Planning horizon affects prophylactic decision-making and epidemic dynamics

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Motivation

– Infectious diseases remain a major **threat to human health**. For example, the recent outbreaks of SARS, H1N1 flu, and Ebola


nature International weekly journal of science

Journal home > Archive > Review > Abstract

Review

Nature **459**, 931-939 (18 June 2009) | doi:10.1038/nature08157; Received 12 May 2009; Accepted 26 May 2009; Published online 14 June 2009

Emergence and pandemic potential of swine-origin H1N1 influenza virus


SCIENCE & HEALTH

WHO: Influenza Pandemic Remains Global Threat

Lisa Schlein

– **Human behavior** has been recognized to play a significant role in the spread of infectious diseases


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Ebola: the power of behaviour change

Thursday, 27 November 2014

Behaviour change in local communities appears to be playing a key role in the reduction of Ebola cases in Liberia, according to School experts.

News: 2016, 2015, 2014, 2013, 2012, 2011, News and press archive, Features


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RESEARCH ARTICLE

The Contribution of Social Behaviour to the Transmission of Influenza A in a Human Population

Adam J. Kucharski, Kin O. Kwok, Vivian W. I. Wei, Benjamin J. Cowling, Jonathan M. Read, Justin Lessler, Derek A. Cummings, Steven Riley

Published: June 26, 2014 • http://dx.doi.org/10.1371/journal.ppat.1004206

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Related Work

Aspects of human behavior incorporated in infectious disease models:

- Individual responses to different types of **public health interventions**
- Influence of **risk of infection** and **social cost** on individual behavioral changes
- Effect of **awareness** or **fear spreading** on individual behavioral decisions

Objective

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Understand how **individuals' planning horizons** influences behavioral changes (i.e., adopt or not prophylaxis) and how this in turn influences epidemic dynamics

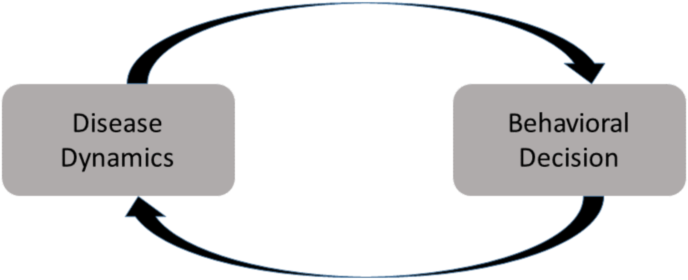
Objective

Definition

Planning horizon is the time in the future over which individuals consider to make a behavioral decision to adopt prophylaxis

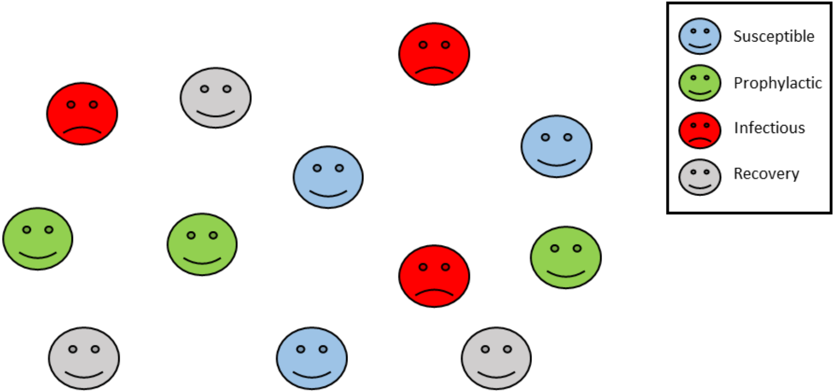
SPIR Model

The **SPIR** model (**S**usceptible, **P**rophylactic, **I**nfectious, **R**ecovered) is an **epidemiological agent-based model** that couples individual behavioral decisions with a disease dynamics model



