LETTERS

AGENT-BASED MODELING: USE WITH NECESSARY CAUTION

Agent-based modeling—a tool employing multiple interacting agents to reveal emergent properties of systems that are not properties of the individual agents themselves[1]—has made significant in-roads into many social science disciplines,[2] including public health. I congratulate Dennis Gorman and his colleagues on their effort to leverage these new tools to address specific public health concerns.[3] However, given the novelty of agent-based modeling methodology and the resistance of those favoring traditional analytic methods,[4] great care in application is necessary to increase the likelihood of acceptance. In this spirit, I offer a few concerns.

Most important, it is imperative to be clear about what agent-based models have to offer. Gorman et al. claim that their "models demonstrate that the basic dynamics underlying social influences on drinking behavior are shaped by contacts between drinkers and focused by characteristics of drinking environments."[3(p2055)] The offered models demonstrate no such thing. At most, the models provide insight into the spatial dynamics of agents following programmed rules that respond stochastically to other agents in a highly stylized environment.[5] Whether this teaches us about drinking behavior is an empirical question.[4] Similarly, the "bar"[3(p2058)] is nothing more than a probabilistic sink that guarantees to attract the "drinkers" who in no way "*chose* to spend a greater portion of their time at this site"[3(p2059)] (emphasis added).

Ecological validity and simple face validity are also important concerns. In one instance, Gorman et al. sought to identify ecological components of drinking behavior that they suggest might be thought of as a college population that moves from a specific site with a given probability each day, operationalized as a random walk.[3(p2056)] However, each of these students will have his or her own sink in the form of an apartment or a dorm room that he or she should return to (at least on most days). Gorman et al.'s random-walk method quickly produces probabilistic homelessness.

Finally, precision is required in specifying models and reporting results. For example, a lattice can be bordered or unbordered (i.e., moving off the right side puts you on the left side) and conversion can be asynchronous or synchronous (all agents determine the new agent type before all agents convert together). I replicated a family of models with NetLogo 3.1.1 (Center for Connected Learning and Computer-Based Modeling, Evanston, Ill) to determine the likely characteristics of Gorman et al.'s models, with good results (Figure 1). (The "bar" model runs 20000 periods in approximately 40 seconds on a 1.6 Ghz Pentium processor; models are available from the author upon request.) This replication also helped me to sort out the mathematical error in Gorman et al.'s Figure 1[3(p2056)] (The ordinary proportion for conversion from susceptibles to drinkers,

$$\frac{d(i)}{s(i)+r(i)+d(i)} = \frac{d(i)}{t(i)},$$

shown on the state diagram, rather than double this proportion as specified in the body

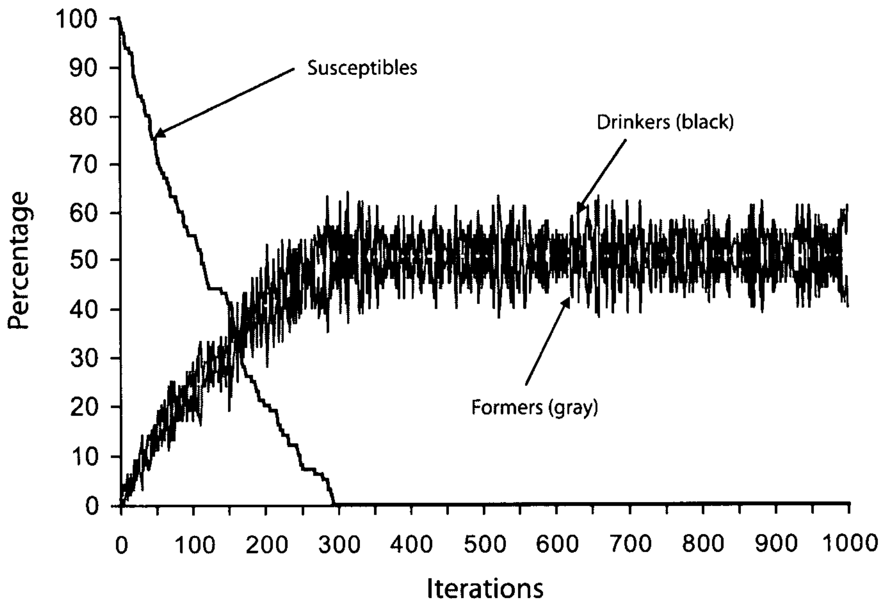

FIGURE 1—Replication of Gorman et al.'s[3] primary model: $P = .3$; $\gamma = .3$; $\rho = .3$ on an unbordered lattice with synchronous conversions.

