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Agent-Based Models and Systems Science Approaches to Public Health

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This issue of the *American Journal of Preventive Medicine* (AJPM) contains two articles^{1,2} that use agent-based models (ABMs), a form of computational modeling that is relatively new to public health and preventive medicine. There have been only two previous papers featuring ABMs published in AJPM, and those only recently.^{3,4} This commentary attempts to provide some context for these articles and for the use of ABMs and systems science methods in general. These are powerful tools for health policy planning (among other uses), and as such will undoubtedly become more frequently used in the future.

We see these two ABM articles^{1,2} as part of a movement in public health to embrace systems science methodologies and the interdisciplinary study of complex systems. For at least a decade, the NIH has promoted such approaches, including the National Cancer Institute (NCI)'s Cancer Intervention and Surveillance Modeling Network (CISNET, since 2000),⁵ the National Institute on Biomedical Imaging and Bioengineering's Interagency Modeling and Analysis Group (IMAG, since 2003),⁶ and the National Institute of General Medical Sciences' Models of Infectious Disease Agents Study (MIDAS, since 2004).⁷ Because of their ability to incorporate information from a variety of disparate sources, systems science methodologies naturally lend themselves to interdisciplinary research approaches, which are increasingly being recognized as crucial for addressing our most daunting health problems.⁸

Only in the last few years have these methods been picked up in a significant way in health-relevant behavioral and social science research. The NCI led the way with an exploration of systems thinking under its Initiative for the Study and Implementation of Systems.⁹ In 2006, the NIH Office of Behavioral and Social Sciences Research (OBSSR) made systems-based approaches one of its four core priorities,¹⁰ and soon thereafter OBSSR and CDC joined forces to produce a video lecture series designed to introduce behavioral and social scientists to systems science methods.¹¹ In October 2007, OBSSR launched the Behavioral and Social Sciences Research (BSSR)-Systems Science Listserv, a mailing list that publishes announcements related to systems science and public health. In 2008, OBSSR issued the first NIH funding announcement focused on behavioral and social science research that required applicants to propose a systems science approach.¹² Since 2008, systems science

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approaches have been encouraged in many NIH funding announcements anchored in behavioral and social science.^{13–15}

Private foundations are also entering this space: the Robert Wood Johnson Foundation joined with the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) and OBSSR to support systems science approaches via the Envision modeling network under the National Collaborative for Childhood Obesity Research (NCCOR, www.nccor.org). And private corporations recognize the value of such approaches: IBM recently hosted the IBM Almaden Institute on Smarter Health Through Modeling and Simulation (www.almaden.ibm.com/institute/2010) and is using systems science approaches to investigate complex health issues, such as obesity.¹⁶ Schools of Public Health and other health-related academic departments across the country are beginning to incorporate systems science into their curricula and research programs; for example, collaboration between the University of Michigan's Center for the Study of Complex Systems (www.cscs.umich.edu/) and the Center for Social Epidemiology and Population Health (www.sph.umich.edu/cseph/about/index.html); Columbia University's Mailman School of Public Health; the University of Pittsburgh's Public Health Dynamics Laboratory (www.phdl.pitt.edu/); and Johns Hopkins' National Center for the Study of Preparedness and Catastrophic Event Response (PACER; www.pacercenter.org/pages/about.aspx).

Why has there been a surge of interest in systems science approaches to public health? There are many contributing factors, including technology (i.e., processing power); software applications that make modeling practical; and the widespread adoption of personal computers, which make these methods accessible. Without these technologies our use of such methods was limited, and so we simplified complex problems down to simple problems that could be handled with less-powerful computers and statistical software packages. But now, we can study the complexity of problems by using systems science methodologies. Uses of modeling in public health include synthesizing knowledge from disparate disciplines, identifying gaps in existing knowledge, identifying cost–benefit tradeoffs, and generating hypotheses.¹⁷

The utility of any model is that it can represent complex processes in a simplified form to enhance understanding. Models permit experimentation in a virtual environment. For ABMs, aspects of the real world are represented in a computer program as “agents”, which follow simple behavioral rules. Such models are based on what is known (or assumed) about individual behavior, and population-level behavior emerges given various starting conditions.

In this issue of AJPM, Yang et al.¹ use an ABM to explore walking behavior in a community. Low levels of physical activity are associated with increased health risks, and so interventions to increase physical activity are likely to confer health benefits. But exactly which interventions will have substantial effects at the population level is not well understood. Here, walking behavior was simplified in an agent-based model in which each agent was assigned a probability of walking or not walking for leisure, errands, or commuting. The model was used to explore how land use and safety issues might affect walking behavior, thus informing intervention development.

Also in this issue, Auchincloss et al.² use an ABM to explore the impact of food preferences and prices on dietary disparity related to income, demonstrating that to overcome observed patterns of income-related dietary disparity, both preferences for healthy food and availability of cheap healthy food are necessary. Their model helps tease out the social determinants of health in a situation in which empirical data are lacking.