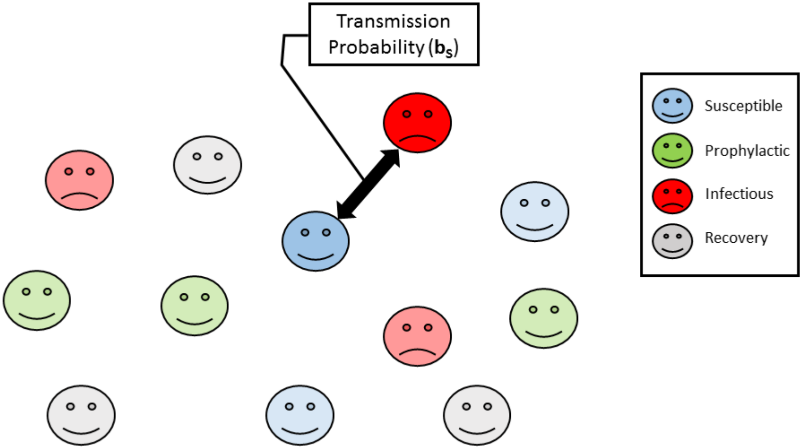
SPIR Model

Agent States



Disease Dynamics Model

Event 1: Interaction and Infection



Disease Dynamics Model

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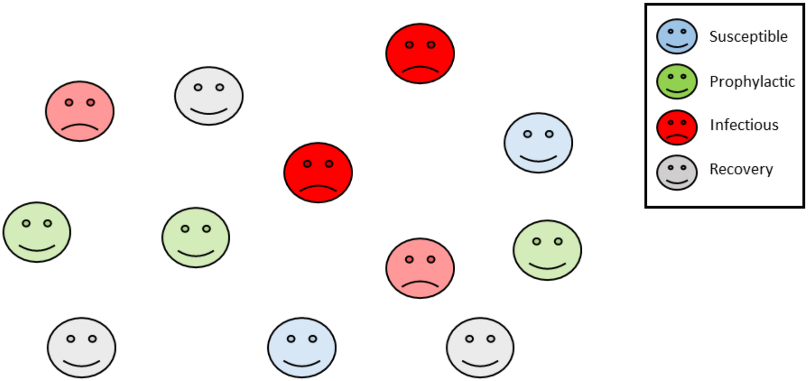

Disease Dynamics Model

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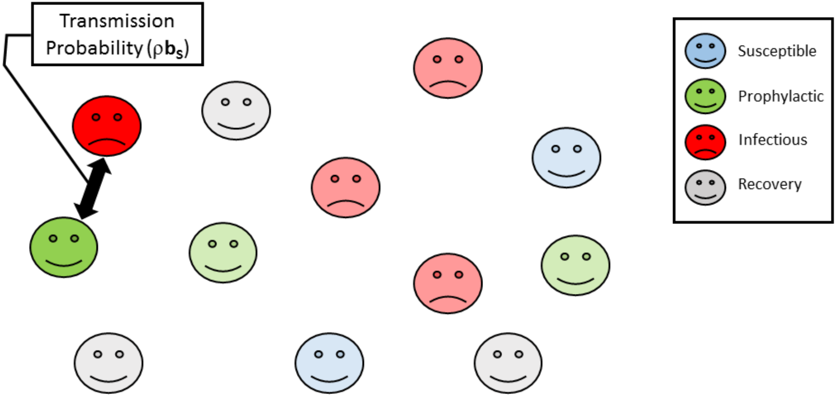
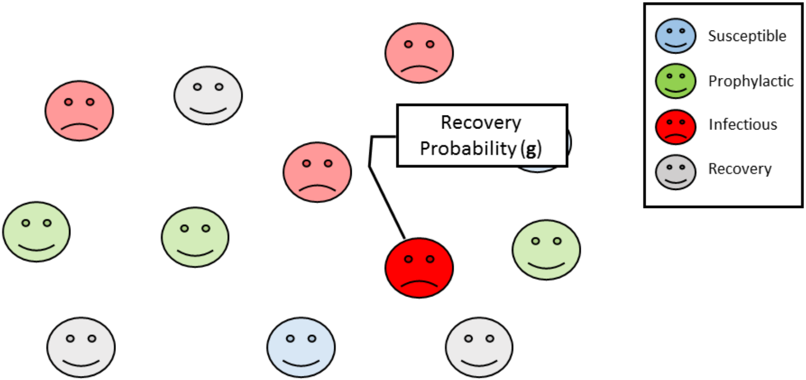


