Observations on Modeling Social Identity: Suggestions to Address the Challenges of Social Identity

Norman L. Johnson

Abstract In the last two decades, social identity (SI) modeling and simulation have significantly advanced. They are building on and, in many cases, improving the over a half-century of validated SI experimental studies and theories. In this paper, observations on modeling and simulation of SI explore niches of additional opportunities based upon multiple perspectives: the evolution of social organisms, non-competitive theories of evolution, emergent properties of collective problem solving, advances in non-social computational modeling, epidemiological simulations, and complexity science. Based on these observations, specific recommendations are provided for expanding SI modeling and simulation. The main recommendation is to develop a general model of SI based on the observation that all social organisms share common traits, such as the innate drive to form SI or how individual states of uncertainty or stress trigger SI, but also recognize that complex species present more complex expressions of SI. Other recommendations are: SI models must accommodate that not all expressed SI traits have origins in or require higher fitness, all or many SI traits have triggers and maybe trigger thresholds that must be modeled, the inclusion of emergent group performance that may change SI behavior and strategies, and the development of a SI community model for research and realistic applications.

Keywords Social identity · Agent-based model · ABM · Diversity · Group performance · Emergent properties · Multilevel system · Evolution theories · Conformity · Complexity science

1 Introduction to Broadening the Approach to SI Modeling

All social organisms, almost by definition, can be said to express SI. Yet, there appear to be few researchers attempting to model what is common to all social organisms, particularly SI. The author's realization of the universality of social identity in social

---

N. L. Johnson (✉)
Referentia Systems, Honolulu, HI 96819, USA
e-mail: norman@santafe.edu

F. Squazzoni (ed.), *Advances in Social Simulation*, Springer Proceedings in Complexity,
https://doi.org/10.1007/978-3-031-34920-1_23

organisms became apparent while attending the 2002 *Self-Organisation and Evolution of Social Behaviour Workshop* [11]. By construction, the organizers included an equal representation of experimentalists and theoreticians/modelers. The publication of the workshop proceedings in 2005 captured why a unified approach to social organisms is beneficial: *"Self-organisation of social systems can be observed at all levels of biological complexity, from cells to organisms and communities. Although individuals are governed by simple rules, their interactions with each other and their environment leads to complex patterns. … The study of social systems from the perspective of complexity science leads to unusual results that show that, by self-organisation, complex patterns of behaviour may arise from very simple behaviour. By building these rules into certain computer models we develop a new type of understanding. This method may be applied to social systems of all kinds and of all organisms. Yet, so far, it has rarely been used among biologists. Moreover, biologists are little aware of the use of this method in the study of social systems in humans"* [11]. Much has changed since the writing of this introduction: agent-based models (ABM) in social sciences and SI modeling are common [18, 22]. Yet, while many citations of the workshop publication appear after 2005, none address a unified modeling approach to social organisms, even in biology. Notably, none seem to associate SI with social organisms, except humans.

While the text above argues for the use of complexity science, a multilevel and evolutionary analysis for modeling SI also has benefits and is captured in personal communication by J.J. van Bavel in 2018, "*I follow the logic of consilience laid out by E.O. Wilson, which is that a theory that operates successfully at multiple levels of analysis is more likely to be true and stand the test of time. On those grounds, I think there is a lot to be gained by not only looking at social psychological aspects of identity but seeing how these unfold at higher levels of analysis (social systems) and lower levels of analysis (the brain and cognition)…Moving up and down levels of analysis can generate new predictions and insights that might be hard to see if we always stick at the same level of analysis*" [4]. This quote adds an evolutionary and multilevel perspective to the discussion of SI modeling.

This paper examines SI modeling from various perspectives, including how the evolution of social organisms of different species represents different levels of adaptation of SI, matching the complexity of their environment. It proposes alternative approaches or missed opportunities for SI modeling and simulation. The goal is not to subsume the more than five decades of SI clinical experiments and theory but to explore the niches which may have been overlooked, mainly as they might be applied to mature ABM applications to advise and solve real-world challenges.

2 Observations on the Modeling Social Identity

The following section captures observations on the modeling of SI, followed by a section selection of publications that illustrate the observation and recommendations.

