# The Interplay between Influenza Epidemiology and Vaccination Behavior: An Inductive Reasoning Game approach with Social Networks

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## Introduction

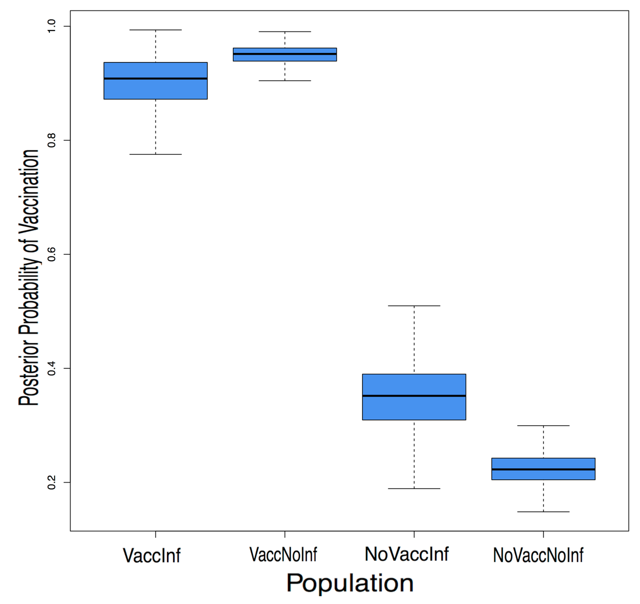
The decision to seek influenza vaccination depends upon perceptions related to the risks and benefits of the vaccine, the seriousness of influenza and transmission risk. Such perceptions and their formation depend on

1. **Personal** past experiences with influenza and its vaccine.
2. **Local** observations and influences in ones social network (SN): e.g., infection cases, vaccination uptake and immunity.
3. **Global** effects such as media feedbacks regarding the severity of the influenza in the population and general vaccination uptake.

Understanding the complex interplay between perceptions formation, SN influences and influenza epidemiology is critical to informing effective policies to increase vaccination.

## Behavioral Model (BM)

We conducted a survey to learn about perceptions of influenza and its vaccine.