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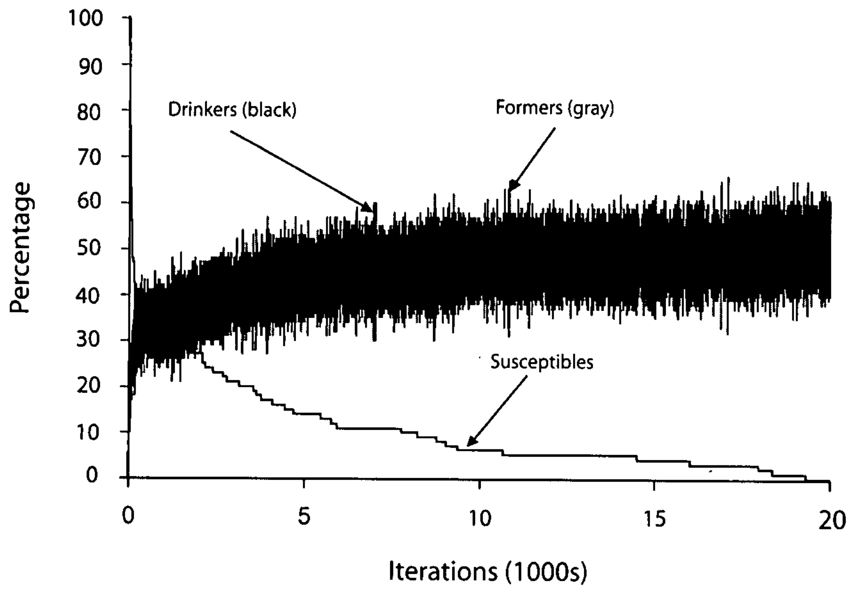

Note. Drinkers probability of moving toward bar = 0.5 and probability of moving away from bar = 0.1.

FIGURE 2—Replication of Gorman et al.'s[3] "bar" model: $P = .3$; $\gamma = .3$; $\rho = .3$.

text of the diagram is what I believe was intended.)

With this replicated model, I was also able to investigate concerns about the authors' claim that with a "bar" on the lattice, susceptibles leveled "off at a constant nonzero value."[3(p2059)] Analytically, this could not be the case. Indeed, the clustering of drinkers makes the conversion of a susceptible on a random walk a low-probability event, but the susceptibles do eventually go to zero (taking a mean of 10 822 periods over 50 runs), a characteristic missed because of incorrect assumptions of scale (Figure 2).

For agent-based modeling to meet its promise, practitioners should resist the temptation to overstate the implications of model outcomes, carefully design agent-based models with an eye toward ecological validity, and provide precise specifications and results based on families of models subjected to repeated tests. ■

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MEZIC ET AL. RESPOND

We would like to thank Jones for replicating our modeling efforts and identifying the typographical error (not mathematical error) in the equation presented in the text of Figure 1 (where "=" is replaced by "+").[1] We are glad to see that his replication of the basic model and agent rules lead to the same conclusions drawn in our article. We also are pleased to have the opportunity to clarify some important points about the relevance of this modeling exercise to the very real problems communities experience with alcohol availability (whether through bars or other sources) and alcohol-related problems. The public health importance of these nascent modeling efforts should be underscored.

We fully acknowledged that agent-based models represent "a simplified version of the real-world processes of interest," and we accept that such simulations should be evaluated in the context of real data. Indeed, we were very careful to describe both the details and the limitations of our models and not overstate their potential implications. Furthermore, our work since the article's publication that uses data from several US cities demonstrates that contact with realistic situations can be established.[2] The models we presented demonstrate the feasibility of modeling relationships between sources of alcohol and related problems with simple systems of agent-based rules. Our further work demonstrates that these simple rules, applied in 2 dimensions and reflecting the geographic distributions of outlets in community areas, may also predict the incidence of alcohol-related problems across community areas.[3] Thus, we stand by our original statement that the "models demonstrate that the basic dynamics underlying social influences on drinking behavior are shaped by contacts between drinkers and focused by characteristics of drinking environments."[2(p2055)]

Contrary to the observation of Jones, our models do not produce "probabilistic homelessness." Indeed, the timescale of a day is represented by 1 step. Thus, "visits to a bar" means only that an agent has been there on a particular day. The agent's presence on that day implies that it might also be in the vicinity of (or visit) the same bar the next day, and so