JASSS

André Grow, Andreas Flache and Rafael Wittek (2015)

An Agent-Based Model of Status Construction in Task Focused Groups

Journal of Artificial Societies and Social Simulation **18** (2) 4
<http://jasss.soc.surrey.ac.uk/18/2/4.html>

Received: 18-May-2014 Accepted: 16-Dec-2014 Published: 31-Mar-2015

Abstract

Status beliefs link social distinctions, such as gender and race, to assumptions about competence and social worth. Recent modeling work in status construction theory suggests that interactions in small, task focused groups can lead to the spontaneous emergence and diffusion of such beliefs in larger populations. This earlier work has focused on dyads as the smallest possible groups in which status beliefs might emerge from face-to-face interaction. In today's societies, however, many task focused interactions take place in groups larger than dyads. In this article, we therefore develop an agent-based computational model that enables us to study the emergence of status beliefs in groups larger than dyads. With this model, we address questions such as: Do basic principles of task focused interaction systematically favor the emergence of status beliefs in groups larger than dyads? Does the time-frame over which small groups interact affect the likelihood with which status beliefs emerge? How does group size affect the emergence of status beliefs? Computational experimentation with the new model suggests that behavioral principles known to spontaneously create hierarchical differentiation between individual group members also tend to align these hierarchies with categorical differences and thereby facilitate the emergence of status beliefs. This tendency is stronger in smaller groups, and in groups that interact either for a very short or very long time.

Keywords:
Status Characteristics, Status Beliefs, Status Construction, Task Focused Groups, Agent-Based Computational Modeling

Introduction

1.1 Men are frequently expected to be better at math than women (Nosek, Banaji, & Greenwald 2002), white students are often assumed to perform better than black students (Steele & Aronson 1995), and physically attractive people are often assumed to be more competent than unattractive people (Jackson, Hunter, & Hodge 1995). Each of these observations illustrates how status characteristics can affect the abilities and skills that others expect us to possess. A status characteristic is any social distinction that separates individuals into at least two categories that are believed to differ in social worth and general competence (Berger, Fisek, Norman, & Zelditch 1977). Status characteristics shape interactions and are an important source of inequality. Social scientists therefore have a long-standing interest in explaining how social distinctions attain status value (e.g., Balkwell & Balswick 1981; Hendrix & Hossain 1988; Stover & Hope 1984).

1.2 A classical explanation for the creation of status characteristics is based on statistical association (e.g., Bielby & Baron 1986; Phelps 1972). According to this reasoning, a trait like gender can become a status characteristic if members of one gender are on average more resourceful in terms of income, education, and competence than members of the other gender.

1.3 More recently, Mark, Smith-Lovin, & Ridgeway (2009) described a mechanism by which social distinctions can attain status value, even in the absence of resource differences between members of different categories. Drawing on status construction theory (SCT) (e.g., Ridgeway 1991, 2000; Webster & Hysom 1998) and related research on the emergence of status hierarchies in task focused groups (Bales 1950, 1970), Mark et al. highlighted that task focused groups can spontaneously develop hierarchies of influence and deference in which some individuals appear more competent than others, even when this is objectively not the case. When hierarchical differentiation occurs consistently between members of different social categories, group members can come to believe that the distinction generally coincides with competence differences. Once emerged, such beliefs can diffuse throughout the population, because individuals carry them into new group contexts, treat new interaction partners accordingly, and thereby create hierarchies that teach their beliefs to others. By that, status beliefs can both emerge and spread, even when there are no objective resource differences between members of the different social categories.

1.4 In their formal modeling efforts, Mark et al. (2009) focused on dyads as the smallest possible groups in which hierarchical differentiation can occur. Focusing on dyads is a useful starting point for examining status construction processes, because it allows us to abstract from some of the complex interaction dynamics that might develop in larger groups. For instance, in dyads, any hierarchical differentiation that might emerge is necessarily fully aligned with any social distinction that differentiates group members. This enables us to abstract from more complex hierarchical structures that might arise in larger groups and that might provide partially contradicting information about competence differences between members of different social categories. However, many of the task focused interactions that take place in today's societies occur in groups larger than dyads. If we want to assess the importance of status construction in the creation of social inequality, we need to understand the emergence of status beliefs under such more complex conditions.[1]

1.5 In this article, we contribute to research in SCT by developing an agent-based computational model that combines insights into hierarchy formation in groups larger than dyads (e.g., Fisek, Berger & Norman 1991) with insights into status belief formation (e.g., Ridgeway & Correll 2006). By that, we complement Mark et al.'s (2009) study of belief diffusion at the population level with a study of the factors that might facilitate belief emergence at the group level. We address questions such as: Do basic principles of task focused interaction systematically favor the emergence of status beliefs in groups larger than dyads? Does the time-frame over which small groups interact affect the likelihood with which status beliefs emerge? How does group size affect the emergence of status beliefs?