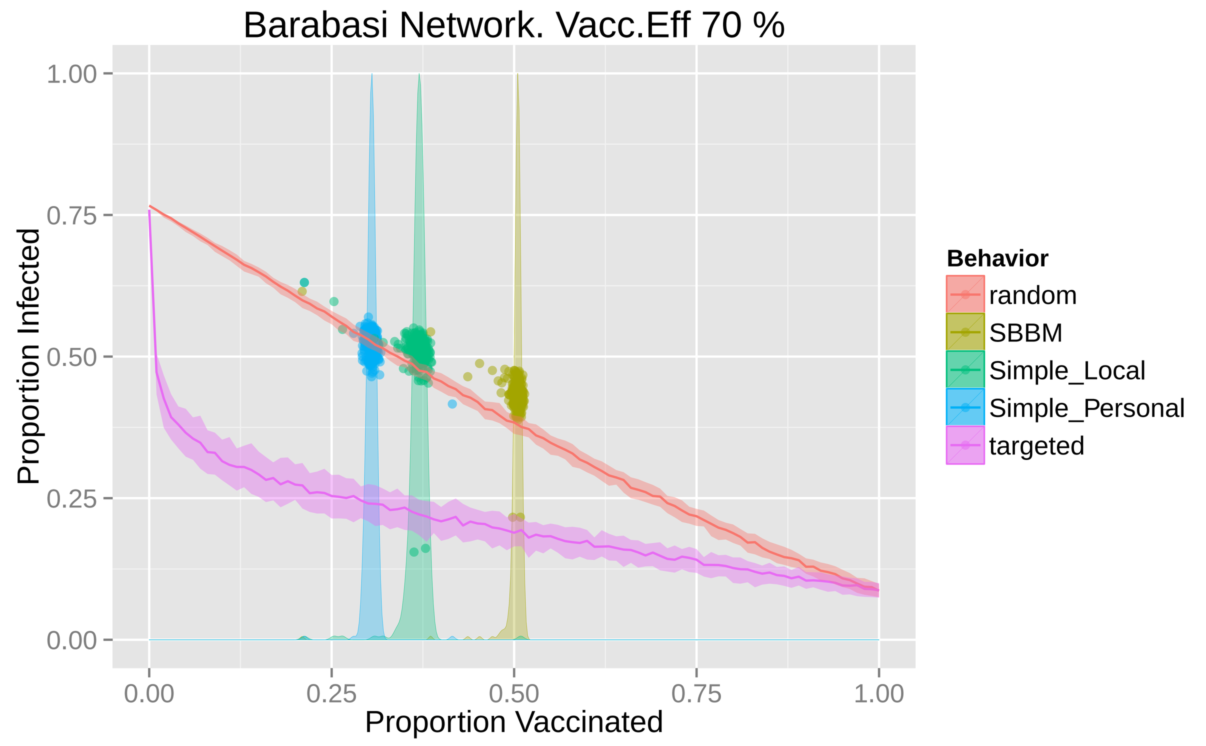


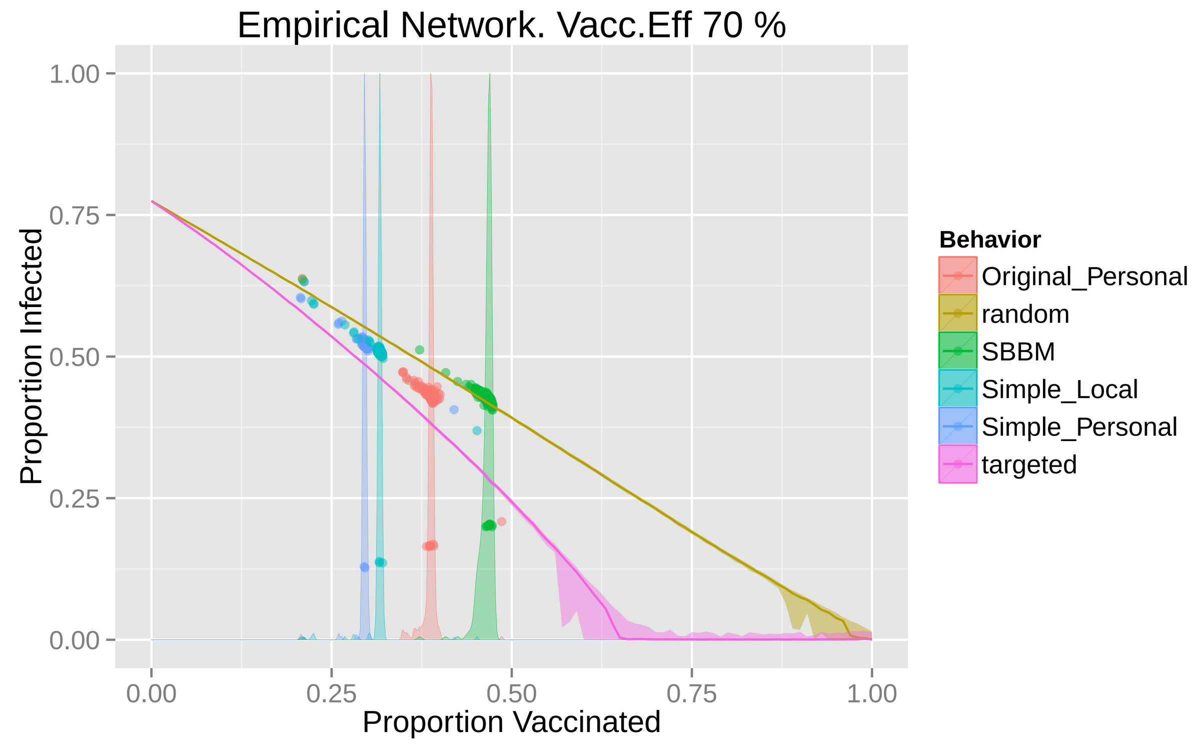

We used our survey to parametrize our suvey-based BM (SBBM) describing how agents learn and weight information. *E.g., weights:*

