# Protective behaviour during an epidemic: Feedback between social and viral contagion

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# Model context

TELL ME: European funded project about communication during an epidemic

- Simulation is one of the outputs
- Other partners developing communication kit

Help health agencies plan communication

- enter details of epidemic scenario
  - severity, vaccine delay, hand washing efficacy etc
- try out communication plans
  - packages of messages
- compare the effect of the communication package on epidemic size

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# Broad model logic

Abstract model to examine the interaction between protective behaviour and epidemic

- Simplified version of TELL ME model
  - all communication removed

Two component models with mutual feedback:

- Spatially explicit difference equations for viral contagion
- Agent based model for protective decision making
  - Includes social contagion of behaviour as norms is part of decision
- Feedback process: protective behaviour → epidemic spread → threat perception → protective behaviour

# Two component models (detail)

Difference equations to run epidemic

- SIR compartment model
  - counts for each disease state
- Each location / patch runs own SIR counts
  - Some travel
- Infectivity reduced where protective behaviour adopted

ABM: agents adopt/drop protective behaviour if weighted average of three factors above/below threshold

- Attitude: uniform [0,1] distribution
- Norms: proportion of visible agents with behaviour
- Threat: discounted cumulative visible incidence

Heterogeneity:

- Attitude within location
- Norms / Threat location specific

# Automatic control of epidemics

Ideal world:

- Norms exaggerate response to threat, so that protective behaviour ‘gets ahead’ of the epidemic front and contains the disease
- After the epidemic ends, protective behaviour stops

Objective:

- Is there a suitable combination of behaviour input parameters to allow this ‘automatic’ control?
  - Weights, incidence discount, threshold for adoption
- If so, how large (in parameter space) is the suitable combination?
  - Is it easy to find, so intervention not required?

# Experimental Design – full parameter space

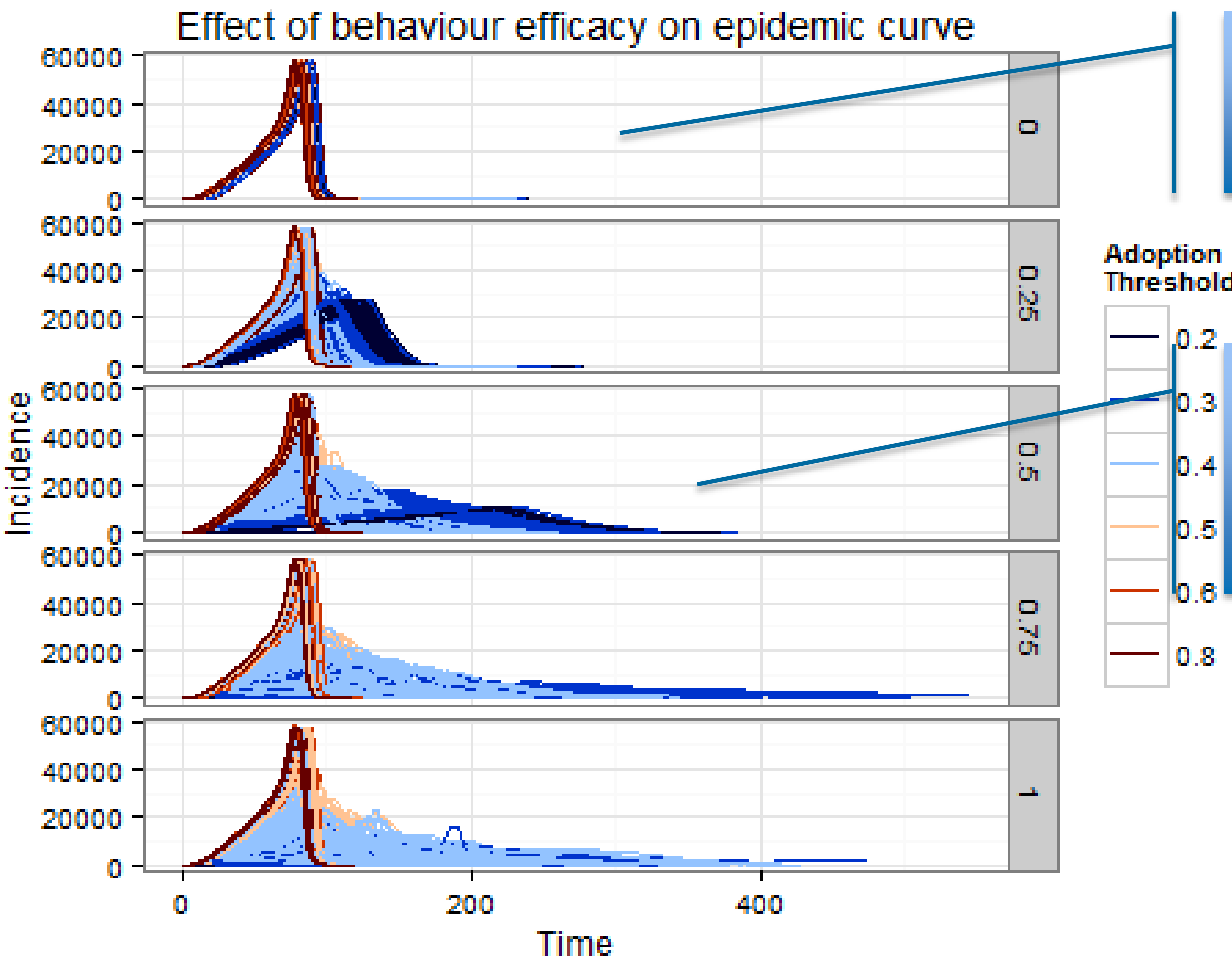
Approach: Simulations that focus on interesting parameter space
- Thresholds
- Weights and incidence discount

