of this group had not been invited to parties and thus remained entirely uninfected.

A mathematical model for zombie infection⁸ was quickly



Courtesy of Sony Pictures Canada

designed (Figure 1). As shown by the model, humans could be infected by contact with a zombie, whereas zombies could be created either through the conversion of humans or reanimation of the dead. The model assumed that zombies could be killed in encounters with humans, as often happened when humans ran over zombies in their cars. Initially, such deaths were assumed by authorities to be part of a concerted effort at eradication of zombies, but were later revealed to be simply a result of rush hour. Some drivers were surprised when these recently deceased zombies returned to life and attacked them. Other drivers simply handed the zombies some spare change and waited for the reanimated creatures to clean their windshields.

The model showed two equilibria: the disease-free equilibrium (with no zombies) and the doomsday equilibrium (where everyone is a zombie). The application of a linear stability analysis showed that — in the absence of further interventions — the disease-free equilibrium was unstable and the doomsday equilibrium was stable. This finding was not promising.

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Simulations based on a city of roughly 500 000 people demonstrated that an entire such city would be replaced by zombies after about four days (Figure 2A). Were this mass replacement of a population to occur in a city such as Ottawa, it may be unlikely anyone would notice. Nevertheless, nearby cities such as Montreal would no longer be in the bagel-supplying business in such a scenario, and that result would be serious.

Given this model, even a small outbreak would lead to a collapse of society as we know it. Explaining to the mathematicians that this outcome might be a bad thing took time because, initially, they were not able to see the downside. However, they were quickly mobilized after realizing their supply of caffeine and science fiction DVDs would dry up.

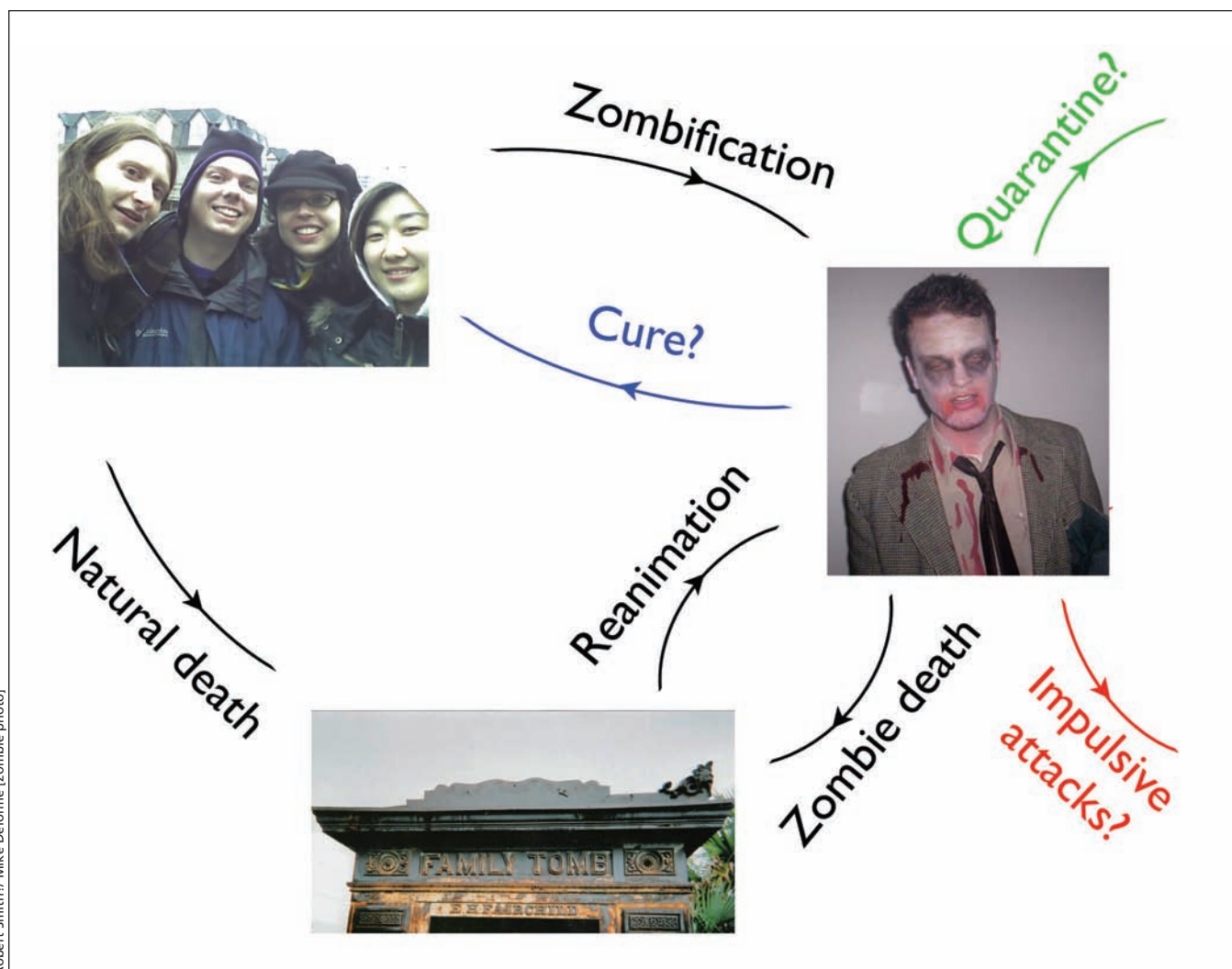
Three interventions were proposed. The first was quarantine (Figure 1, green arrow), whereby a small proportion of the zombies would be kept in isolation. But given that the infection was so virulent, even leaving a few zombies in the wild

