7

AGENT-BASED MODELING AS A TOOL FOR STUDYING SOCIAL IDENTITY PROCESSES

The Case of Optimal Distinctiveness Theory

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Researchers studying social identity and intergroup relations have traditionally approached group behavior as an interaction between the individual, the group, and the social context in which the individual and group are embedded. This approach has been quite fruitful, as evidenced by the proliferation of theories and studies over the last several decades that have identified the psychological and sociocontextual features that are likely to give rise to particular group behaviors (e.g., in-group bias, discrimination, intergroup hostility). However, these theories are based largely on how *individuals* are predicted to respond and behave under particular circumstances, often without explicit consideration of the interdependence among individuals or the group-level outcomes that may emerge as a result of the interactions among individual actors. This approach is similar to a traffic engineer attempting to understand traffic patterns by examining the motivations and behaviors of individual drivers. Individual-level theories may tell the engineer that drivers attempt to maximize the speed of their car and avoid erratic fellow drivers. But understanding why traffic jams occur requires consideration of how the behavior of one driver affects the behavior of multiple other drivers and how these behaviors unfold over time. In this chapter, we echo the sentiment of other researchers (e.g., Goldstone & Janssen, 2005; Smith & Conrey, 2007) and argue that understanding group-level phenomena requires studying both individual-level processes and the global structures that emerge as a result of interactions among individuals.

Although the accumulated research within social psychology has provided the field with many good theories of how individuals react and behave in group contexts, we know relatively little about how these individual-level behaviors contribute to larger patterns of group behavior (e.g., intergroup segregation, status hierarchies, group formation). To understand these patterns of group behavior, psychologists have focused primarily on the psychological needs that individuals attempt to satisfy through their group memberships. For example, according to social identity theory (Tajfel & Turner, 1979), individuals are hypothesized to associate themselves with groups that compare positively to other groups as a means of bolstering self-esteem. Other theories, such as optimal distinctiveness theory (ODT; Brewer, 1991), focus on individuals' desires for inclusion and distinctiveness from others as predictors of group identification. Although social-psychological research has advanced our understanding of the psychological underpinnings of group identification, the work is limited by the tendency for researchers to focus on single motivations as opposed to multiple motivations operating simultaneously. In addition, the work relies heavily on studies of individual actors without considering the interdependencies among the actors or the large-scale patterns of outcomes that emerge when multiple actors connected within social networks interact and mutually influence each other over time.

On the other side of the coin, group formation has been a topic of interest within fields such as sociology and computer science, where the emphasis has been on studying how groups and communities evolve (e.g., Backstrom, Huttenlocher, Kleinberg, & Lan, 2006). However, this research typically lacks an explicit treatment of the intraindividual processes that guide the behavior of individual actors. For example, studies in this area may tell us that groups tend to fragment after reaching a particular size, but they are silent regarding what motivates individual actors to exhibit the behavior that gives rise to this emergent pattern (for an exception, see Grönlund & Holme, 2004).

The primary goal of this chapter is to discuss the potential benefits of applying a systems-oriented approach to the study of social identity processes and group behavior. In particular, we have been utilizing agent-based models (ABM) in our own research to explore hypotheses inspired by ODT (Brewer, 1991). Agent-based models simulate the behavior of individuals through the creation of virtual agents who follow preprogrammed rules. These rules are often derived from existing psychological theories. What is of interest, however, is what *emerges* from the interactions among these agents (Goldstone & Janssen, 2005). Two decades of research on ODT has resulted in an impressive array of studies that demonstrate that the needs for inclusion and differentiation can have profound effects on the perceptions, judgments, and behavior of individuals (Leonardelli, Pickett, & Brewer, 2010). For this Festschrift volume in honor of Marilynn Brewer's prolific research career, it seemed fitting to take the study of optimal distinctiveness to a different level of analysis and explore the patterns of group behavior that emerge from a system of autonomous agents who follow one very simple rule: seek optimal distinctiveness.

In this chapter, we first describe agent-based modeling and review some examples of how ABM has been successfully used to further the field's understanding of important social psychological phenomena. We then describe our recent efforts at developing an agent-based model to examine the macrostructures that emerge when agents are programmed to seek optimal distinctiveness and continue with additional examples of how ABM might be fruitfully applied to study the emergent outcomes of the motives of individual group members. We then conclude with a discussion of the benefits of agent-based modeling for the study of social psychological phenomena more broadly.