39 combinations of weights:
- Weights for norms, threat and attitude sum to 1
- Norms and Threat weights in range [0.2, 0.5] by 0.05
- Attitude weight in range [0.2, 0.6]

For each set of weights, 120 sets of other parameters
- Threshold in {0.2, 0.3, 0.4, 0.5, 0.6, 0.8}
- Efficacy in {0, 0.25, 0.5, 0.75, 1}
- Discount for cumulative incidence in {0.02, 0.04, 0.08, 0.12}

Single run for each parameter combination (work in progress)
- $R_0$ = 4 to ensure epidemic
- recovery period 5 ticks, 30% travel transmission with 85% in neighbours

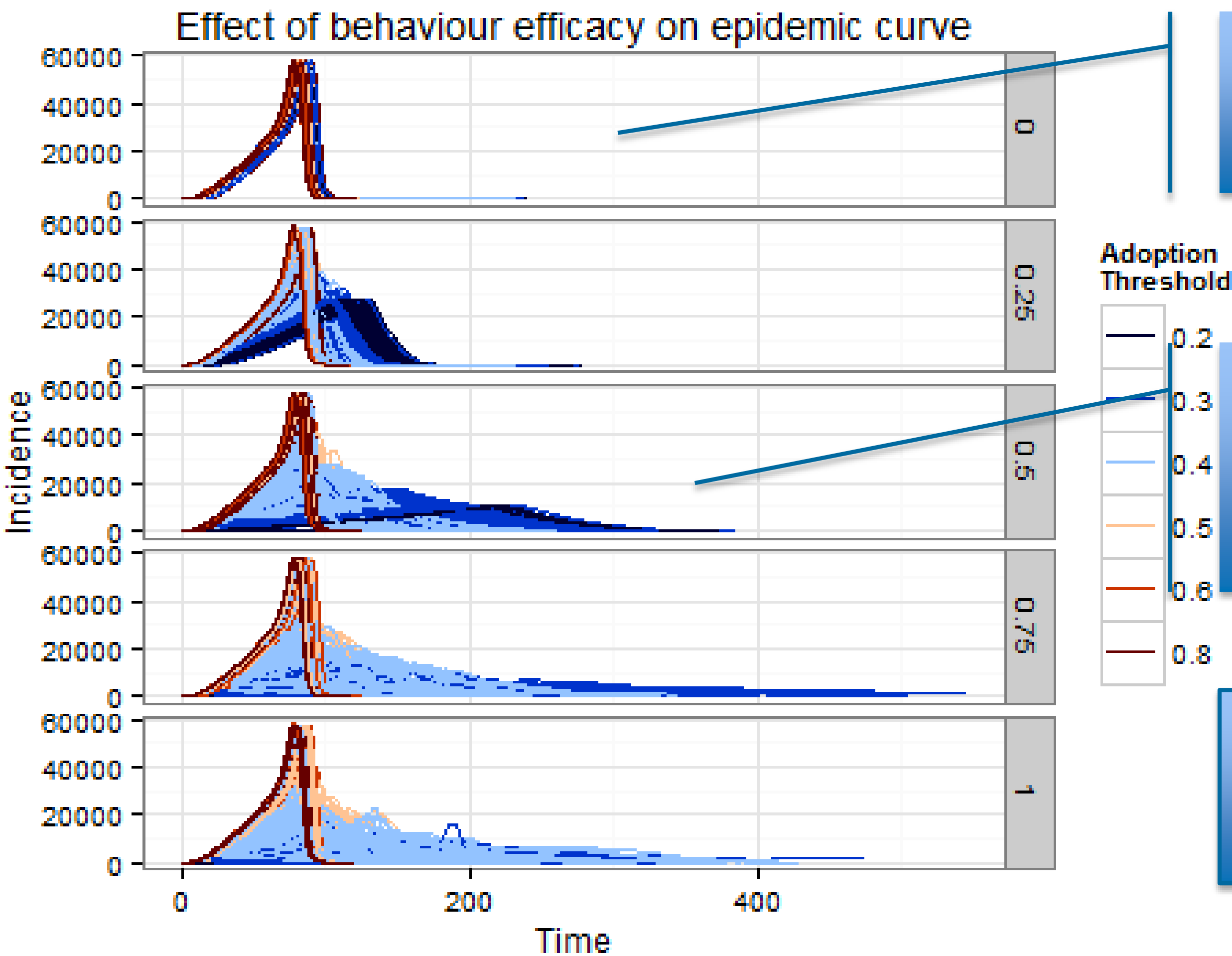
# Protective decisions can influence epidemic




Individuals respond, but behaviour useless so epidemic has natural curve

As behaviour more efficacious, adoption leads to delay in epidemic peak and reduction in its size.