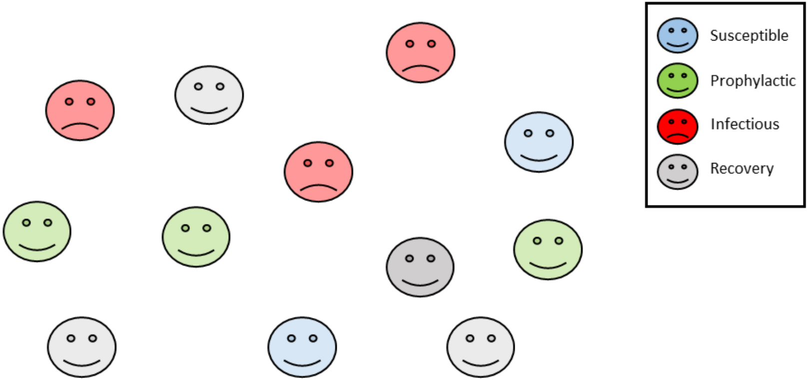
Disease Dynamics Model

Event 2: Recovery



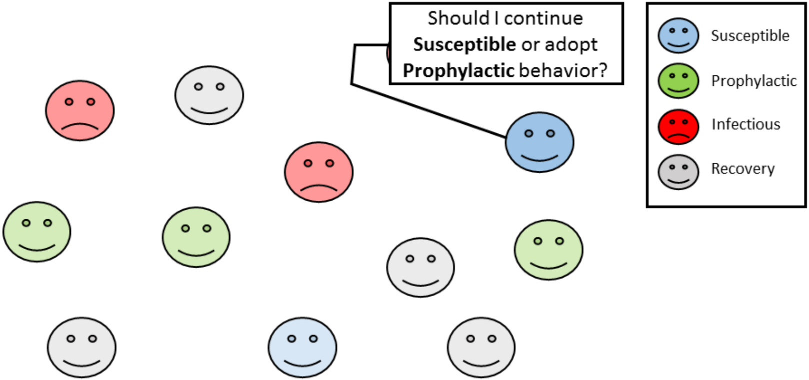
Disease Dynamics Model

Event 2: Recovery



Disease Dynamics Model

Event 3: Behavioral Decision

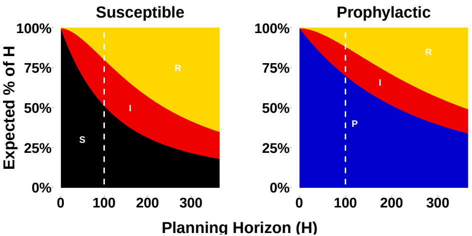


Behavioral Decision Model

- Agents use a **rational choice model** to decide whether to adopt Susceptible or Prophylactic behavior
- Agents adopt the behavior that has the **largest utility** over the **planning horizon H**
- Agents have **identical** and **complete knowledge** of the disease and its prevalence
- Agents assume the disease prevalence **remains at its current value** during the next H time steps

Behavioral Decision Model

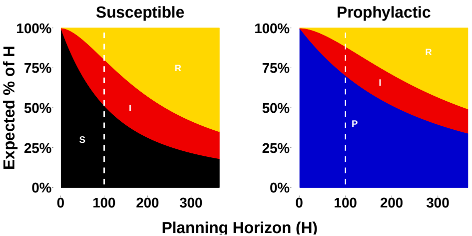
1. Expected Time



$T_S = 52, \quad T_I = 30, \quad T_R = 18 \qquad T_P = 70, \quad T_I = 19, \quad T_R = 11$

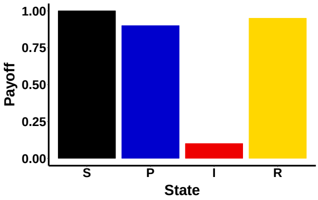
Behavioral Decision Model

1. Expected Time



$T_S = 52, \quad T_I = 30, \quad T_R = 18 \qquad T_P = 70, \quad T_I = 19, \quad T_R = 11$

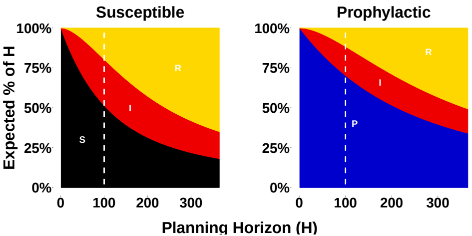
2. Payoff



Ex: $u_S = 1.0$, $u_P = 0.9$, $u_I = 0.1$, $u_R = 0.95$

Behavioral Decision Model

1. Expected Time



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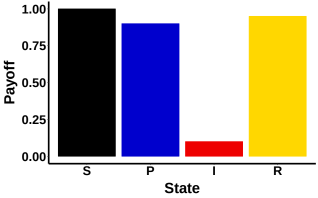