2.1 SI is Fundamental to all Social Organisms, Not Just Humans

A complete treatment of the multilevel evolution of SI is beyond the scope of this paper, but an observation supports the utility of such an exercise. An example from the *Social Behaviour Workshop* cited in the Introduction is the observation that all social organisms—from slime molds to social insects to social spiders to social mammals to lower and upper primates—exhibit a type of social copying when stressed or uncertain, capturing the transition from an individual activity to collective coordination. For example, when stressed from lack of water or nutrients, a slime mold (the social amoeba) shifts from independent behavior to coordinated action, including self-sacrifice—the extreme expression of SI, leading to propagation [7, 19]. On the other end of the evolutionary spectrum, humans are also observed to switch to social copying when uncertain or stressed [5, 26, 29]. This observation is revisited in the discussion of the CONSUMAT model in §2.3. Hence, the behavior of copying or imitating peers under uncertainty and stress is a candidate for a universal feature of SI in social organisms.

What if SI modeling started with the goal of capturing what is shared across all social organisms as a foundation on which to build more complex descriptions that are species-specific? This modeling approach is standard in the hard sciences, where dynamical theories (governing equations) are developed in the broadest descriptions, such as the equations of motion, followed by applying specialized constitutive models and simplifying assumptions to model specific problem areas. With the accessibility of extreme computing resources, the hard sciences have had even greater success in realistic modeling across many fields where simplified models combined with high-resolution simulations proved to be as good or better than complex models at a lower spatial resolution, e.g., ABM in epidemiology [8, 9], simplified constitutive models in continuum mechanics, and the direct numerical simulation of turbulence. A similar understanding is developing in modeling social behavior, particularly with ABM's advantages of self-organizing functionality [14, 18]. Is an opportunity being missed in SI modeling where more realistic SI behavior can be captured from simplified SI models combined with realistic, dynamic social networks generated or changed by the SI model? Recent publications and reports that address this question are provided in §3.3.

2.2 *Behavior-Changing Social Identity Can Form from Trivial Differences*

Another aspect of simplifying SI models may involve considering that some aspects of an individual's SI are less complex and more flexible than is often argued for humans. How would this observation affect SI modeling? The unlikely answer may be found in evolutionary theory.

One misconception about the origins of social behaviors in primitive social organisms is that the details of their expressions are genetically pre-programmed. But a researcher of social wasps, Gadagkar, concluded from decades of research that ecological, physiological, and demographic factors dominate the influences of genetic relatedness in selecting for or against social traits [7]. This suggests that the expressions of SI may be more fluid than previously believed, even in the least complex social organisms. To generalize Gadagkar's conclusion: SI is an innate drive in all social organisms, but where the expressions depend on the species' complexity and local environment.

Many experiments show how humans can form strong and behavior-changing SI from minimal differences, such as experiments with children using random, trivial differences [24]. Akerlof and Kranton's 2000 paper summarizes: *"… competition is not necessary for group identification, and even the most minimal group assignment can affect behavior. 'Groups' form by nothing more than random assignment of subjects to labels, such as even or odd. Subjects are more likely to give rewards to those with the same label than to those with other labels, even when choices are anonymous and have no impact on [their] own payoffs. Subjects also have higher opinions of members of their own group"* [2]. Does the ease of formation of behavior-modifying SI from random attributes change SI models, and in what way?

This suggestion to modify SI models does not reduce the significance of over a half-century of experimental research on SI, particularly by the influential work of Tajfel [25] and the extensions of Tajfel's Social Identity Theory (SIT) after his early death, both in maturation and to the successful application of SIT in a variety of unrelated fields, as reviewed by Brown [4]. One resolution of the mature and validated SI theories with the above observations is that the behavior-changing formation of SI is an innate drive or need in all social organisms, but where the expression of the need is dependent on the social sophistication and environment of the species. One could also argue that Tajfel's SIT applies in social situations where a mature expression of SI is preexisting or the experimental design stimulates the strong formation of SI. But in experiments where random associations without payoff lead to SI formation, the innate need for the development of SI is triggered without recourse to competitive motivations.

