

## Chapter 5.11

# Projecting Health Care Factors into Future Outcomes with Agent-Based Modeling

**Georgiy Bobashev**  
*RTI International, Russia*

**Andrei Borshchev**  
*XJ Technologies, Russia*

### ABSTRACT

Human behavior is dynamic; it changes and adapts. In this chapter, we describe modeling approaches that consider human behavior as it relates to health care. We present examples that demonstrate how accounting for the social network structure changes the dynamics of infectious disease, how social hierarchy affects the chances of getting HIV, how the use of low dead-space syringe reduces the risk of HIV transmission, and how emergency departments could function more efficiently when real-time activities are simulated. The examples we use build from simple to more complex models and illustrate how agent-based modeling opens new horizons for providing descriptions of complex phenomena that were not possible with traditional statistical or even system dynamics methods. Agent-based modeling

can use behavioral data from a cross-sectional representative study and project the behavior into the future so that the risks can be studied in a dynamical/temporal sense, thus combining the advantages of representative cross-sectional and longitudinal studies for the price of increased uncertainty. The authors also discuss data needs and potential future applications for this method.

### INTRODUCTION

#### Risk Factors and Predicted Dynamic Risks

Predicting the future of health outcomes is always a challenge. Almost all specific health outcomes can depend on hard-to-predict factors. For example, the number of new influenza cases in a town depends on the random contacts among its residents. At the

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same time, some stable causal dependencies can provide robust background for ballpark estimates, qualitative analysis, and often quantitative assessment of relative risks. In the same example, children at school have a much higher chance of getting the flu than a single adult working on a construction site. The challenge of modeling is to differentiate between the actual critical factors that shape the outcome and the uncertainty surrounding the prediction. In a few instances it is possible to combine the two approaches (Bobashev et al., 2000) so that a mathematical model part captures the robust dynamics and a statistical part accounts for the unexplained variation.

Naturally, modeling strategy depends on the objectives. Beyond that, a clear understanding of the scales on which the outcome resides drives the modeling approach such as system dynamics, agent-based, process (Colizza, 2007 Riley, 2007).

Often global patterns and relationships are the results of the interactions of many local behaviors and decisions (Epstein, 2007). Thus, the description of these local factors becomes critical for understanding how interventions should be structured and which sub-population is the most responsive to an intervention.

Stable and reliable global patterns of the spread of communicable disease could arise dynamically from local and seemingly unpredictable behavior; for example, random network contacts could lead to exponential growth of HIV prevalence. Thus, the studies of local behavior and contact structure could be critical for the description of global outcomes.

In order to project the outcome into the future, one usually needs the following:

- A clear definition of the initial outcome values and risk factors (i.e., the values of the outcomes at the starting (initial) time point. For example, an individual at the baseline could be either HIV positive or negative;
- A description of the actions that individuals may take in the future (e.g., attending a ball game during a flu epidemic season);
- The collection of factors determining the actions, which could relate to a number of independent variables as well as the past actions or past states simultaneously (e.g., mixing matrices, which probabilistically describe a choice of a sexual partner, reflect that individuals are more likely to seek partners with some similar and dissimilar qualities to themselves so that, as some studies have shown, individuals who have many sexual partners are likely to have sex with those who themselves have many sexual partners [Turner et al., 2006]); and
- The translator of the behaviors into the outcomes (e.g., HIV is transmitted per direct syringe-sharing with a certain probability, which is lower if the syringe is rinsed in bleach).

Simulation models put the ingredients together and, by iterating behavior over time, provide updated outcome values as the events occur (see Figure 1).

### **Agent-Based Models as Tools for Projecting Behavior into the Future**

Agent-based modeling is a method of developing simulation models that suggests that the modeler focuses on describing the behavior of individual entities (e.g., patients, staff, households, companies). Such entities—agents—are put into a certain environment where they interact, change their state, move, or are created or destroyed. The system level (aggregate) behavior emerges as a result of simulation of multiple individual behaviors (Borshchev & Filippov, 2004). Agents in agent-based models (ABMs) are typically acting under control of a simulation engine on a computer and in virtual (model) time. The agent-based approach is particularly helpful when a researcher

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