Ex: $u_S = 1.0$, $u_P = 0.9$, $u_I = 0.1$, $u_R = 0.95$

3. Utility Calculation

$$U_S = u_S T_S + u_I T_I + u_R T_R$$
$$U_P = u_P T_P + u_I T_I + u_R T_R$$

Ex:

$$U_S = 1.0 \times 52 + 0.1 \times 30 + 0.95 \times 18 = 72.1$$
$$U_P = 0.9 \times 70 + 0.1 \times 19 + 0.95 \times 11 = 75.35$$

Behavioral Decision Model

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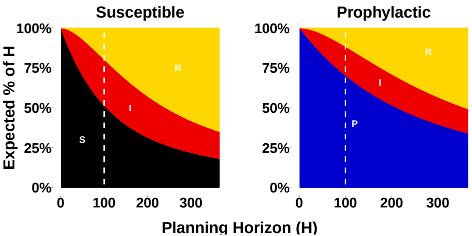

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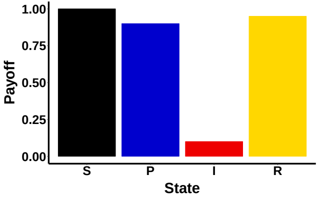

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4. Decision Making

$$\text{Decision} = \begin{cases} \text{Prophylactic} & \text{for } U_S < U_P \\ \text{Susceptible} & \text{otherwise.} \end{cases}$$

Ex: $(U_S = 72.1) < (U_P = 75.35)$

Decision = Prophylactic

Behavioral Decision Analysis

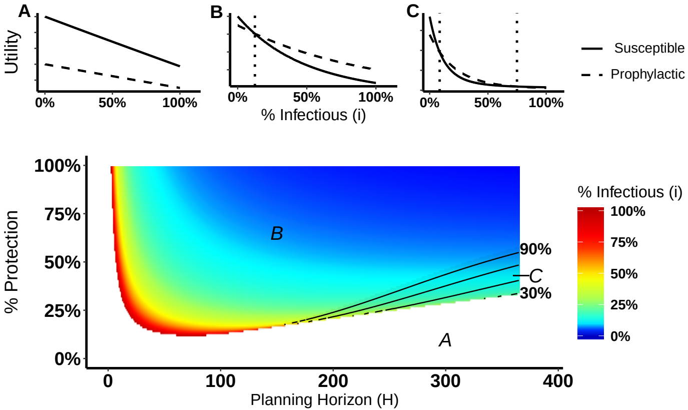
Switching Point

What is the **proportion of infectious agents** beyond which it would be **advantageous** for an agent to **switch** from Susceptible (i.e. non-prophylactic) to Prophylactic **behavior** or vice-versa?

Behavioral Decision Analysis

Switching Point

What is the **proportion of infectious agents** beyond which it would be **advantageous** for an agent to **switch** from Susceptible (i.e. non-prophylactic) to Prophylactic **behavior** or vice-versa?



Influence on Epidemic Dynamics

Research Question

How does **planning horizon** affect prophylactic decision-making and epidemic dynamics?

Influence on Epidemic Dynamics

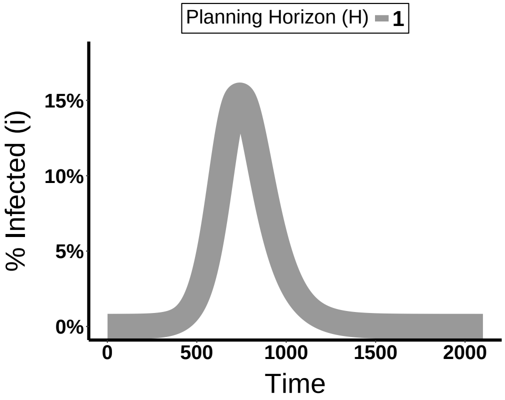
Research Question

How does **planning horizon** affect prophylactic decision-making and epidemic dynamics?