Just as models and simulations have been used to understand specific health-related issues such as disease progression,¹⁸ systems science methods show great promise for exploring policy options prior to enacting them, and for understanding how policies might be designed to work synergistically together.¹⁹ Modeling and simulation have been used to address broad health issues, including optimizing vaccination policies²⁰ and managing national healthcare policy.²¹

The next steps in modeling and simulation are to draw on evidence from specific disciplines to build models that help us see a more comprehensive picture of the interactions among the disparate systems that create overall health. It seems clear to us that ABMs—and modeling, simulation, and systems science methods more generally—can be used effectively to improve public health.

References

1. Yang Y, Roux AVD, Auchincloss AH, Rodriguez DA, Brown DG. A spatial agent-based model for the simulation of adult daily walking within a city. *Am J Prev Med.* 2011; 40(3):XXX–XXX.
2. Auchincloss AH, Riolo R, Brown DG, Cook J, Roux AVD. An agent-based model of income inequalities in diet in the context of residential segregation. *Am J Prev Med.* 2010; 40(3):XXX–XXX.
3. Lee BY, Brown ST, Cooley P, et al. Vaccination deep into a pandemic wave potential mechanisms for a “third wave” and the impact of vaccination. *Am J Prev Med.* 2010; 39(5):e21–9. [PubMed: 20965375]
4. Lee BY, Brown ST, Cooley PC, et al. A computer simulation of employee vaccination to mitigate an influenza epidemic. *Am J Prev Med.* 2010; 38(3):247–57. [PubMed: 20042311]
5. National Cancer Institute. Cancer Intervention and Surveillance Modeling Network. cisnet.cancer.gov/index.html
6. National Institute on Biomedical Imaging and Bioengineering, Interagency Modeling and Analysis Group. www.nibib.nih.gov/research/multiscalemodeling/imag
7. National Institute of General Medical Sciences, Models of Infectious Disease Agents Study. www.nigms.nih.gov/Initiatives/MIDAS
8. Stokols D, Hall KL, Taylor BK, Moser RP, Syme SL. The science of team science: Assessing the value of transdisciplinary research. *Am J Prev Med.* 2008; 35(2 Suppl):S77–S252. [PubMed: 18619407]
9. National Cancer Institute. Tobacco Control Monograph No. 18, NIH Pub. No. 06–6085. Bethesda MD: USDHHS, NIH; 2007. Greater than the sum: Systems thinking in tobacco control.
10. Mabry PL, Olster DH, Morgan GD, Abrams DB. Interdisciplinarity and systems science to improve population health: a view from the NIH Office of Behavioral and Social Sciences Research. *Am J Prev Med.* 2008; 35(2 Suppl):S211–24. [PubMed: 18619402]
11. USDHHS, Office of Behavioral and Social Sciences Research. Systems Science and Health Symposium Series. 2007. bit.ly/aLavsD
12. USDHHS, NIH. Using systems science methodologies to protect and improve population health (R21): PAR-08-224. grants.nih.gov/grants/guide/pa-files/PAR-08-224.html
13. USDHHS, NIH. Social Network Analysis and Health (PAR-10-145, R01. grants.nih.gov/grants/guide/pa-files/PAR-10-145.html; and PAR-10-146, R21 <http://grants.nih.gov/grants/guide/pa-files/PAR-10-146.html>
14. USDHHS, NIH. Behavioral and social science research on understanding and reducing health disparities (R01): PAR-10-136. grants.nih.gov/grants/guide/pa-files/PAR-10-136.html
15. USDHHS, NIH. Systems-Oriented Pediatric Obesity Research and Training (SPORT) Center of Excellence (U54). RFA-HD-10-001. grants.nih.gov/grants/guide/rfa-files/RFA-HD-10-001.html
16. Maglio, P.; Cefkin, M.; Haas, P.; Selinger, P. Social factors in creating an integrated capability for health system modeling and simulation. In: Salerno, J.; Chai, S-K.; Mabry, PL., editors. Lecture Notes in Computer Science; Proceedings of the 2010 International Conference on Social

- Computing, Behavioral Modeling, and Prediction (SBP10); Bethesda, MD. March 29-April 1, 2010; Springer; p. 44-51.6007/2010
17. Mabry PL, Marcus SE, Clark PI, Leischow SJ, Méndez D. Systems science: a revolution in public health policy research. *Am J Public Health*. 2010; 100(7):1161–3. [PubMed: 20530757]
 18. Epstein JM. Modelling to contain pandemics. *Nature*. 2009; 460(7256):687. [PubMed: 19661897]
 19. Serman JD. Learning from evidence in a complex world. *Am J Public Health*. 2006; 96(3):505–14. [PubMed: 16449579]
 20. Hutton DW, Tan D, So S, Brandeau ML. Cost effectiveness of Hepatitis B screening and vaccination among adult Asian and Pacific Islanders in the United States. *Ann Intern Med*. 2007; 147(7):460–9. [PubMed: 17909207]
 21. Milstein B, Homer J. Analyzing national health reform strategies with a dynamic simulation model. *Am J Public Health*. 2010; 100:811–9. [PubMed: 20299653]