| | Personal | Local.Inf | Local.Vacc | Global.Inf | Global.Vacc |
|---|---|---|---|---|---|
| VaccInf | 0.96 | 0.01 | 0.01 | 0.01 | 0.01 |
| VaccNoInf | 0.94 | 0.01 | 0.01 | 0.00 | 0.03 |
| NoVaccInf | 0.05 | 0.17 | 0.13 | 0.34 | 0.31 |
| NoVaccNoInf | 0.16 | 0.23 | 0.23 | 0.18 | 0.20 |

We also considered additional conceptualized BMs where agents are more likely to take advantage of perceived *herd immunity* in the SN.

## Results: Incidence and Vaccination Coverage




Plots show the proportion infected ($q(p)$) for different values of proportion vaccinated ($p$) for the BA and the empirical SNs using 70% vaccine efficacy over the course of 300 sequential influenza seasons. The random and targeted curves provide guidance of the effects of vaccinating randomly and preferentially for a given coverage $p$.

If the SN is scale-free (i.e., BA) then the BMs do not do better at reducing incidence than random vaccination and we could never approach the ideal situation (targeted vaccination). If SN is organized in any of the other structure (including our empirical SN), the behavioral models tend to matter and we can do better than random in most cases.

## Approach

We constructed an agent-based model (ABM) for the dynamics of seasonal influenza, where our agents continually adapt to influenza-related experiences using inductive thought to re-evaluate whether or not they should get vaccinated.

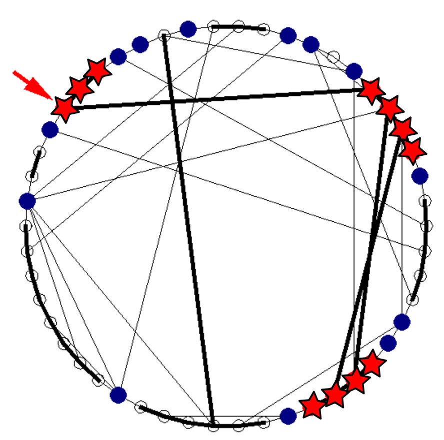
*Their decisions to obtain vaccination changes influenza epidemiology, which in turn, modifies their behavior to seek vaccination.*

Our agents interact over a SN which influences how behavior spreads and provides preferential paths for influenza transmission.

We used our ABM to explore the dynamic interplay between vaccination behavior, influenza epidemiology and the SN stucture.

## Flu Transmission Model

We used an SIR model over the underlying SN that considers both site and bond percolation.



We considered $N \sim 10^5$ using Erdős-Rényi, Small-World and Barabási-Albert (BA) graphs and an empirically fitted SN of Santa Monica.

Agents that vaccinate become immune according to the vaccine's efficacy (blue nodes). Other agents remain susceptible to infection.

Probability of Transmission $T$ is computed from the $R_0$ value which determines the active bonds (bold lines) and who gets infected (red nodes).