would result in a restart of the outbreak. Including quarantine thus made no difference to the stability of the doomsday equilibrium (Figure 2B). That was a bit of a downer, to be honest.

The second intervention was a theoretical cure that would convert zombies back into humans (Figure 1, blue arrow). Although the mathematicians were reminded that such a cure was entirely theoretical and likely could not be developed within four days, they were quite taken with the idea of proving results based on things that couldn't possibly exist. This response was annoying, because they should have been concentrating on zombies instead.

With a cure, humans and zombies could coexist. But unless the cure were 100% effective, humans would survive only in small numbers (Figure 2C) — most likely in shopping malls, abandoned farmhouses or the Winchester pub.

Finally, the idea of impulsive attacks was considered (Figure 1, red arrow). This intervention would involve an escalating series of discrete attacks on the zombies, using an



Robert Smith?/ Mike Delorme [zombie photo]

Figure 1: Schematic diagram of the basic mathematical model (black arrows). Humans (friendly Canadians, in this example) can either die naturally or be converted into zombies — which is not terribly pleasant, but does come with that nifty jacket and tie. Zombies can reanimate the dead or be killed by humans (although it must be said that the latter doesn't bother them too much). Possible intervention include quarantine of the zombies (green arrow), a potential cure (blue arrow) or impulsive attacks (red arrow).

advanced mathematical theory called impulsive differential equations. These equations are similar to ordinary differential equations, except that sometimes they jump up onto tables, paint themselves purple and start singing show tunes for no reason whatsoever.

The projected outcome of this intervention was more promising. At regular intervals, humans would mobilize their resources and attack the zombies. Each attack would be carried out with more force than the last one. The humans would keep fighting with increasing intensity until either the zombies were destroyed or the humans were torn apart from limb to limb and their flesh consumed by the ghoulish undead. Still, you've got to laugh, haven't you? If humans could manage these impulsive attacks, the zombies could be destroyed after 10 days (Figure 2D).

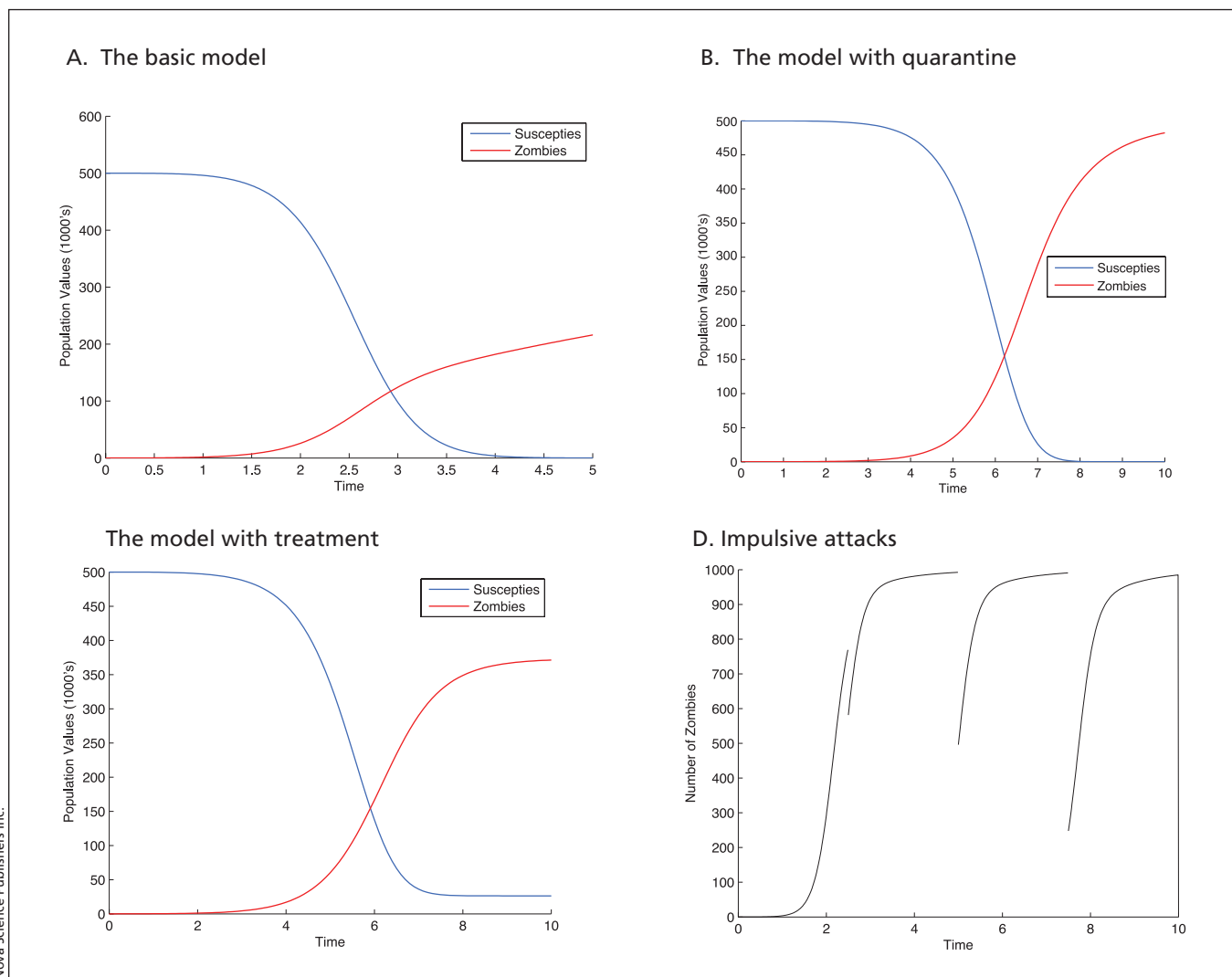
The overall model had limitations, of course. The numerical contributions of natural births and deaths had been