WHAT IS AGENT-BASED MODELING?

Social behavior, from persuasion and attitude change, to interpersonal relationships, to group interactions, results not only from the intrapsychic psychological processes of isolated individuals but also from interactions among multiple individual agents over time. In fact, in many cases, collective outcomes differ drastically from what any party expects or desires. For example, in studies of bystander intervention, because all participants assume that someone else is helping, the outcome is that no one helps. In the case of the commons dilemma and other social dilemmas, when self-interested individuals overuse a resource (grazing grounds, fisheries) or use a resource without paying for it (public television), the resource may be destroyed to the detriment of all. Despite the importance of these "emergent" effects among individual actors, explanations of such phenomena among social psychologists have focused almost exclusively on the processes that characterize how isolated individuals perceive, understand, and react to various stimuli.

At the same time, other disciplines have focused almost entirely on aggregate or population-level outcomes of social behavior. For example, economic, sociological, and political-science research often seeks to explain the proportions of populations that adopt a particular innovation. Researchers in sociology and physics have focused on social information networks and the flow of information through these networks that results in opinion convergence, group formation, and other outcomes. In contrast to the individual, process-oriented approach of social psychology, these approaches are largely unconcerned with the intrapsychic processes that characterize the psychology of individual actors. What happens to specific individuals and why are not of concern; rather, the concern is what happens to whole populations over time.

In recent years, researchers have increasingly sought to integrate the individual, process-level approach with the aggregate, group-level approach to provide a fuller understanding of social psychology and behavior (for a review, see Smith & Conrey, 2007). Perhaps the most effective means of combining these approaches is through the use of agent-based modeling (also called *multiagent modeling*). An agent-based model is a simulated multiagent system that can be constructed to capture key elements of social psychological processes and behavior. In such systems, each agent typically represents an individual human acting according to a set of established behavioral motives and rules. These behavioral motives and rules generally reflect the kinds of individual-level processes that have been widely studied by psychologists. In an ABM, many simulated agents interact with one another and/or their environments over simulated time, based on the individual processes that guide the agents' actions. Importantly, the outcomes of the agents in such a system are interdependent: each agent's ability to achieve its goals depends not only on what it does but also what other agents do. Thus, the model permits observation of the emergent, aggregate consequences of many agents interacting interdependently and dynamically over a period of time (for a recent example, see Mason, Conrey, & Smith, 2007).

In essence, then, ABM is a tool for bridging the individual and aggregate levels of analysis. The extensive knowledge that psychologists have garnered regarding individual-level psychology is implemented by the rules that guide the behavior of individual agents. These processes also may be represented in the rules governing the natures and outcomes of interactions among agents. The aggregate level emerges as the multiple agents interact with one another and the environment over time. Beyond integrating these different levels of analysis, the great advantage of this approach is that, in many cases, the consequences of multiagent interactions over time fail to match what might be expected based on the behavioral propensities of individual agents, as in the cases of bystander intervention and the commons dilemma. Such emergent processes are all but impossible to study in the context of controlled laboratory experiments.

Some Illustrative Examples

Segregation In one of the earliest applications of ABM in the social sciences, Schelling (1971) examined how segregation between social groups can arise through the actions of individual agents, even when no agent specifically desires segregation. Schelling's model assumed that each agent used a single, simple rule: do not be in the minority in your neighborhood. To implement the model, agents moved to random empty spaces if the proportion of "in-group" agents surrounding their current space fell below a certain threshold, such as 50%. The rule was applied until all agents stopped moving, settling into their spaces. The final result, which occurred under a wide range of moving thresholds, was almost complete segregation among the agents, with clear group boundaries. This model was important because it offered the counter-intuitive conclusion that extreme segregation may inevitably result from the extended interactions and choices of individuals who do not necessarily desire extreme segregation. The model also makes clear that such an outcome does not require the intervention of a central, organizing agency (e.g., real-estate agents) in order for segregation to occur, but rather may emerge in a self-organized fashion from individual-level motives. Finally, the model was important in demonstrating the significance of an agent's definition of *neighborhood*. When agents were programmed to define their neighborhoods narrowly, segregation was a very likely outcome. In contrast, if agents defined their neighborhoods more broadly (e.g., the whole population of agents in a wider region—a city vs. a neighborhood), extreme segregation was far less likely.