# Protective decisions can influence epidemic

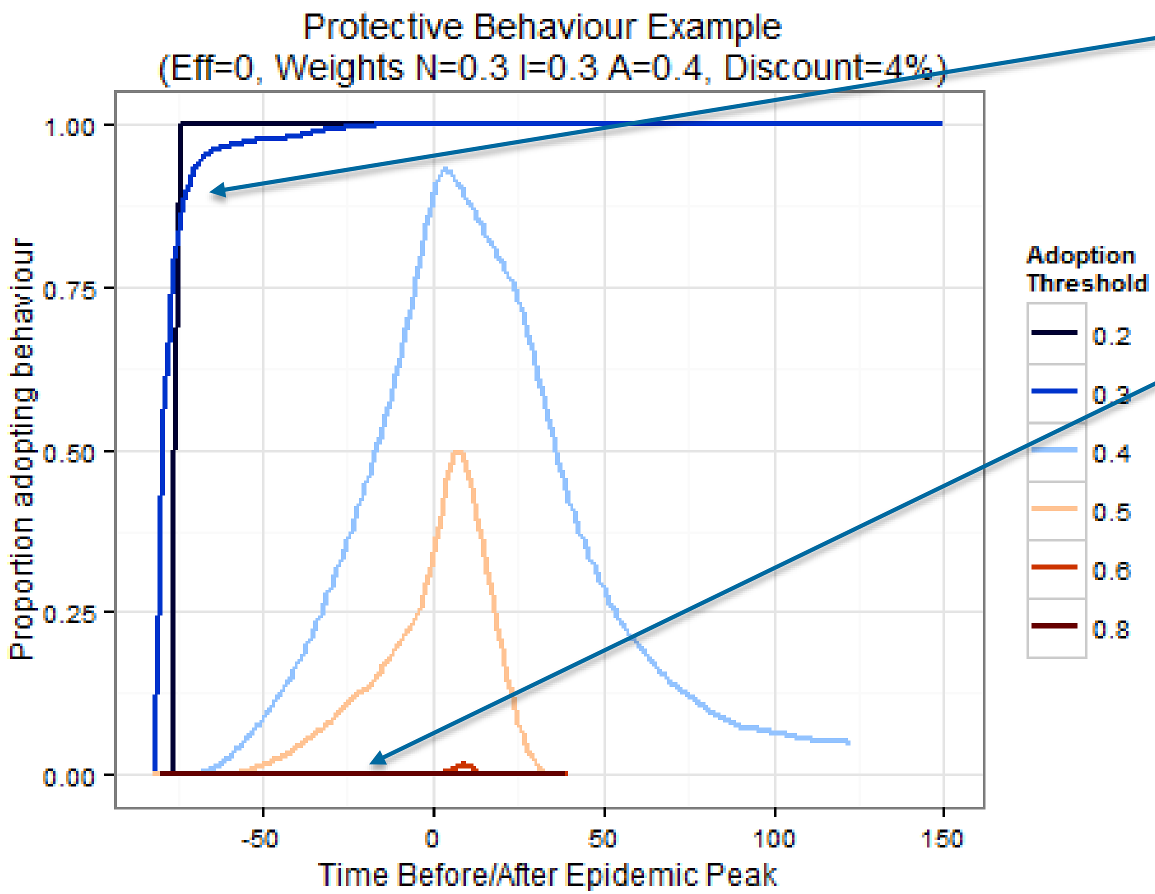



Individuals respond, but behaviour useless so epidemic has natural curve

As behaviour more efficacious, adoption leads to delay in epidemic peak and reduction in its size.

Hence, reasonable to expect suitable parameters would assist epidemic control

# Three types of behaviour responses to epidemic




Behaviour adopted, but maintained indefinitely

Behaviour never adopted, so unable to control epidemic

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# Three types of behaviour responses to epidemic