ignored because of the brief timescale involved and the unlikelihood that mathematicians would be engaged in breeding. Inclusion of population demographics in the model suggests a limitless supply of new bodies would be available for zombies to infect, resurrect and convert. We must therefore act quickly and decisively to eradicate zombies before they eradicate us.

Conclusion

Mathematical modelling suggests that several potentially promising avenues of intervention against zombies would in fact be useless. Neither quarantine nor a cure are viable options and would only delay the inevitable by a few days. The best option remains arming oneself to the teeth, hitting the zombies hard and then hitting them harder the next time.

The 2009 epidemic was successfully contained using this last option. When the next zombie outbreak occurs, rapid



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Figure 2: Projected population dynamics (based on type of intervention) in the context of a zombie outbreak. In the basic model (A), zombies eradicate humans after 4 days, leaving nobody to host daytime variety television shows or stop you from entering nightclubs (i.e., no loss there). (B): Quarantine delays the inevitable. Slightly. (C): A cure allows zombies to live in harmony with humans, which would be more fun for zombies than humans. (D): Only episodes of blind, aggressive, unfeeling violence are effective. And that's just on the part of humans.

management of the spread of infection is imperative. Should we be unable to contain the outbreak, we face the extreme possibility of a world whose population is made up entirely of mathematicians and zombies. One of these groups spends all its time lurking in the darkness, with wild eyes, hair askew and brains that don't work like those of normal humans. And the other group is the zombies.

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REFERENCES

1. Scriber B. What can zombies teach us about swine flu? [blog]. *National Geographic Magazine* 2009 Aug.12. Available: http://blogs.ngm.com/blog_central/2009/08/what-can-zombies-teach-us-about-swine-flu.html (accessed 2009 Oct. 22).
2. Smith? R. Zombie math and swine flu. *Ottawa Citizen* 2009 Sept. 12. Available: www.ottawacitizen.com/health/Zombie%20math%20swine/1986332/story.html (accessed 2009 Oct. 22).
3. Chase S. Scholars put braaaaains together to thwart zombies. *Globe and Mail* 2009 Aug. 15.
4. Wallace K. Mathematicians use zombies to learn about swine flu. *Toronto Star* 2009 Aug. 18. Available: www.thestar.com/article/682691 (accessed 2009 Oct. 22).
5. Goldstein J. What's the best way to fight zombies? Someone did the math. *Wall Street Journal* [NY] 2009 Aug. 18. Available: <http://blogs.wsj.com/health/2009/08/18/whats-the-best-way-to-fight-zombies-someone-did-the-math/> (accessed 2009 Oct. 22).
6. Ghosh P. Science ponders 'zombie attack'. *BBC News* 2009 Aug. 18. Available: <http://news.bbc.co.uk/2/hi/science/nature/8206280.stm> (accessed 2009 Oct. 22).
7. Hanlon M. Forget swine flu — could we cope with a plague of the Undead? Scientists ponder the threat of a zombie attack. *The Daily Mail* [UK] 2009 Aug. 26. Available: www.dailymail.co.uk/sciencetech/article-1209052/Forget-swine-flu-cope-plague-Undead-Scientists-ponder-threat-zombie-attack.html (accessed 2009 Oct. 22).
8. Munz P, Hudea I, Imad J, et al. When zombies attack!: Mathematical modelling of an outbreak of zombie infection. In: Tchuente JM, Chiyaka C, editors. *Infectious disease modelling research progress*. Hauppauge (NY): Nova Science Publishers; 2009. p. 133-50. Available: www.mathstat.uottawa.ca/~rsmith/Zombies.pdf (accessed 2009 Oct. 22).

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