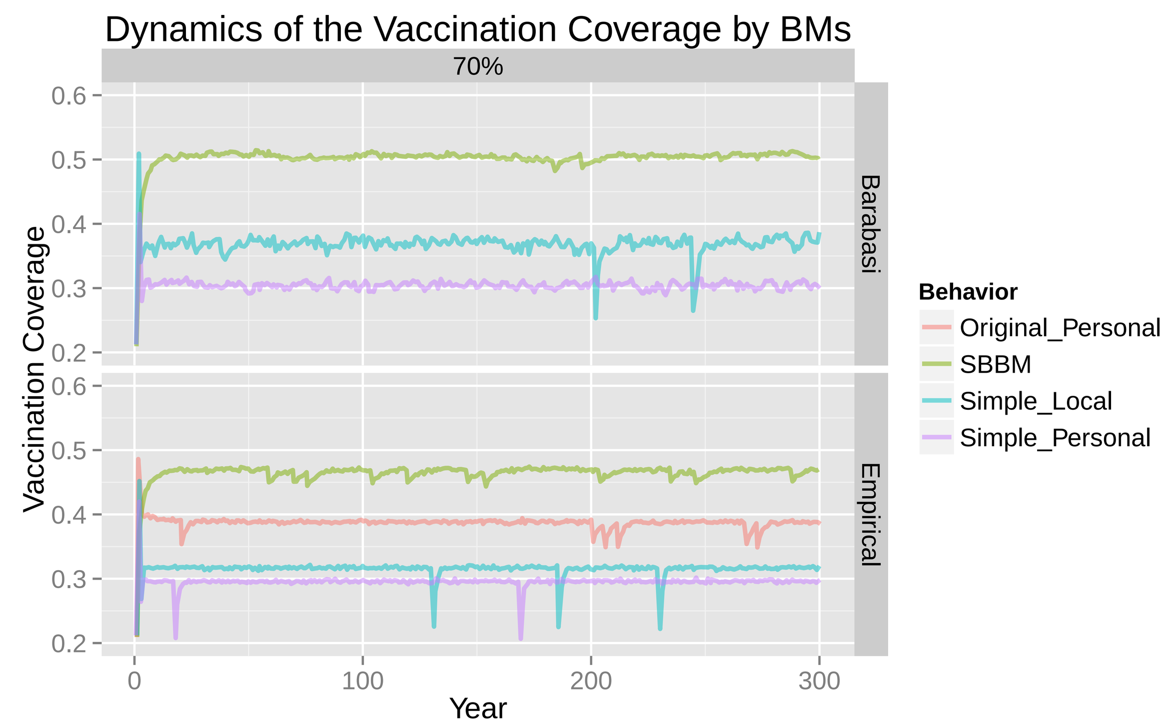
## Adaptation and Clustering

Odds-ratios comparing the probability of non-vaccinated (S) and vaccinated (V) individuals being connected to similiarly non-vaccinated and vaccinated nearest neighbors, respectively, relative to a baseline provided by the random vaccination.

| SN | BM | SS/SV | VV/VS |
|---|---|---|---|
| Barabasi | Simple_Personal | 0.738 | 1.38 |
| Barabasi | SBBM | 0.878 | 1.16 |
| Empirical | Simple_Personal | 1.01 | 1.24 |
| Empirical | SBBM | 0.989 | 1.06 |

The results reveal that non-vaccinators are less likely to cluster together and that vaccinators are more likely to cluster together. This is very significant in the case of BMs that assume agents strongly seek to take advantage of *herd-immunity*.

## Coverage Dynamics




As found by our previous models, large decreases in vaccination coverages are still observed in BMs that assume fast adaptation. This is less pronounced for the case of our SBBM.

## References

[1] R. Vardavas and C.S. Marcum Chapter in the Book Titled: *Modeling the Interplay between Human Behavior and the Spread of Infectious Diseases*. Springer Series on Behavioral Epidemiology, 2013

[2] Parker AM, Vardavas R, Marcum CS, Gidengil CA. Conscious consideration of herd immunity in influenza vaccination decisions. Am J Prev Med. 2013 Jul;45(1):118-21.

## Conclusion

Our results indicate a strong inteplay between the structure of SNs and the learning and adaptation process of individuals' vaccination behavior. Within the empirical network, many BMs are able to approach the targeted intervention, suggesting that the population could realize good coverage while keeping vaccination voultary. Policies based on incentives could facilitate these.

## Other Related Work

We have also worked on modeling the interplay between SNs, risk perceptions and health outcomes for Breast Cancer.

We are submitting an RO1 proposal to NIAID to extend this research work. We are also submitting a proposal to NSF that uses a similar approach to model Tax Evasion.