Mate Choice Kalick and Hamilton (1986) used ABM to simulate the well-known empirical fact that people tend to end up with romantic partners of about equal attractiveness to themselves. Highly attractive people end up with highly attractive people, moderately attractive people end up with moderately attractive people, and so on. A common explanation for this fact was that people actively seek partners with similar levels of attractiveness, presumably due to the fear of being rejected by more attractive prospects (e.g., Berscheid, Dion, Walster, & Walster, 1971) or from a general preference for similarity in all attributes. However, repeated studies found no support for the proposed similarity preference. Instead, all people demonstrate a strong preference for the most attractive potential partners (e.g., Curran & Lippold, 1975). Kalick and Hamilton sought to resolve this paradox via ABM.

In their simulation, 500 "male" and 500 "female" agents were given attractiveness values and then were randomly selected in pairs. Upon selection, the two agents paired off together only if both agents extended an offer to the other. The process continued until all agents were paired. When the likelihood of an offer was set to correlate with the attractiveness of the potential partner (e.g., .9 for a 9/10 on attractiveness, .1 for a 1/10), the result was a correlation in attractiveness of the two agents of around .5 to .6—matching the observed level among humans. The simulation showed that this result occurs because the most attractive agents tend to pair up early and are, therefore, removed from the population. As time passes, the attractiveness of the remaining agents decreases. Once again, the value of this model is in demonstrating the counterintuitive effects of a simple rule (seeking the most attractive possible partner) iterated dynamically across many agents and over time.

Person Perception More recently, Smith and Collins (2009) used ABM to simulate the processes by which impressions of people are constructed, transmitted, and filtered through social networks. Among other variables, their model assigned values to agents representing how probable they were to "behave" in a positive or negative manner. The model assumed that agents will repeatedly interact only with agents who act positively toward them. One outcome was that agents formed more negative impressions of other agents than was warranted by the agents' probabilities of positive and negative behaviors. This result is due to the fact that positive interactions with an "unlikeable" agent could be corrected through repeated interaction, whereas negative interactions with an objectively "likeable" agent are not corrected because they result in decreased future interaction (see Denrell, 2005, for a mathematical model of this process). The model also showed that when agents are permitted to "gossip" with one another about third-party agents, impressions of the third parties became less negative, even though the communicating agents were likely to have equally negative views of the third party. This is because the opportunity to gossip with one another provided agents with a larger sample of information about the third party, which more accurately described the overall positivity of the third party. Thus, this model showed that simple rules about interacting and communicating with other agents have important effects on the nature and accuracy of social impressions when the processes iterate across multiple agents and over time. These outcomes had not been anticipated based on what had been known about individual-level impression formation processes. A particularly useful feature of this model is that it included three different levels of variables: (1) individual-level variables that described the internal workings of the agents, (2) dyadic-level variables that described how pairs of agents interact, and (3) system-level variables that described how influence spread through the whole community of agents.

APPLYING AGENT-BASED MODELING TO OPTIMAL DISTINCTIVENESS THEORY

According to ODT (Brewer, 1991), social identity is conceptualized as deriving from a "fundamental tension between human needs for validation and similarity to others (on the one hand) and a countervailing need for uniqueness and individuation (on the other)" (p. 477). Membership in moderately sized groups is considered to be optimal because there is a sufficient number of other individuals in the group, which allows for a sense of inclusion and belonging with other group members. At the same time, however, the group can be used as the basis for distinguishing the individual from nongroup members, thereby satisfying the need for distinctiveness. For example, a person may choose to join a group of sailing enthusiasts because doing so provides a sense of belonging with fellow sailors, while simultaneously allowing the individual to be distinguished from others (e.g., runners).