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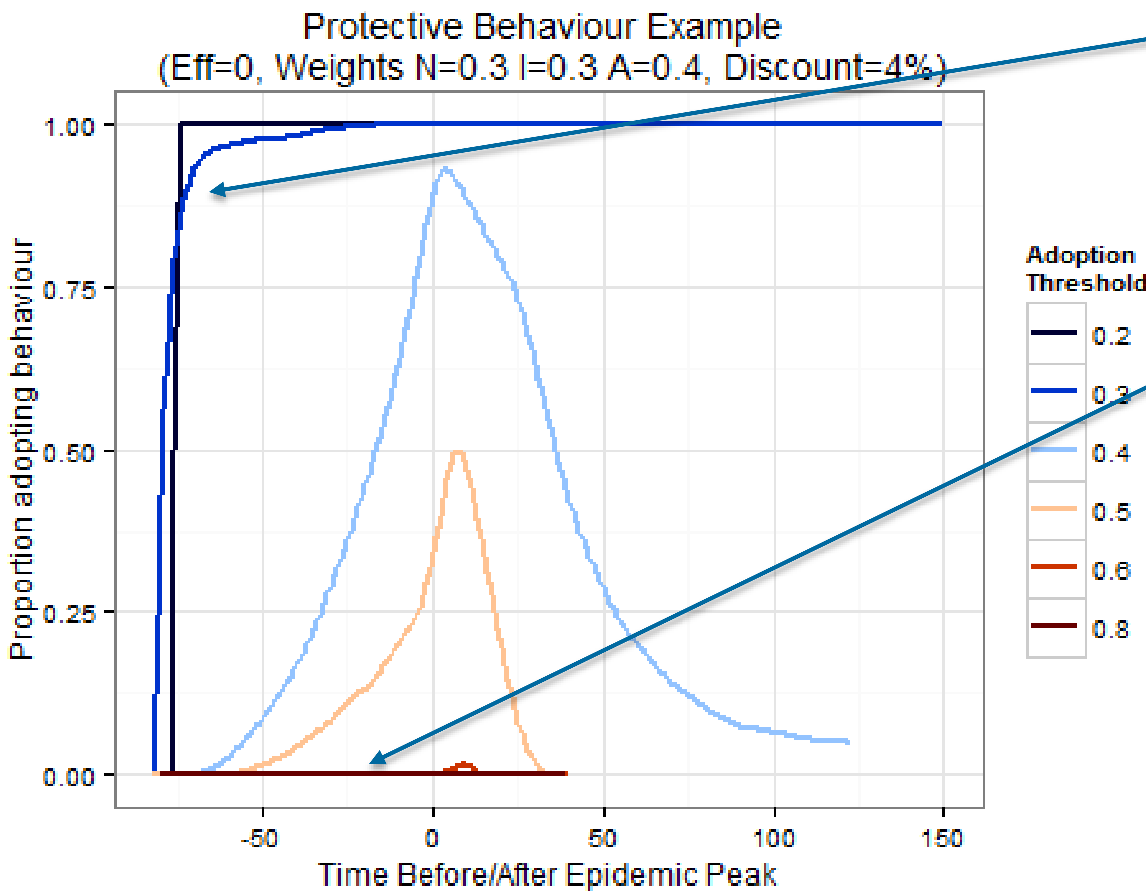


Behaviour adopted, but maintained indefinitely

Behaviour never adopted, so unable to control epidemic

Need thresholds where behaviour responds but then abandoned

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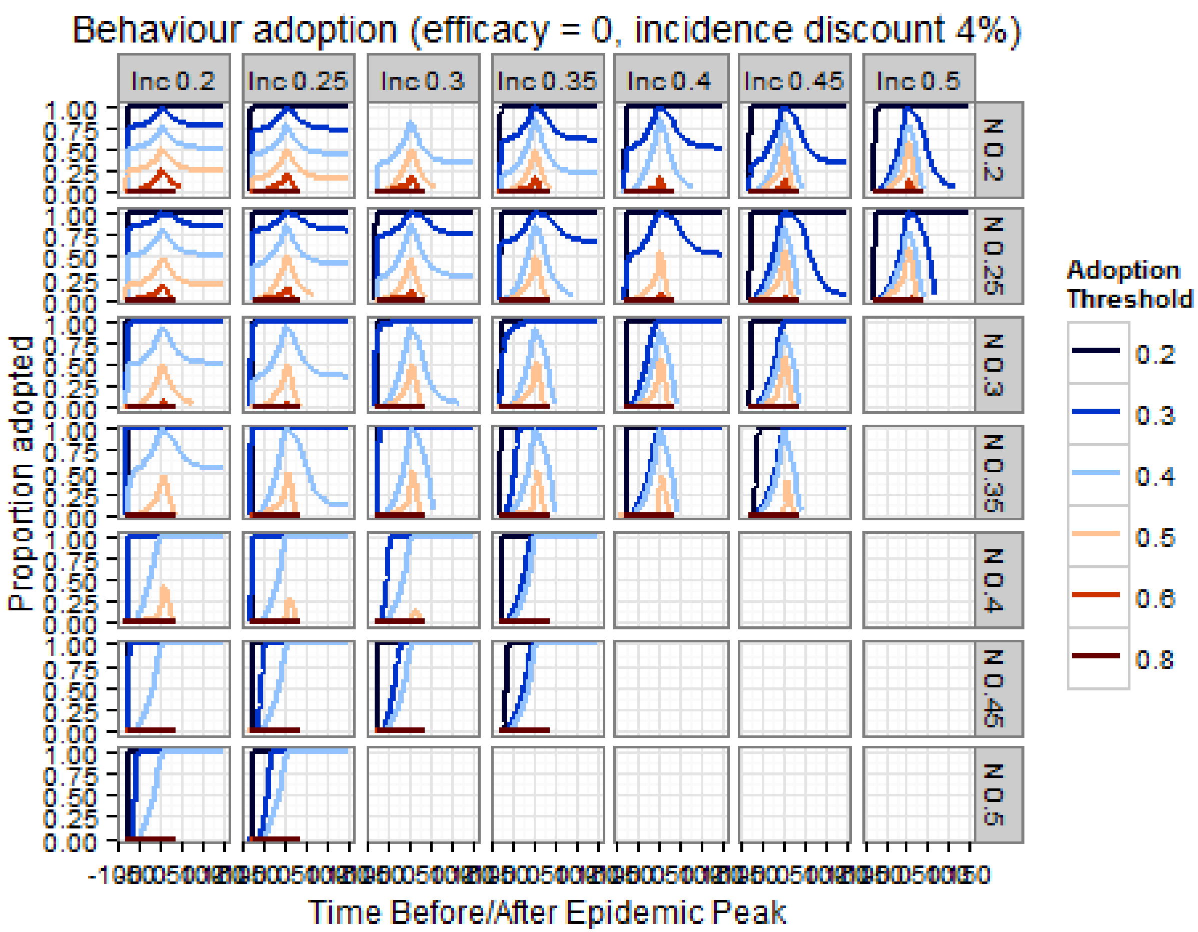
# Adoption threshold: full parameter space