Another argument by analogy on the possibility that SI is an innate need that finds a variety of expressions comes from the history of evolutionary theory. A common popular belief, even bias, is that all "evolutionary" features expressed in the animal species have an evolutionary significance of higher fitness during formation. Many academic papers have written justifications for an observed feature in a species simply because of the assumption that if it occurred, there must be an increase in fitness due to the feature from selective evolution. A more mature evolutionary theory proposes that once the engine of diversity creation exists, the engine continues to create lasting diversity, even if the evolutionary selection pressure is lessened or absent [15]. Hence, the observed diversity in mature expressions of nature isn't exclusively because of evolutionary fitness but also because of the lack of evolutionary fitness and selection. For example, the extreme diversity of coloration in birds may not be associated with any increased fitness due to the coloration, but because the diversity creation of colors is *not selected* by an increase in fitness, and the diversity production engine freezes in evolutionary color changes.

When the above argument is applied to SI, possibly the innate need to form SI without payoffs or changes in self-esteem can induce behavior-modifying SI from trivial, non-competitive, random features. A possible characterization of this process is that the need for SI is an innate attractor in the individual, in complexity parlance, which requires a minimal stimulus to cause SI formation and where the expression of SI depends on the individual's internal state and external environment. There is nothing specific to human SI in this speculation. Hence the viewpoint provides a unified SI foundation for all social organisms. This innate SI attractor may have been overlooked as a universal, cross-species trait due to experimental designs that trigger mature expressions of SI. This observation leads to the next topic of triggers and thresholds in SI dynamics.

2.3 Triggers, Thresholds, and Habitual Behavior in SI Dynamics

There are unasked questions concerning experiments where SI occurs from minimal or random differences discussed in §2.2. What are circumstances in which a new SI is induced, or a pre-existing SI expression is triggered? Or when multiple SIs exist in an individual, what circumstances cause the expression of one SI over another? Or, more generally, what are the endogenous (individual) and exogenous (environmental) conditions that form or stimulate the expression of a SI or selection of one SI from multiple SIs? Is the formation of SI a gradual or abrupt process? Can the expression of a SI be a habitual state, not requiring rational choice? These questions become more relevant as the expression and management of multiple SIs within an individual are recognized and modeled [20]. While answering all of these questions is beyond this paper, this subsection examines the importance of modeling triggers and thresholds of SI behaviors and distinguishing between modeling conscious and habitual states.

An example of an ABM that best explores these questions was developed for consumer dynamics by Jager et al. in 2000 to implement a composite model from the many validated but niche behavioral theories [13]. The CONSUMAT model used three dominant behavioral models for individual choice: (1) bounded rationality, (2) social awareness and imitation of other consumers (peers), and (3) a rest state of habitual behavior—the thoughtless repetition of prior choices. The CONSUMAT model was tested using an ABM on different social networks. As a weak form of validation but a significant achievement, the full spectrum of consumer buying dynamics is replicated with different parameter selections: high volatility in product choice, prolonged time volatility with instabilities, highly stable choices with a high diversity of product selection, and highly stable with low diversity of product selection.

A trigger of an individual behavioral state is implemented to initiate a specific decision process. The two triggers in CONSUMAT that initiate the individual's transition from habitual behavior to an activated decision state are (1) increased stress and uncertainty, leading to social imitation and copying (as discussed in §2.1), and (2) dissatisfaction from a historical comparison of needs fulfillment, leading to a rational choice of different options based on bounded awareness. These modeling choices capture the realistic behaviors: (1) an individual will sustain habitual behavior unless triggered to a heightened state of internal or external awareness, and (2) triggers of different internal states induce different types of behaviors.

Perhaps, one reason that habitual SI behavior appears not to be included in experimental studies is that the experimental design often induces an activated SI state, either consciously or unconsciously. The absence of SI habitual states in experiments appears to be carried over to the simulations of SI, as captured in the pre-review of the current state of SI models [22]. The above modeling observations can be applied to SI models: (1) some aspect of habitual behavior needs to be included, and (2) different triggers select between different types of behavior, including SI and non-SI behaviors.

In private communications with Jager, he shared that adding thresholds was necessary for the dynamic realism in CONSUMAT, where a threshold of a trigger captures a tipping point from habitual to behavioral change: a behavior does not gradually appear with a non-zero stimulus trigger, such as uncertainty, but first appears at a threshold level. Again, specific to SI models, what are the different SI behaviors and their triggers, and do they require a threshold before the behavior is expressed?