Existing research supports the idea that people prefer memberships in distinctive social groups (e.g., Leonardelli & Brewer, 2001; Pickett, Silver, & Brewer, 2002), but this work is based primarily on people's subjective reports of their existing group memberships and does not examine how group formation processes are shaped by the needs for inclusion and distinctiveness. Furthermore, tests of ODT have often been limited to experimentally heightening the need for either inclusion or distinctiveness (e.g., Pickett et al., 2002) and have not been able to precisely examine the patterns of behavior that emerge at varying levels of the needs for inclusion and distinctiveness. Finally, these tests of ODT generally hold variables such as status constant, and thus we know relatively little about how the needs for inclusion and distinctiveness play out in the context of other competing motives (e.g., self-esteem).

Current Research Program

As an initial step toward closing these research gaps, we have embarked on the development of a program of research in which we apply agent-based modeling to the study of social identification processes and group behavior. The overarching goal of this research program is to gain insight into global patterns of group behavior (e.g., the formation and dissolution of groups, the emergence of group-based status hierarchies) by modeling the behavior of individual actors and examining the dynamic outcomes of the interactions among those actors.

Because simplicity is a virtue in the world of agent-based modeling, our first attempt at examining individual-level social identification processes and subsequent macrolevel outcomes centered on the relatively simple question of how the individual-level desire for membership in an optimally distinct group influences group formation and dissolution processes. In existing experimental tests of ODT, arousal of inclusion and distinctiveness needs led study participants to exhibit a preference for groups that were most likely to meet those needs (e.g., groups that were at an optimal level of inclusiveness). However, a group's level of inclusiveness is not static and, in fact, may be in a constant state of flux particularly when group boundaries are relatively permeable. This led us to the assumption that the desire for optimal distinctiveness at the individual level pushes individuals toward joining or leaving the groups based on the size of the group and the individual's preferred level of group inclusiveness. In addition, we sought to examine the macrolevel outcomes of this process. A reasonable prediction is that in a multigroup environment, a number of moderately sized groups will emerge such that all agents in a system are able to meet their optimal distinctiveness goal. In other words, as agents join groups of the desired size, they will stay in those groups unless the groups become overly large or overly small until the whole system settles into a state of equilibrium. Thus, in an ideal world, the end equilibrium state will contain groups whose sizes match the preferred level of group inclusiveness of the individuals in that system.

However, this ideal split might be difficult to achieve for a variety of reasons. First, in the real world, when a popular commodity exists, there can often be an overabundance of interest. For example, when a new checkout lane opens up at a grocery store, for a short while it has the shortest line at the store. However, as people standing in line at other lanes switch to the newly opened lane, it quickly develops a line just as long as the other lanes until all the lines are of roughly equal length. Although all individuals at the store seek the shortest line, a comparatively short line does not exist for very long. Second, through simple random fluctuations, frontrunners can emerge early in a contest leading to the demise of other contestants. In social groups, groups that start off closest to an optimally distinct size may become overwhelmingly popular such that the less popular groups shrink over time until they reach the point of nonexistence, ironically leading to groups at the end that fail to be optimal.

Simulation Environment

Our plan in setting up our simulations was to vary specific aspects of the modeling environment—the number of initial groups, the number of agents, the number of other agents that any particular agent could "see" in their environment (i.e., the local environment), and the optimal distinctiveness seeking rule (e.g., agents' preferences for groups of a particular size)—and then to observe the movements of the agents and the ultimate patterns that emerge. For our simulations, an agent-based model was written in Java, using the MASON simulation library (Luke, Balan, Panait, Cioffi-Revilla, & Paus, 2003). MASON is a discrete-event multiagent simulation package that can be used to model a wide range of dynamic events, for example, swarms and complex social interactions. The program also allows users to visualize the movement of individual agents and the patterns that these movements produce.

Our initial simulations focused primarily on varying the group-size preferences of the individual agents (while holding other aspects of the simulation environment constant) and examining the number and size of the groups that emerged. What this meant for the individual agents is that they all followed the rule of joining whatever group was closest to the preference value set for that simulation (e.g., 33%, 25%, 45%). If the most optimally distinct group in the agent's local environment happened to be the group to which the agent already belonged, the agent kept their group membership. If a different group was more optimally distinct in the agent's environment at that particular time step, the agent would discard its current group membership in favor of the more optimally distinct group membership. Agents assessed their group memberships asynchronously. After specifying these parameters, we allowed the program to run—that is, proceed through a series of time steps where an assessment of the local environment and the opportunity to change group membership occurred at each time step—until the system reached an equilibrium point and a stable pattern emerged.