Note: Assumes uptake and drop behaviour at same threshold value

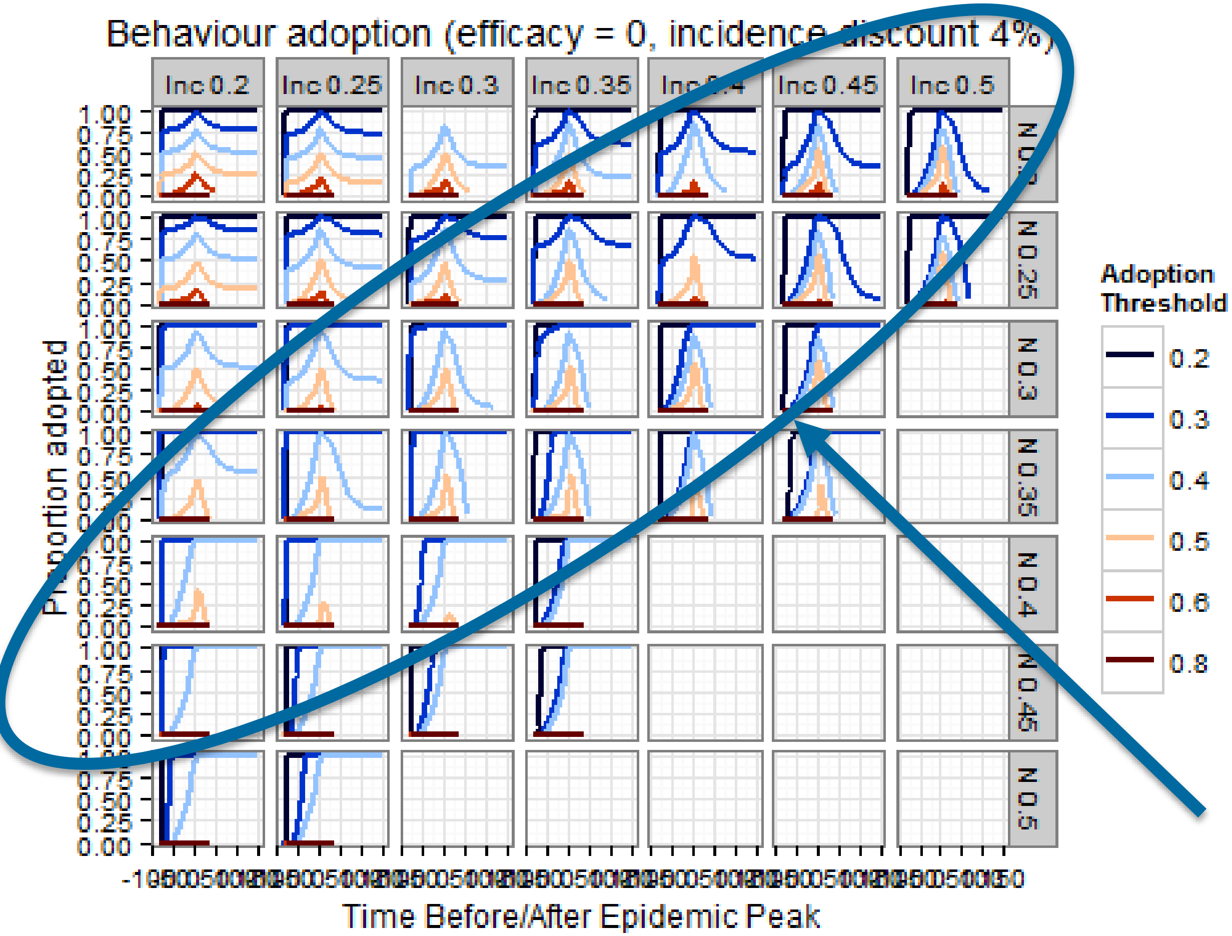



Only mid range threshold values show behaviour being adopted and then dropped:

- Low threshold (≤0.3, darker blue) and behaviour maintained
- High threshold (≥0.6, darker red) and behaviour never adopted

# Adoption threshold: full parameter space

Note: Assumes uptake and drop behaviour at same threshold value




Only mid range threshold values show behaviour being adopted and then dropped:

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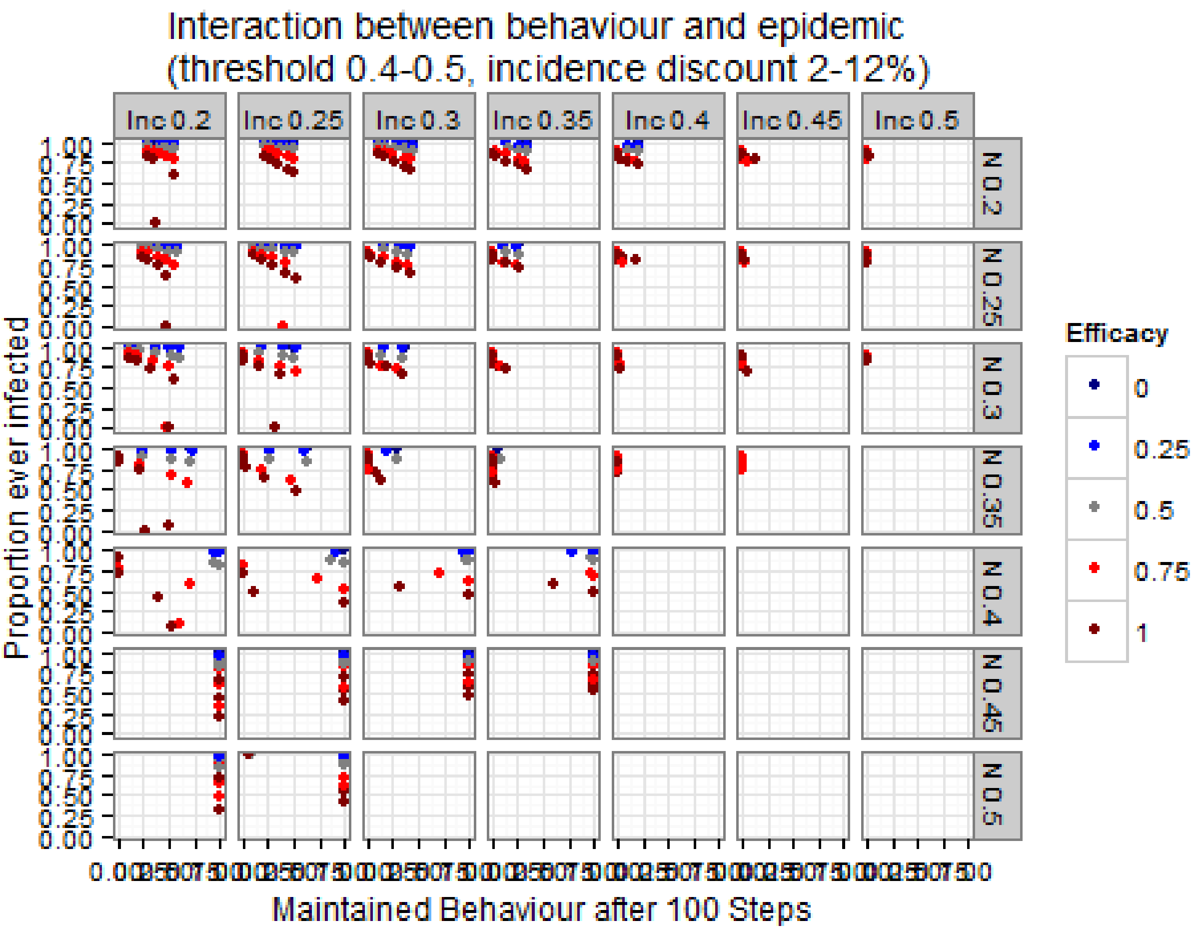
Only applies to subset of weight combinations