Table: Experiment simulation input parameters

Type	**Name**	**Value**
General	Number of Agents	100,000
Biological	b_S	0.031
	ρ	0.1
	g	0.015
Behavioral	d	0.01
	$\{u_S, u_P, u_I, u_R\}$	$\{1, 0.95, 0.1, 0.95\}$

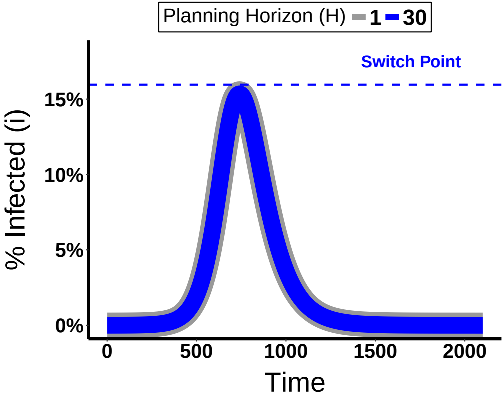
Influence of the Planning Horizon



Baseline

- Never consider adopting prophylactic behavior
- No impact on the epidemic dynamic

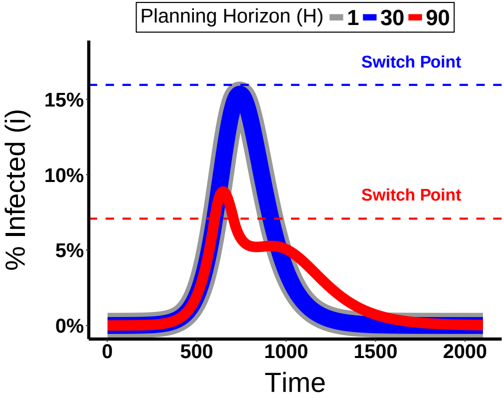
Influence of the Planning Horizon



Short

- Consider adopting prophylactic behavior
- Never adopt prophylactic behavior
- No impact on the epidemic dynamic

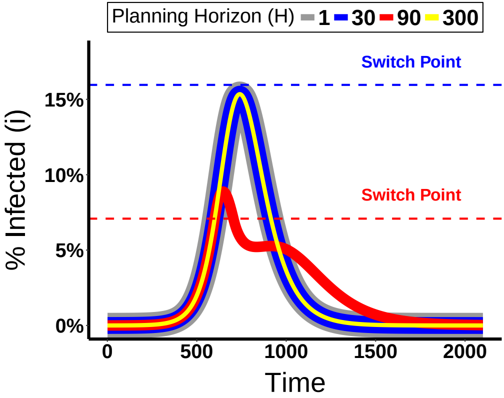
Influence of the Planning Horizon



Intermediate

- Adopt prophylactic behavior
- Impact on the epidemic dynamic

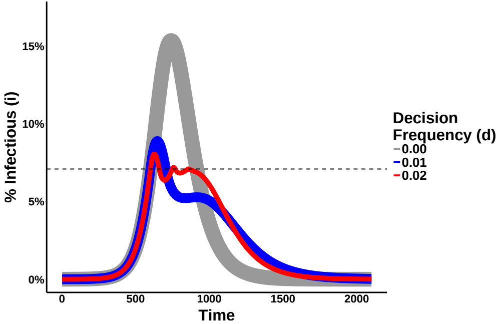
Influence of the Planning Horizon



Long

- Never consider adopting prophylactic behavior
- No impact on the epidemic dynamic
- "*Get it over with*"

Influence of the Decision Frequency



Increasing d

- Reduces the peak size
- Prolongs the epidemic
- Generates secondary infection waves

Conclusions

- Agents **do not engage** in prophylactic behavior for **short** and **long** planning horizons; for **intermediate** planning horizon agents adopt prophylactic behavior **depending on the disease parameters**.
- The adoption of prophylactic behavior **is not always monotonically** associated with the **prevalence of the disease**.
- Adoption of prophylactic behavior **reduces the epidemic peak size** while **prolonging the epidemic** and potentially **generates secondary waves** of infection.
- **Increasing decision frequency** makes the effects of adopting prophylactic behavior stronger.

Future Work

- Evaluate scenarios composed of **heterogeneous agents** (e.g., different risk perception, payoff structure, etc.) and different **topological structures** (e.g., scale-free network).
- Perform comparative studies with **different behavioral decision models**. For example, relax some of the assumptions of rationality.
- Incorporate **social influence aspects** into the behavioral decision model.

Thank you

Questions?

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