The most notable finding that emerged from these simulations was the number and size of the groups that were produced. When a multigroup environment was set up at the outset (e.g., four equally sized groups or six equally sized groups), programming agents to prefer membership in groups that represented 33% of the population resulted, ironically, in the formation of two groups of equal size (each representing 50% of the population). Because all agents in the simulation were programmed to join the group in their local environment that was closest to the preference set point, agents tended to gravitate toward the same groups. With each time step in the simulation, less popular groups drifted further from the preference set point until they were no longer represented in the environment. Additional simulations that varied the group-size preference of the agents incrementally always resulted in the formation of groups that were less than optimal (i.e., which failed to match group members' size preferences). These simulations suggest that when all individuals within a particular environment share the exact same preference for a particular group size, their joint actions may actually impede the formation of groups of the preferred size. In future simulations, it will be of interest to explore what conditions would actually lead to the optimal satisfaction of agents' group-size preferences. It may be the case that when preferences are distributed more normally, more adaptive patterns of group formation emerge.

These results highlight the fact that the creation of optimally distinct groups does not simply happen because each individual group member desires membership in a group of optimal size. As in the real world, these simulations do not involve an omniscient being who has complete knowledge of the environmental space and can assign group memberships in a way that ensures an optimal group size. Instead, individual agents make choices based on the choices of other agents, and the result can sometimes be less than desired, as was the case in the simulations presented here. However, it is important to keep in mind that there are many simulations that could be run and the outcomes of those simulations may differ from the simulations presented here. Thus, our results should not be taken to mean that the spontaneous formation of optimally distinct groups cannot emerge, but rather that the formation of optimally distinct groups did not emerge under the conditions that were specified here.

Future Applications of Agent-Based Modeling to Optimal Distinctiveness Theory

As noted above, in future research, agent-based modeling can be used to examine the conditions under which the needs for inclusion and distinctiveness—as well as self-esteem—actually do lead to the formation of optimally distinct groups. A central tenet of ODT is that group identification will be greatest among groups in which the needs for inclusion and distinctiveness are equally satisfied. Thus, we plan to run simulations to determine whether attempts to satisfy this "equal satisfaction" constraint lead to the formation of groups that are of moderate size (i.e., optimally distinct). Over time (i.e., sequential time steps of the model), agents could band together into groups, and groups that are very small compared to other groups in the context might expand (by attracting other members) and groups that are very large might contract (by expelling members). These patterns of expansion and contraction could ultimately lead to convergence on a set of moderately sized groups to which most members of the population belong.

We are also very interested in the larger scale patterns that emerge from the individual-level needs for belonging, distinctiveness, and self-esteem. Using U.S. census data, Lau (1989) examined the extent to which African Americans in various settings reported feeling close to other African Americans. Lau found group identity to be strongest among African Americans who lived in areas in which 40%–70% of the population was also African American. It is possible that living in areas that are neither predominantly white nor predominantly African American creates an optimal level of both distinctiveness and inclusiveness for African Americans, thereby fostering greater group identification. Because of the difficulty of studying migratory patterns of populations in real time and the inability to experimentally manipulate features of real-world social contexts, agent-based modeling provides a very useful tool for studying the influence of the needs for inclusion and distinctiveness on the formation of groups in geographical space. Tests of ODT have not examined whether group members migrate to particular locations as means of satisfying their needs for inclusion and distinctiveness. Through agent-based modeling, we can create populations with simulated neighborhoods and vary the initial numbers of group members in various neighborhoods. We can then create agents with inclusion- and distinctiveness-seeking rules and examine whether agents tend to settle in neighborhoods where there are a particular percentage of other in-group members in that neighborhood. More specifically, what one might expect are neighborhoods that are dominated by groups that each share a moderate proportion of the population (e.g., 35%) as opposed to highly heterogeneous neighborhoods with many groups with a small share of the population. Furthermore, we can examine how features such as initial proximity to other group members and interaction patterns among agents contribute to these migration patterns.