To provide a perspective on the above observations, a comprehensive framework for mapping and comparing behavioral theories in models of social-ecological systems was proposed in 2017 [21]. The framework is intended for applications in natural resource management, but the social-psychological framework proposed generally applies and shares goals and features of the CONSUMAT development from 17 years earlier. While the presentation does not include the concept of social identity—"identity" is only stated once in a long list of individual need states where *"Needs are motivational goals/factors for behaviour,"* social norms are cited as a crucial element of a person's behavior and central to social science disciplines. Overall, one main recommendation of the study is the necessity for a comprehensive model to switch appropriately between different behavioral modes, including habitual behavior.

While no mention of triggers appears in the framework paper, the one threshold reference is *"What defines a loss versus a gain is a threshold, or more precisely, a reference point that is a reflection of people's expectations or beliefs about past* *outcomes."* An example of a habitual fisher agent provides an informative description, illustrating that threshold levels need not be fixed: *"Every time step that it brings back a catch and its needs are satisfied the behaviour becomes stronger and the threshold to switch to a different behaviour becomes higher. If the satisfaction drops below a threshold, the agent will start deliberating about alternative behaviour."*

In summary, a comprehensive SI model needs to have a rest state of habitual behavior as a foundation, with activated states of behavior with corresponding triggers and thresholds, based on internal states and external influences.

2.4 Emergence and Emergent Properties in SI Group Utilities

The word "emergence" has become a common descriptor in many social science publications; for example, in 2008, *"90% of papers on complexity and social simulation explicitly refer to emergence"* [23]. Emergence is now commonly used to mean appearance, expression, coordination, and, possibly the least useful, surprise, and consequently has lost its technical meaning [3]. This widespread usage of emergence does not capture the definition for an emergent multilevel property: a feature observed in the group (global) but not observed or expressed in the individual (local).

For most modeling studies of SI, the goal is to provide a descriptive model of known or proposed SI features for evaluation, where the expression of SI or its utility is not treated as an emergent property. One example of a limitation of not including emergent dynamics and features in the modeling is when the utility of the group has an emergent component but is not captured, which can, in turn, cause the lack of the individual utility to reflect the full expression of the group utility and, therefore, might change the conclusions of the study. This limitation is in addition to the additional difficulty that if the group utility is explicitly modeled within the individual, the question arises as to the realism of the modeling: the group utility cannot typically be objectively known because individuals have only perceptions of group utility but no mechanism to evaluate the group state objectively. The exception to this statement is when group payoffs are explicitly made to individuals by an intentional group structure.

An excellent example of the hazards of omitting emergent properties is the decades of studies on the evolutionary origin of cooperation in publications. Many of these studies largely fail in their goal because the models explicitly include cooperative behavior as an option within the individual behavior. In this explicit modeling approach, the simulations cannot demonstrate the emergent origin of cooperation but only the desirability or selection of cooperation. By contrast, if an agent behavioral model doesn't include cooperation, but the global dynamics of the simulation exhibit emergent cooperation, then the model and simulation can be strongly stated to capture the origin of emergent cooperation. Then, by using evolutionary processes, once the emergent property increases individual fitness, the emergent cooperative expression can be internalized within the population of individuals through selective genetics [15].

The ABM simulations of Hemelrijk in 1997 of the dynamics of herd structure [10] illustrate the above argument. In simulations with only aggressive individual behavior, Hemelrijk observed that a stable interaction could occur between a strong individual and multiple weaker individuals in the formation of the dominance structure of the herd. The multiple weaker individuals exhibited emergent cooperation, even though the behavioral model did not include individual cooperative behavior. Many models at the time claimed to demonstrate that cooperation was an evolutionary adaptation to higher fitness. Yet, the individual models typically included cooperation as an individual option and arguably failed in their demonstration [10].

While the evolutionary origins of SI may be less attractive to many researchers, the above discussion has relevance to SI modeling choices and possibly SI theories. For perspective, one of the significant advancements in evolutionary theory in the last two decades is the resolution of the controversy concerning group utility in evolution, as captured in a monograph by two of the most influential evolutionary theorists, Wilson and Wilson, in 2007: *"Current sociobiology is in theoretical disarray, with a diversity of frameworks that are poorly related to each other. Part of the problem is a reluctance to revisit the pivotal events that took place during the 1960s, including the rejection of group selection and the development of alternative theoretical frameworks to explain the evolution of cooperative and altruistic behaviors… Multilevel selection theory (including group selection) provides an elegant theoretical foundation for sociobiology in the future, once its turbulent past is appropriately understood"* [28]. Although SI should be a key component of sociobiology theories, it is not mentioned in the monograph. While this omission is significant to the history of SI theories, the discussion of its implications is beyond the scope of this paper. Still, specific aspects of the multilevel evaluation of utilities are relevant to ABM SI modeling and can be discussed.