1.6 To preview results, our computational experiments suggest that behavioral principles known to spontaneously create hierarchical differentiation between individual group members also tend to align these hierarchies with categorical differences and thereby facilitate the emergence of status beliefs. Formulated differently, our results suggest that task focused interaction in small groups might have an inherent tendency to create conditions that facilitate the emergence of status beliefs. This tendency is stronger in smaller groups, and in groups that interact either for a very short or very long time.

1.7 In what follows, we first describe the theory that underlies our model. Next, we present the model itself and subsequently submit it to systematic computational experiments. We close the article with presenting the results of our experiments and discussing their implications for future research.

Task Focused Interaction and the Formation of Status Beliefs

2.1 SCT is part of the expectation states framework – a set of theories that examine the emergence of hierarchical differentiation in newly established groups with a collective task focus (for overviews of the framework see Correll & Ridgeway 2003 and Wagner & Berger 2002). In this framework, hierarchical differentiation is defined as inequalities in task participation and influence among group members; collective task focus means that group members perceive successful task completion as their primary goal and that success can only be reached through team work (cf. Berger et al. 1977, 1980). Those group members who are relatively more active on the task and whose opinions have more weight in decision making processes hold higher positions in the group's hierarchy.

2.2 Examples of groups that fit the framework's scope are student learning groups and work teams. The tasks that such groups have to fulfill might vary considerably. We focus on small discussion groups as a prototype of task groups that has frequently been studied in empirical research and simulation studies. The members of such groups have to develop a solution for a complex problem that might not have an objectively correct solution. Theoretical and empirical research in SCT has focused on social distinctions that create two categories (e.g., gender with the categories man and woman). We follow this tradition here and refer to members of the different categories with the letters *A* and *B*. Throughout this article we make the assumption that this characteristic is salient and is the only attribute that initially differentiates group members.

2.3 Drawing on the expectation states framework, we first review behavioral processes that can lead to the emergence of hierarchical differentiation, even in the absence of resource and competence differences among group members. Subsequently, we review how the observation of consistent hierarchical differentiation between members of different social categories can lead to the emergence of status beliefs. Finally, we discuss how small group interaction might bring such consistency, and thereby status beliefs, about.

The emergence of hierarchical differentiation

2.4 The expectation states framework builds on the notion that when previously unacquainted individuals meet in a group setting with a collective task focus, "they act as if one of the subtasks of the group is to decide who has high and who has low ability at the task – thus to take advantage of high ability members and not be misled by low ability members" (Driskell 1982, p. 232). Assumptions about relative abilities are represented by so-called *performance expectations* (Berger et al. 1977) that group members hold for each other.

2.5 Performance expectations affect the way group members coordinate their work on the task (Balkwell 1991a; Berger, Rosenholtz & Zelditch 1980; Driskell 1982). First, those who are expected to perform relatively better than others are more likely to receive *performance opportunities*. This means that they are more often asked for their opinion, more often receive the opportunity to make suggestions, and are given more time to elaborate their views. Second, the contributions of those who are expected to perform relatively better receive more positive *performance evaluations*. This means that even when their suggestions are qualitatively similar to the suggestions of group members for whom performance expectations are relatively lower, their suggestions are still more likely to be accepted and appreciated.

2.6 When individuals lack objective information about each other's competence, they look for cues that might provide such information. The two cues that are relevant in the context of this article are *status characteristics* and *behavior interchange patterns* (Fisek et al. 1991; Webster & Rashotte 2010). Status characteristics are connected to beliefs about competence differences between members of different social categories. For instance, when gender is a status characteristic that favors men over women, individuals tend to believe that men are generally more competent than women. Performance expectations therefore tend to be higher for male than for female group members. Behavior interchange patterns are interactions among group members that might indicate competence differences between them. For instance, when group member A_1 appreciates and accepts the suggestions of group member A_2, whereas A_2 criticizes and rejects A_1's suggestions, a behavior interchange pattern becomes established in which A_2 appears more competent than A_1. As a consequence, group members are more likely to pay attention to A_2's suggestions, even compared to other group members A_3, A_4, and A_5, who were not themselves involved in the interaction. Conversely, group members are likely to pay less attention to A_1's suggestions, even compared to other group members.