In addition to examining the group formation process, a fruitful avenue for future research is examining the dissolution of groups and the formation of subgroups. According to ODT, feelings of deindividuation should motivate people to adopt more exclusive group identities as opposed to seeking total individuation. Thus, the need for distinctiveness can be satisfied in two complementary and sometimes sequential ways: (1) making *intragroup* distinctions, that is, dividing an overly inclusive group into more distinctive subgroups with which to identify, and (2) making *intergroup* comparisons between one's subgroup and another subgroup. Although subgroup differentiation is a proposed outcome of the operation of inclusion and distinctiveness needs within a group context, very few studies have specifically tested the hypothesis that people respond to membership in an overly inclusive group by engaging in a drive for subgroup distinctiveness. In addition, the studies that do exist (e.g., Hornsey & Hogg, 1999) use outcome measures, such as bias against other subgroups, as indicators of differentiation as opposed to examining the splintering and division of groups as they occur over real time. An advantage of ABM is that it provides a window into the differentiation process as it occurs over simulated time. We can assign agents to highly inclusive groups and study how the relative strength of the needs for inclusion and distinctiveness affects the formation of subgroups (e.g., the number of subgroups formed and the stability of the groups). It is also possible to model group dissolution—when members abandon a group altogether—to see whether the psychological forces under study are sufficient to produce that outcome.

USING AGENT-BASED MODELS TO STUDY GROUP-BASED STATUS HIERARCHIES

In addition to using ABM to study processes directly related to ODT, ABM can be applied to other questions of interest to social psychologists. In this section, we describe how ABM might be employed to study the conditions that lead to the emergence of group-based status hierarchies.

Most modern human societies are characterized by the presence of group-based status hierarchies. Although these hierarchies may be predicated upon different features (e.g., age, gender, education level), what these hierarchies have in common is the presence of one or more dominant social groups that enjoy disproportionate social advantages while other groups suffer disproportionate social disadvantages (Sidanius & Pratto, 1999). In addition to being pervasive, these hierarchies also tend to be both stable and consensual in that there is typically high agreement among society members on the ordering of groups within the status hierarchy. For example, Sidanius and Pratto (1999) asked 723 UCLA undergraduates to rate the social status of five ethnic groups (whites, Asians, Arabs, blacks, and Latinos). These researchers found extremely high consensus among respondents in the ratings of the groups (average intraclass $r = .999$) and found that this consensuality in the perceived social status of American ethnic groups was largely unaffected by the group to which the respondent belonged.

Although the ubiquity of group-based status hierarchies in modern human societies is widely acknowledged, less agreement exists regarding the proximal mechanisms that drive these hierarchies. Traditional theories of prejudice argue that group-based hierarchies are a product of oppression by members of the dominant social group. Through both individual acts of discrimination and institutional discrimination, dominant groups can subjugate others and maintain their status differential. Other theories such as social dominance theory (Sidanius & Pratto, 1999) and system justification theory (Jost, Banaji, & Nosek, 2004) take a different stance and propose that members of groups at the low ends of the status hierarchy are also active contributors to their own oppression. By supporting policies that favor dominant groups and adopting ideologies that justify the hierarchy, subordinates contribute to the formation and maintenance of these hierarchies. A third perspective on the formation of group-based hierarchies comes from SIT (Tajfel & Turner, 1979). According to SIT, the need for self-esteem is thought to lead group members to adopt various behavioral and cognitive identity management styles. One of these identity management styles is social competition, a form of intergroup discrimination that is used to create or protect high in-group status.

It is clear that many forces may be involved in the formation of status hierarchies. Yet it is also possible that a phenomenon as complex as the formation of group-based hierarchies may emerge from a fairly simple set of psychological motives. Within the social-psychological literature, researchers have had a long-standing interest in understanding the motivational underpinnings of social categorization and group identification. Work in this area has revealed a core set of motivations (self-esteem, distinctiveness, belongingness, uncertainty reduction, and power) that appear to drive individuals to seek out group memberships and that predict individuals' loyalty and adherence to groups. Traditionally in this area, researchers have tended to develop simple motive-feature match models that predict that identification should be strongest when individual motives and group features match (Riketta, 2008). However, researchers have typically not considered what happens when individuals attempt to satisfy multiple motives simultaneously. In addition, in the real world (i.e., outside the psychological laboratory), individuals are embedded within social networks (e.g., societies) where they interact and mutually influence each other. Thus, particular patterns of broader-scale outcomes may emerge as a function of multiple individuals with different sets of motivations interacting over time. However, it is impossible for simple, nondynamic models to adequately capture these emergent patterns.