The key to determining utilities in the context of SI is capturing the benefits and costs expressed at multiple levels: for agents, an SI group of agents, and communities of SI groups. A feature of all ABM treatments of SI is the use of agent and group utilities, either as payoffs or for strategy evaluations. For example, if a rational choice model is used, then the utility of an agent determines the agent's behavior. If different individual or group management strategies are examined, group utilities are used to evaluate them. While it is beyond the goal of this paper to review the models of SI utilities, such as the commonly used self-esteem [25], the emergent sources of utility appear to be overlooked in multilevel SI models of individual and group(s).

In the late 1990s, two groups of researchers independently discovered how diverse groups could outperform the average individual and how even a group of high-performing experts can be outperformed by a group of individuals with a diversity of individual performance or skills [12, 14]. Identical to the challenges faced in gaining acceptance of group selection described by Wilson and Wilson [28], both first attempts to publish these results were rejected, with a reviewer of my 1998 submission stating, *"I don't see what is wrong, but it can't be right."* Two decades later, these concepts are popularly accepted and published as "collective intelligence" and are key to understanding the invisible hand in optimizing stock markets and managing large research programs [16]. The following asks if a similar bias has occurred in the history of SI modeling.

One example of emergent utility is when an optimal but emergent group solution to a problem may not be comprehensible to the individual. In a 1998 report, I analyzed how information derived from a collection of independent agents solving a maze can be aggregated to obtain the shortest path [14]. Because a myotic agent has no global perception of the maze, the agent has no mechanism to judge the quality of its chosen path. A significant discovery was that any reduction in the contribution of experiences by the agents in the aggregation for the group solution led to reduced group performance. This discovery led to an analysis that found that group performance correlated with the diversity of individual contributions to the group solution. This diversity correlation occurs only for a range of problem complexity that confounds an expert solution but is not so great as to cause the individual's contribution to be noise [16].

In the 1998 study, it was assumed that all agents had a common worldview (they agreed on options in the maze), reflecting a common SI. In a later study of the same maze problem but using agents with different worldviews or SI (they disagree on options), the resulting biases lowered the group performance unless the biases themselves were diverse or, more accurately, uncorrelated [16]. An additional discovery of the 1998 study was that the optimal emergent group performance was when each individual could communicate their full experience to the group solution, not their best option, nor a uniform weighting of all options. One way to understand these results is that in complex problem domains, individuals have diverse and non-overlapping areas of experience. One individual, including an expert, cannot perceive the global problem in complex problem domains. The collective aggregate of experience or skills always yields a better solution than an average performer and often the expert.

These results have direct application to the SI modeling: (1) emergent group utility can be uncorrelated with aggregate individual utility, which in turn, may alter conclusions about the efficacy of SI, (2) a higher emergent utility of a SI group requires compatibility of individual contributions—a shared worldview or SI, (3) because the emergent solution is robust to uncorrelated bias and even extreme noise in the individual contributions [14], SI groups may show higher emergent performance in experiments in the presence of miscommunication, misinformation, or low SI coherence, and (4) optimal SI group performance occurs when individuals of a SI group can communicate their complete experience, which could be restricted by repressive SI conformity. In summary, including emergent properties in multilevel SI simulations can result in more robust and realistic models, change the conclusions of studies, and contribute a new understanding of SI in group performance.

3 Illustration of the Above Observations to ABM SI Studies

This section examines three recent papers describing ABM implementations of SI theories to illustrate the observations of the prior sections. These studies were selected based on the quality of the behavioral models and implementation choices, representing this author's view of the sophisticated state of SI modeling. While few papers were selected to illustrate the observations presented herein, the advantages of the observations are hopefully helpful to other publications and identify SI modeling additions for more realistic applications.