2.7 Both status characteristics and behavior interchange patterns tend to create stable hierarchical differentiation between group members, even in the absence of objective competence differences. When there are status differences between social categories from the outset, the relatively higher performance expectations that group members have for members of a status advantaged category will lead the members of this category to dominate group interaction (Berger et al. 1977). In the absence of salient status characteristics, group members who manage to make suggestions that are accepted by other group members in an early phase of group interaction increase the performance expectations that others have for them. This leads to a "self-fulfilling prophecy" (Meeker 1994, p. 107) in which they become more likely to receive subsequent performance opportunities and their subsequent suggestions are more likely to be evaluated positively. This implies that small, randomly created status differences tend to grow and become stable over time.

The emergence of status beliefs

2.8 Individuals tend to infer competence differences from behavior interchange patterns. When such patterns are juxtaposed with differences in a salient social distinction (e.g., men generally accept the suggestions of women, whereas women generally reject the suggestions of men), there is a chance that group members "misattribute" (Webster & Hysom 1998, p. 357) seeming competence differences to differences in the distinction. That is, they acquire status beliefs that turn the distinction into a status characteristic.

2.9 The likelihood with which such belief acquisition takes place depends on how *comprehensively* and *consistently* the social distinction is associated with apparent competence differences (Ridgeway 2000, pp. 96–97). Comprehensive means that individuals have observed a number of behavior interchange patterns between different members of different social categories (Ridgeway 2000). Consistent means that in these patterns members of one category generally appeared in the higher competence role, whereas members of the respective other category almost invariably appeared in the lower competence role (Ridgeway 2000; Ridgeway & Correll 2006). When both conditions are fulfilled, individuals tend to have little doubt about the observed association and are thus likely to acquire a corresponding status belief.

2.10 Even when individuals doubt an observed association between categorical differences and relative competence, they have reason to act as if they would personally believe it. Consistent displays of influence and deference between members of different categories imply some degree of consensus among others as to who should assume leadership roles and who should have the chance to contribute to important collective tasks (Ridgeway & Correll 2006). Acting against such consensus bears the risk of social "backlash" (Ridgeway et al. 2009: 47) that can incur significant costs for the individual. This creates a subjective incentive to comply with the perceived consensus.

The emergence of consistent hierarchical differentiation between social categories

2.11 As highlighted earlier, Mark et al. (2009) focused on dyads as the smallest possible group in which hierarchical differentiation can emerge. If there are only two individuals and if these individuals differ in a salient social distinction, any hierarchy that emerges will consistently favor one of the two categories to which they belong. In larger groups, more complex hierarchical structures can emerge and these structures might undermine belief formation. Additionally, the outcome of an interaction among two group members not only affects the performance expectations that these group members have for each other; also the performance expectations of the remaining group members will be affected. To date, it has remained unexplored how this increased complexity affects status construction processes.

2.12 We expect that interaction in task focused groups, as described in the expectation states framework, has a tendency to create consistent hierarchical differentiation between members of different social categories, even in groups larger than dyads. More specifically, we expect that the structuring effects that behavior interchange patterns can have on interactions tend to create consistent hierarchical differentiation between members of different social categories. A thought experiment helps understanding why.

2.13 Imagine a group of six individuals, three belonging to category *A* and three belonging to category *B*. Assume that B_1 has made a suggestion for solving the task to A_1 and that after some arguing A_1 has accepted this suggestion. This establishes a behavior interchange pattern between them, which increases group members' performance expectations for B_1 and decreases their performance expectations for A_1, relatively to the rest of the group. As a consequence, the likelihood that B_1 will make a subsequent suggestion increases and when such a suggestion is directed at A_2 or A_3, it is more likely than before to be accepted. When this happens, the initial inequality among members of different categories, as observed in the interaction between A_1 and B_1, is reproduced and strengthened. Similarly, the likelihood that A_1 will make a subsequent suggestion decreases and when such a suggestion is directed at B_2 or B_3, it is more likely than before to be rejected. Also in this case, the initially observed inequality between members of different categories is reproduced and strengthened.

