Why we need to account for human behavior and decision-making to effectively model the non-linear dynamics of livestock disease

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Harnessing complexity to solve problems.

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THE UNIVERSITY OF VERMONT
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Introduction

- Livestock disease in the U.S. results in significant animal welfare issues and economic loses in the billions every year.
- Epidemiological and disease models used to understand the spread and impact of disease rarely incorporate prevention-related human behavior or decision-making.
- Porcine Epidemic Diarrhea virus (PEDv), a coronavirus which serves as our primary example, was first detected in the U.S. in May 2013.

Overarching Hypothesis

Human behavior and decision-making can alter the trajectory of a disease incursion, significantly influencing livestock health and economic consequences.

Methods

- We used experimental simulation games, surveys and workshops to gather data on human decision-making behavior in response to simulated disease outbreak scenarios.
- We developed an agent-based model (ABM) using industry supply chain data as well as aforementioned behavioral. The ABM used an underlying susceptible-infected-susceptible epidemiological model (because of swine turnover, a resistant or recovered population is not realistic).

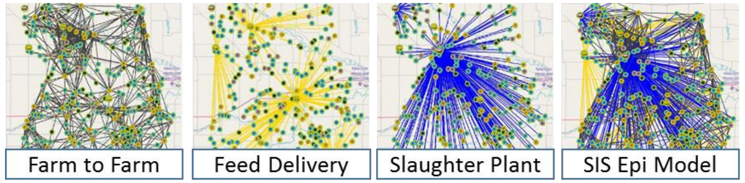

Figure 1. The ABM used autonomous agents acting in a networked supply chain and was parameterized using industry data from the USDA, industry-provided supply chain data, and human behavioral data. Disease spread was simulated using a Susceptible-Infected-Susceptible epidemiological model. Human behavior characteristics were added into the model structure and influenced the probability of disease transfer [1,2].

USDA United States Department of Agriculture

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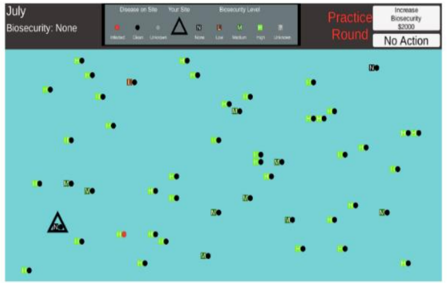

Figure 2. A screen grab of an experimental game designed to collect data on the willingness to invest in preventative health tactics [3,4].

Figure 3. A screen grab of an experimental simulation game designed to collect data on the willingness to follow animal health protection rules to prevent disease incursions [5,6].

Results

- Experimental game results:
  - Risk messages increase in efficacy from poor efficacy using numbers to good efficacy using of graphical displays or infographics (Figure 5) [5].
  - Disease incidence reporting should be encouraged, yet reporting of the prevalence and location of preventative tactics used by the industry should be limited [4].
- Experimental game-derived data allowed for ABM parameterization of the following factors:
  - Categories of risk aversion behavior were used to describe willingness to respond to disease incidence reporting (Figure 6) [3].
  - Learning trends were incorporated that described shifts in individual tactic implementation. Some individuals used a consistent strategy while others switched or learned new strategies (Figure 7).
  - Psychological discounting or incorporating decreased compliance with rules as time increased since an incidence or animal health tactic upgrade or refresher.
- Using the ABM, we demonstrate that changes in communication strategy can result in substantial outbreaks or disease suppression (Figure 8) [1].

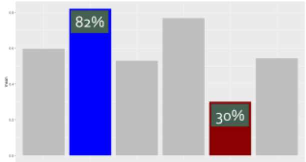

Figure 5. Communication strategies can double or triple willingness to follow rules in the same disease risk environment.

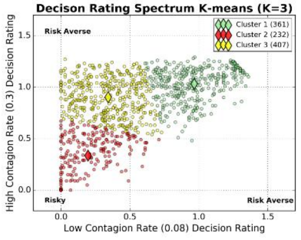

Figure 6. Behavior categorization on a risk aversion spectrum with three clusters of behavior

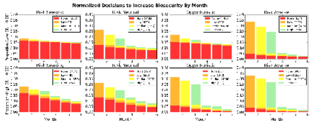

Figure 7. The ABM included heterogeneous strategy switching behavior to incorporate the change in willingness to invest in preventive tactics that was quantified using experimental game data.

Conclusions

- Epidemiological models are unable to capture the reduction in PEDv incidence without incorporating human behavioral responses.
- Behavior and decision-making is *the* critical component for disease modeling
- Risk communication strategy can dramatically influence willingness to practice and invest in disease prevention tactics, with effects shaping the impact of the disease outbreak severity.

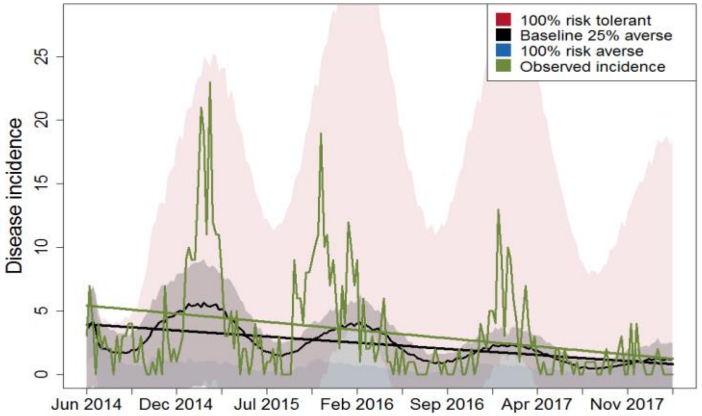

Figure 8. PEDv occurrence (green) decreases over time (green trend line) which can only be matched by a model that incorporates a human response (Black trend line and well-fit model predictions) (Bucini et al. Forthcoming). Switching communication strategy can shift outbreaks from pandemic level (pink shading depicts model runs with risk tolerant populations) to quickly suppressed (Risk averse populations quickly shut down disease outbreaks).

References

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