3.1 ABM of a Comprehensive Social Identity Theory (SIT)

Upal and Gibbon, in 2015 [27], presented a socio-cognitive model of SI dynamics and illustrated how agent-based social simulation could be a valuable tool for theory refinement. The simulations use a rational choice theory that maximizes individual utility. Intergroup behavior is driven by the need to maintain positive self-esteem, derived partially from affiliation with SI groups. Comments on the implemented SIT's accuracy are beyond this paper's scope, but the study is an example of the advanced implementation of a mature behavioral model. The SIT model captures a comprehensive spectrum of socio-structural beliefs, individual and collective strategies, intergroup permeability, and personal and group costs… to name some of the features. The simulations of 100 agents examined 12,000 simulation groups with 500 rounds per group, initializing each run with random distributions of individual resources, agent perceptions of permeability, legitimacy, stability, and individual esteem. The analysis of the simulations examined correlations between the input variables and outcomes of multiple SI management strategies. Given the maturity of the SIT model, the analysis provided extensive results on the sensitivity of different strategies to the model parameters. The strongest correlations observed were that out-group resources were negatively correlated with all SI management strategies. *"This means that agents are more likely to denigrate, glorify, attack and change entry conditions targeting groups that are believed to have few resources"* and *"As in-group resources increase, agents become more likely to engage in collective strategies against the out-group members."* The two unexpected results, labeled "emergent," were (1) the positive correlation between average group resources and all SI actions and (2) the negative correlation between outgroup resources and SI actions.

The reason for citing this study is to note that the implementation of the SIT is linear in all relationships (an explicit assumption) and deterministic (the same initial conditions produce the same outcome). The model excludes triggers and thresholds in behavior, which would introduce nonlinear dynamics. Similarly, there is no modeling of habitual behavior, which adds a strong path dependency in the solutions, another nonlinear behavior. The deterministic nature of the model excludes the possibility of SI forming from random events. The addition of modeling any of these behavioral effects while increasing the complexity of the analysis would result in a more realistic model and results. A final comment is that the unexpected results are labeled emergent patterns, using the more popular definition of emergence. There is no indication in the results that the simulations show emergent behavior as defined in §2.4.

3.2 ABM Study of Trust and Conformity, Using Fitness of Group Diversity

A 2022 paper by Fazelpour and Steel studies the positive and negative effects of different types of diversity on SI performance using an ABM [6]. The problem challenging each agent is selecting two options with unknown payoffs that are sequentially observed to optimize their preference. Their resulting payoff preferences can be shared based on a predetermined and fixed social network. The study's main conclusions are that different types of diversity *"can, in certain circumstances, benefit collective performance by counteracting two types of conformity that can arise in homogeneous groups: those relating to group-based trust and those connected to normative expectations toward in-groups."* The main conclusions duplicate the earlier diversity studies described in §2.4 and [14]. Still, because the simulations include multilevel SI dynamics of information sharing and blocking, the nuances of the effect of diversity on collective SI performance are also revealed. While the use of a fixed social network does not realistically represent SI group formation and change, as discussed in §2.2, the authors' variable weights of social network connections are stated to capture intergroup dynamics, but no details are provided. No modeling information is provided if triggers and thresholds were included in implementing behavior models, communication, or strategies. Habitual behavior is not mentioned.

3.3 Multipurpose SI Community Model for Large-Scale ABM Simulation

A significant advancement of epidemiology and its usefulness in pandemic strategies transpired in the 2000s when ABM simulations with billions of agents were demonstrated at Los Alamos National Laboratory by modifying a molecular dynamics simulation resource. The resulting ABM epidemic modeling resource, EpiCast, simulated pandemics at a national level, capturing the movement and infection state of every individual in the U.S. (300 million at the time) using census and mobility data [8]. The EpiCast results were so influential that pandemic policy decisions of the last century were changed in the U.S. and internationally and have continued today with the COVID pandemic, utilizing the rapid development of vaccines instead of a national quarantine. A critical precursor that made EpiCast possible was developing a 2000-person ABM community model of the infectious spread of smallpox [9]. The advantage of the community model is that it captures the realistic spread of infection through a contact network with movement between homes, workplaces, and public locations. The model was validated with other infectious diseases and became a standard test platform for developing new infectious models. EpiCast replicated this model to duplicate the populations of each county in the U.S., thereby capturing the entire U.S. population.