We propose that group-based status hierarchies may be one such emergent pattern. Individuals within a society are motivated to form or join groups that allow them to feel a sense of belonging with others and a sense of distinctiveness, and that also confer positive social value, which in turn fosters self-esteem. Individuals attempting to satisfy all three of these needs simultaneously should be motivated to form or join relatively small, high-status groups. We predict that all agents in a particular context will want to join the highest status group available and that interaction patterns among agents will create a hierarchical structure. High-status groups should form relatively quickly and then begin excluding other members from the group once the group reaches a certain size (because group members need the group to be small in order to satisfy their need for distinctiveness). Once the highest status group becomes highly restrictive, a second-tier group will form, and so forth. In both laboratory and real-world settings, it is very difficult to observe group formation processes as they evolve. For this reason, agent-based modeling may be particularly useful for testing hypotheses regarding the relationship between individual-level psychological motives and the emergence of group-based status hierarchies.

This research would provide the first ABM examination of the hypothesis that group-based status hierarchies can arise simply from the desire of individual actors to satisfy basic psychological needs. A unique aspect of this particular model is that it suggests that although prejudice and discriminatory practices may contribute to the formation of status hierarchies, these processes may not be necessary and may, in fact, be epiphenomenal. In addition, the modeling would allow one to test whether varying particular features of the interactions among agents in a system and the strength of the different psychological motives leads to different emergent patterns. For example, if the need for distinctiveness is low, there may be greater tolerance for larger social groups resulting in a status dichotomy (one low-status group and one high-status group) as opposed to a proliferation of smaller groups arrayed in a hierarchy. This work has the potential to reveal new insights into the nature of group-based status hierarchies and can allow for the rapid generation of additional testable hypotheses.

CONCLUSION

To date, almost all scientific analyses of group formation and change have focused on either the individual-level, psychological processes that influence the behavior of autonomous persons or aggregate-level outcomes that describe the end states of multiagent interactions. Individual-level analyses do not consider the operation of psychological processes in the context of multiple interdependent agents that interact over an extended period of time. Aggregate-level analyses rarely concern themselves with the psychological motives and processes of individual actors that define the nature of interactions among multiple agents and that play a determinative role in aggregate outcomes. The agent-based modeling that we are conducting combines these two levels of analysis, permitting a richer and more nuanced understanding of how individual-level psychology and group-level behavior interact to produce important outcomes.

By examining multiagent interactions over time, agent-based modeling can reveal important emergent effects that could not be predicted only on the basis of knowledge of individual-level processes. At the same time, the ability to independently manipulate the nature of the agents' individual and dyadic motives and behavior permits direct tests of the roles of these processes in producing aggregate outcomes. Finally, the ABM environment permits the manipulation of social context-level variables that are difficult to systematically vary in laboratory experiments. The ability to examine multiagent interactions over time also is a unique feature of agent-based modeling that cannot be accomplished with standard behavioral laboratory methods.

Yet another important feature of the agent-based modeling approach is its usefulness for theory development. Decades of behavioral laboratory research form the basis for the rules governing the individual-level behavior of agents in the model. However, ABM simulations frequently produce novel and unexpected outcomes that could not have been predicted from individual-level research. These outcomes can then form the basis for further traditional behavioral research, suggesting novel hypotheses to be tested at the individual level. For example, Kalick and Hamilton's (1986) model of mate selection generated the novel prediction that mate pairs formed later in time will be less attractive than those that formed earlier. This, of course, can be directly tested with human participants in a laboratory. Similarly, it is likely that agent-based models that are developed to study group formation and change will generate new hypotheses about how different individual-level motives interact under different conditions. These hypotheses can then be tested in the laboratory. In this way, research moves back and forth between models and empirical investigations (Smith & Conrey, 2007). Thus, agent-based modeling permits the examination of emergent properties that cannot be studied at the individual level, but also suggests novel individual-level hypotheses for testing.

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