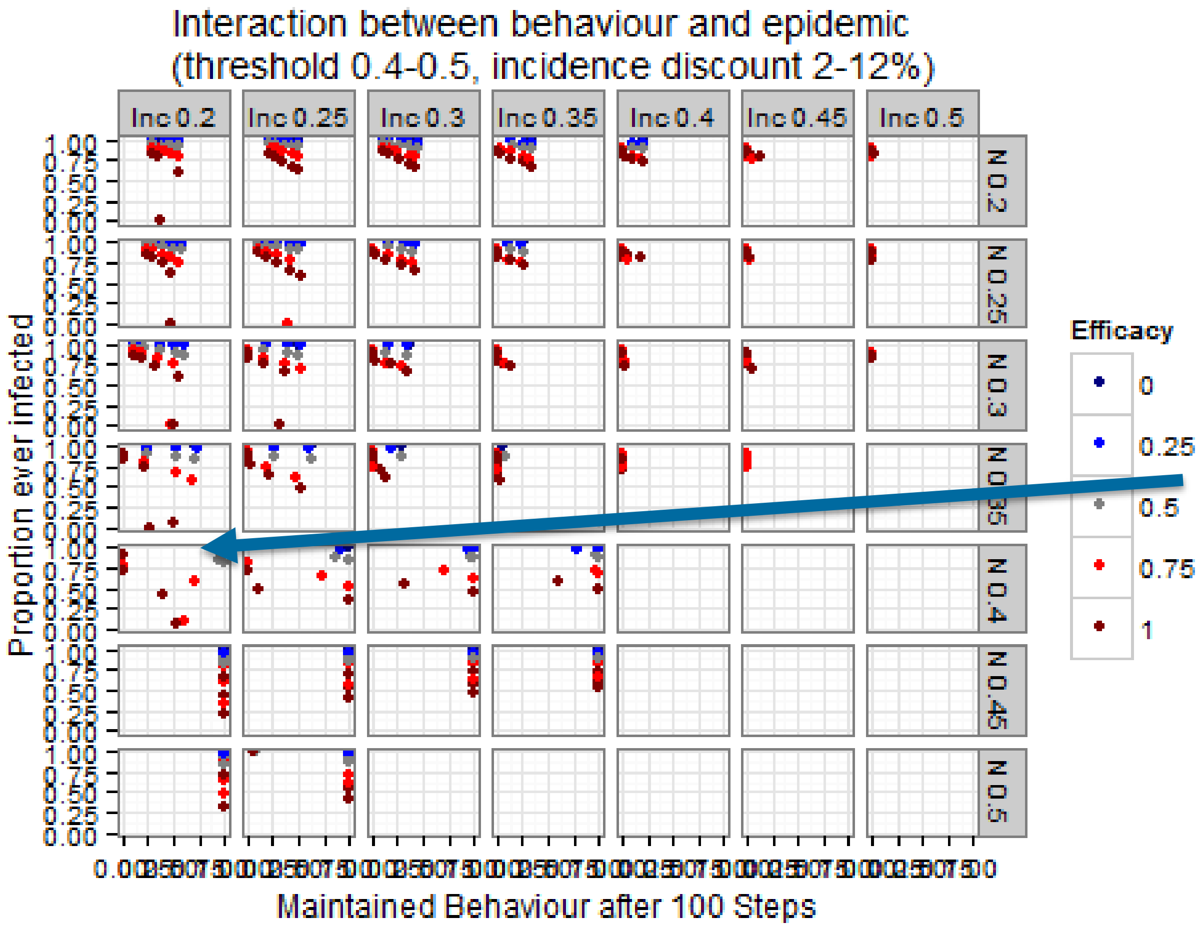
# Focus on relevant weight combinations




Want bottom left corner:

- Bottom is small epidemic
- Left is behaviour dropped after peak

# Focus on relevant weight combinations

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- Bottom is small epidemic
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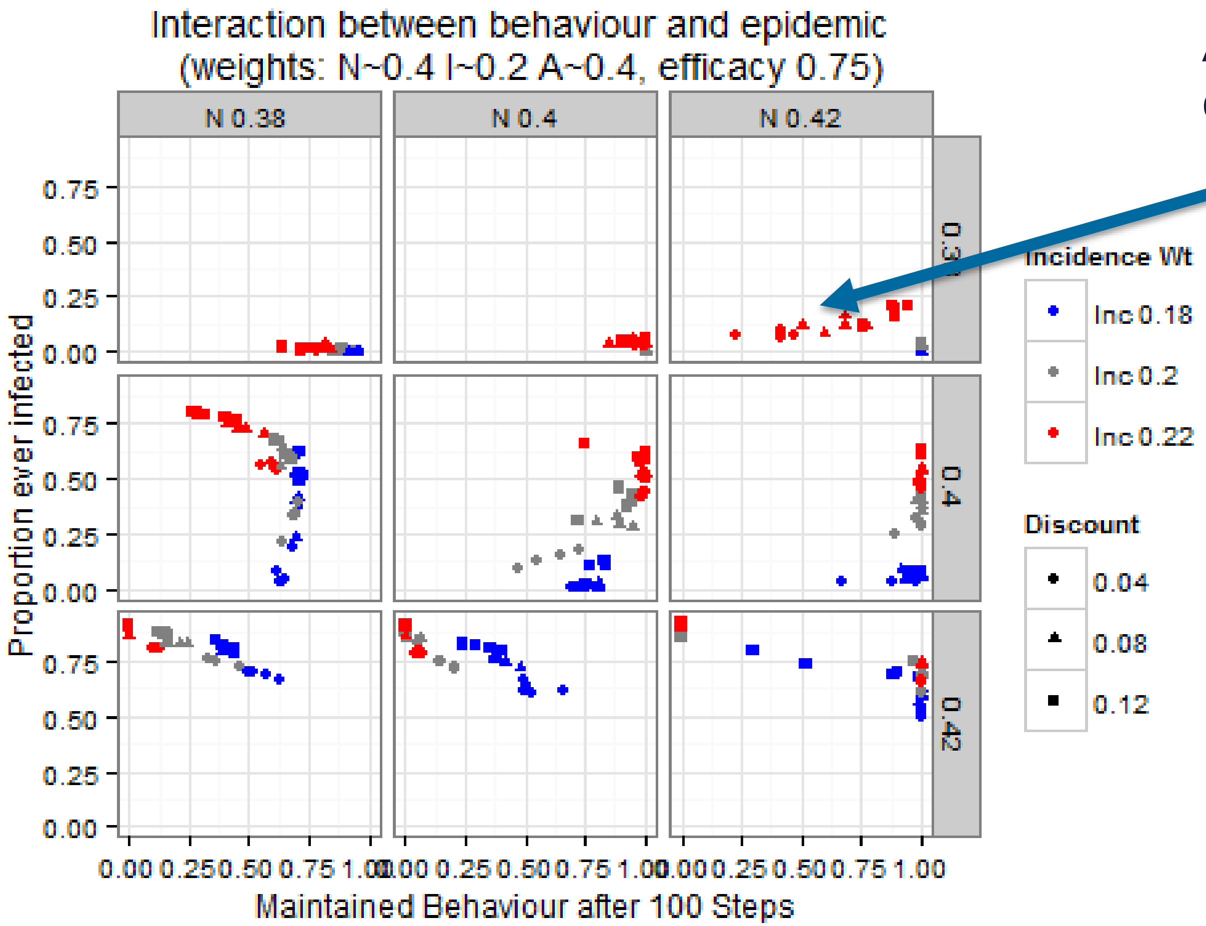
Limited feasible parameter space:

- Norms weight ~0.4
- Incidence (threat) weight ~0.2
- Attitude weight ~0.4

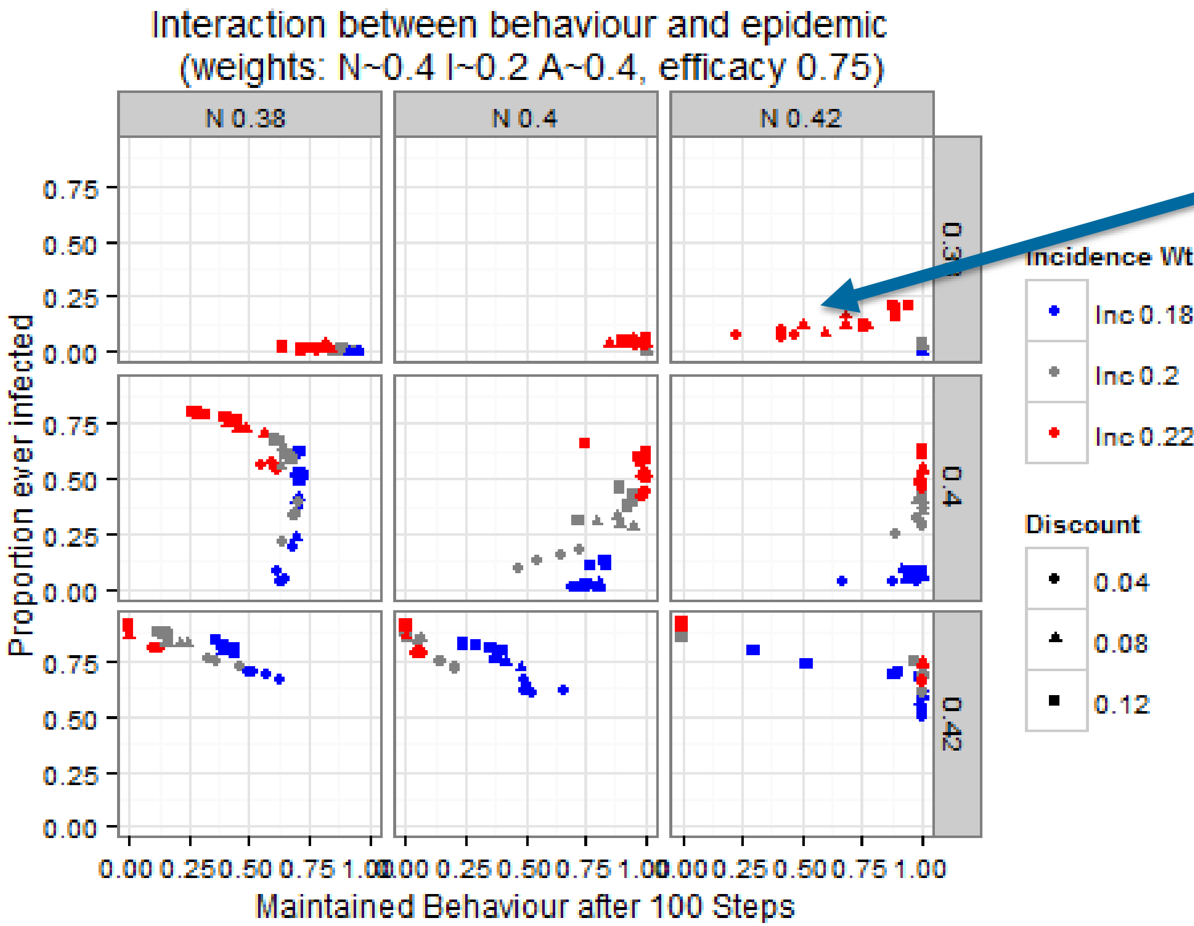
# Multiple simulations in feasible space




Again, want bottom left corner.

- Some apparent solutions

# Multiple simulations in feasible space




Again, want bottom left corner.

- Some apparent solutions

BUT: behaviour isn't being dropped:

- Epidemic controlled quickly
- Part of population never adopts behaviour

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# Conclusions: Problem

No parameter set appears to allow automatic control of epidemic:

- Need relatively high weight for norms in behaviour decision so that behaviour adopted ahead of epidemic
- But behaviour then maintained despite end of epidemic

Social and psychological processes reinforce behaviour

- System behaviour here is an example of the 'Social amplification of risk'
  - Kasperson et al (1988). "The social amplification of risk: A conceptual framework". *Risk Analysis*, 8, 177-187.
- Norms attenuate risk perception early in epidemic
  - Other people aren't worried, so I must be over-reacting
- Norms amplify risk perception post epidemic
  - Other people are still …, so I should

# Conclusions: Potential solutions

Model 'correct' → Communication essential
- Authoritative recommendations
- Triggers adoption and abandonment

Model structure for behaviour decision incorrect?
- Weighted average is simplest implementation of various psychological models of cognitive behaviour
- Could reduce norms weight over time
  - Difficult to justify

Perception of decision making agents incorrect?
- Currently 'see' average threat and behaviour in 3 patch distance
- Could see maximum threat and average behaviour (for example)