Based on the success of EpiCast as a team member and PI, I developed a research proposal in 2009 [17] after concluding a Phase 1 exploratory study for an ABM resource for managing message campaigns in actual geographical regions with polarized SI populations, using a simplified SI model, a replicated community model based on the smallpox community model [9], and data-driven social networks. The combined ABM resource with data assimilation was argued to assist decision-makers in conflict management and policy deployment. Another trial SI community model was proposed in 2022 to study the "emergence of social norms" [1]. This study also adds genetic algorithms to enable the evolution of rules to optimize individual fitness in the presence of information exchange, enabling the discovery, rather than a specification, of collective norms.

The dynamical similarity between a community experiencing an infectious disease with adaptive behavioral changes and a community experiencing SI formation and adaptive behavioral changes suggests that the development and use of a SI community model might be transformational to the testing of new SI models and the development of large-scale policy management resources, similar to the experience of EpiCast.

4 Conclusions and Future Studies

These are highlights of the suggestions that might be included in future SI resources. §2.1: Start with a universal SI model common to all social organisms, and then specialize the model for specific social organisms—the more complex the organism, the more complex the SI. §2.2: Consider that expressions of SI may not require modeling of fitness but can occur by chance, reflecting the attractor nature of SI. §2.3: Consider inclusion of habitual behavior and what triggers and thresholds activate each SI feature. §2.4: Allow for emergent properties in multilevel SI models, particularly in how group performance benefits the individual. And, §3.3: Consider the development of a validated, multi-purpose SI community model with realistic, highly-resolved, SI-driven social networks.

A theme throughout this paper is that the challenge of the high complexity of evolved human SI may hamper the advancement of SI modeling. And how an evolutionary perspective might guide the development of SI models. For this author, the most exciting discovery in examining the evolutionary development of SI is the perspective that human SI might be viewed as an emergent collective consciousness of the group. This observation aligns with an unpublished theory of the author that the evolutionary origin of consciousness or sentience in an organism is the ideation equivalence of the biological sense-of-self of advanced immune systems to address the high internal complexity of a multicellular organism. From this viewpoint, SI evolved as an expression of emergent immunity of the SI group to outside ideas while managing the SI group's high internal complexity or diversity. This leads to the observation that in lower forms of social organisms, SI is not self-aware or emergent but purely responsive at an individual level. And, in higher social organisms, emergent SI provides forms of group awareness and immunity to outside ideas, which the individual cannot understand.

References

1. Agrawal, R., Ajmeri, N., Singh, M.P.: Socially Intelligent Genetic Agents for the Emergence of Explicit Norms. ArXiv abs/2208.03789 (2022)
2. Akerlof, G., Kranton, R.: Economics and Identity. Q. J. Econ. **115**(3), 715–753 (2000)
3. Bedau, M.A., Humphreys, P.: Emergence: Contemporary Readings in Philosophy and Science. MIT Press, Boston (2008)
4. Brown, R.: The social identity approach: appraising the Tajfellian legacy. Br. J. Soc. Psychol. **59**(1), 1–21 (2019). https://doi.org/10.1111/bjso.12349
5. Cialdini, R.: Influence: Science and Practice. Allyn & Bacon, Needham Heights (2001)
6. Fazelpour, S., Steel, D.: Diversity, trust, and conformity: a simulation study. Philos. Sci. **89**(2), 209–231 (2022). https://doi.org/10.1017/psa.2021.25
7. Gadagkar, R.: The Social Biology of Ropalidia Marginata: Toward Understanding the Evolution of Eusociality. Harvard University Press, Cambridge (2001)
8. Germann, T.C., Kadau, K., Longini, I.M., Macken, C.M.: Mitigation strategies for pandemic influenza in the United States. Proc. Natl. Acad. Sci. U.S.A. **103**, 5935–5940 (2006)
9. Halloran, M.E., Longini, I.M., Jr., Nizam, A., Yang, Y.: Containing bioterrorist smallpox. Science **298**(5597), 1428–1432 (2002)
10. Hemelrijk, C.K.: Cooperation without genes, games or cognition. In: Harvey, P.H.A.I. (ed.) Fourth European Conference on Artificial Life. MIT Press, Cambridge (1997)
11. Hemelrijk, C.K. (ed.): Self-Organisation and Evolution of Biological and Social Systems. Cambridge University Press, Cambridge (2005)
12. Hong, L., Page, S.E.: Groups of diverse problem solvers can outperform groups of high-ability problem solvers. PNAS **101**(46), 16385–16389 (2004)
13. Jager, W., Janssen, M., De Vries, H., De Greef, J., Vlek, C.: Behaviour in commons dilemmas: implementing the CONSUMAT approach in an ecological economic model. Ecol. Econ. **35**, 357–379 (2000)
14. Johnson, N.L.: Collective Problem Solving: Functionality beyond the individual. Los Alamos National Laboratory Report, LA-UR-98-2227, Los Alamos, NM (Nov 1998) www.academia.edu/download/84598680/NLJsims_AB_v11.pdf
15. Johnson, N.L., Watkins, J.H.: Interplay of adaptive selection and synergistic performance: as an example of natural selection and self-organization. In: Selection and Self-Organization Workshop, CSIRO-Sponsored Complex-System Science Workshop. Katoomba, Australia (2007). https://doi.org/10.2139/ssrn.2232193
16. Johnson, N.L.: Applied science of collective intelligence: solving the grand challenges facing humanity. Spanda J. **5**(2), 97–108 (2014)
17. Johnson, N.L.: Final report of SAGE: situational awareness for the GTWO environment project, 98 pages (September 23, 2009) CDRL A001AC, N00014-09-M-0190, Office of Naval Research, 8725 N. Randolph, Arlington, VA 22203
18. Miller, J.H., Page, S.E.: Complex adaptive systems: an introduction to computational models of social life. In: Princeton Studies in Complexity. Princeton University Press, Princeton (2007)

19. Ostrowski, E.A.: Enforcing cooperation in the social amoebae. Curr. Biol. **29**(11), R474–R484 (2019)
20. Reed, A., II.: Special session summary: when what I think feel and do depends on who I am: identity effects on judgment, choice and self-reinforcement. Adv. Consum. Res. **31**, 335–338 (2022)
21. Schluter, M., Baeza, A., Dressler, G., Frank, K., Groeneveld, J., Jager, W., Janssen, M.A., McAllister, R.R.J., Mueller, B., Orach, K., Schwarz, N., Wijermans, N.: A framework for mapping and comparing behavioural theories in models of social-ecological systems. Ecol. Econ. **131**, 21–35 (2017) doi.org/https://doi.org/10.1016/j.ecolecon.2016.08.008
22. Scholz, G., Eberhard, T., Ostrowski, R., Wijermans, N.: Social identity in agent-based models: exploring the state of the art. In: Ahrweiler, P., Neumann, M. (eds.) Advances in Social Simulation ESSA 2019. Springer Proceedings in Complexity. Springer, Cham (2021)
23. Squazzoni, F.: Book review of emergence: contemporary readings in philosophy and science. JASSS **11**, 4 (2008). www.jasss.org/11/4/contents.html
24. Stangor, C., Jhangiani, R., Tarry, H.: Ingroup favoritism and prejudice. In: Principles of Social Psychology, 1st International H5P Edition (2022). opentextbc.ca/socialpsychology/
25. Tajfel, H., Turner, J.C.: An integrative theory of intergroup conflict. In: Austin, W.G., Worchel, S. (eds.) The Social Psychology of Intergroup Relations, pp. 33–47. Brooks/Cole, Monterey, CA (1979)
26. Tesser, A., Campbell, J., Mickler, S.: The role of social pressure, attention to the stimulus, and self-doubt in conformity. Euro. J. Soc. Psychol. **13**, 217–233 (1983)
27. Upal, M.A., Gibbon, S.: Agent-based system for simulating the dynamics of social identity beliefs. In: Proceedings of the 48th Annual Simulation Symposium, pp. 94–101 (2015)
28. Wilson, D.S., Wilson, E.O.: Rethinking the theoretical foundation of sociobiology. Q. Rev. Biol. **82**(4) (2007). https://doi.org/10.1086/522809
29. Wooten, D.B., Reed, A., II.: Informational influence and the ambiguity of product experience: order effects on the weighting of evidence. J. Consum. Psychol. **7**(1), 79–99 (1998)