2.14 Evidently, the information that initially supports the belief that *B*s are more competent than *A*s is only based on the interaction between B_1 and A_1 and is thus not very comprehensive. Therefore it is not very likely to induce status beliefs among group members. However, as more *A*s are cast into lower hierarchical positions through their interactions with B_1, and as more *B*s are cast into higher hierarchical positions through their interactions with A_1, more information supporting the observed association becomes available, increasing the likelihood that group members will acquire a corresponding status belief.

2.15 In sum, we expect that the processes that can lead to hierarchical differentiation between individual group members have the tendency to create consistent hierarchical differentiation between members of different social categories and thereby facilitate the formation of status beliefs. However, our thought experiment disregards other possible interactions in the group, such as between B_2 and A_2/A_3 or between B_3 and A_2/A_3. Such interactions might lead to the development of subsequent behavior interchange patterns that further support or undermine the belief that *B*s are more competent than *A*s and the possible number of such interactions quickly increases with group size. Given this complexity, our intuitive reasoning leaves open how likely it is that consistent hierarchical differentiation between social categories arises from the fundamental behavioral processes that the expectation states framework describes and how this is affected by group size.

2.16 To shed more light on this, we developed an agent-based computational model that we submitted to systematic computational experiments. This approach is particularly useful for studying emergent properties of complex human interaction systems (Bonabeau 2002; Macy & Flache 2009) and has already provided valuable insights into status dynamics in small groups (for example see Lynn, Podolny & Tao 2009; Skvoretz & Fararo 1996). Our model builds on the notion that task focused interaction can be broken down into cyclic patterns (cf. Fisek et al. 1991) and draws on earlier formalizations of task focused interaction (Balkwell 1991a; Skvoretz & Fararo 1996). Panel (a) of Figure 1 illustrates the basic cycle that we use in our model. It starts with group members' mutual competence assessments that are represented by performance expectations. These expectations determine the probability that a given group member receives a performance opportunity, in the form of making a suggestion towards another group member. This suggestion, in turn, receives a performance evaluation in the form of acceptance or rejection by the receiver. The outcome of this evaluation can lead to the establishment of a behavior interchange pattern between the sender and the receiver of the suggestion. Subsequently, the structure of behavior interchange patterns feeds back into performance expectations and can lead to the formation of status beliefs among group members.

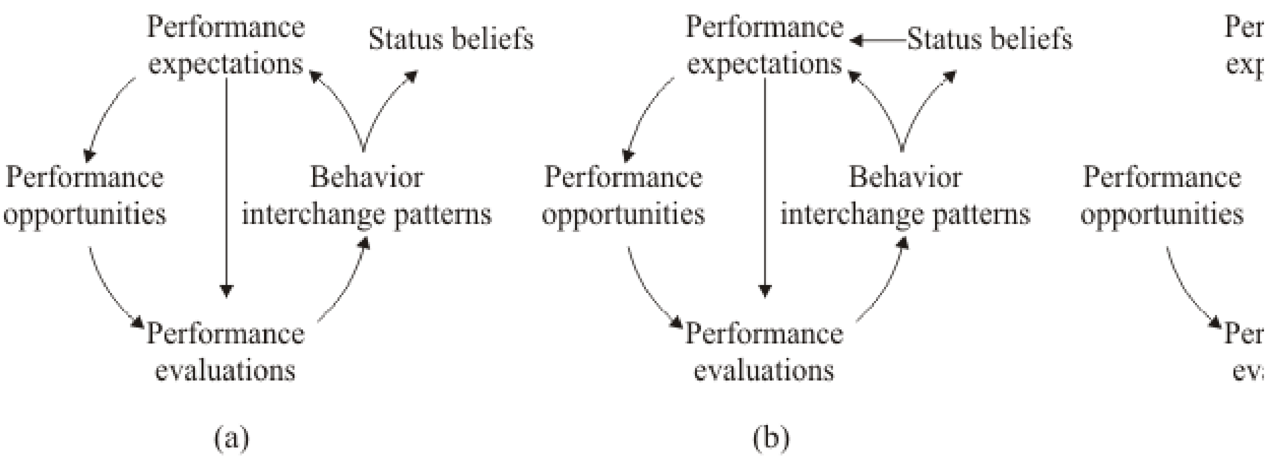


Figure 1. Conceptual representation of the interaction cycles used in three different versions of the model. Arrows indicate caus
model; panel (b): *extended interaction model*; panel (c): *random interaction model*.

2.17 One question that has not been addressed in SCT research so far is how status beliefs affect the interactions in the groups in which they have been acquired. That is, to the best of our knowledge, there are no studies that have examined how the experience of consistent hierarchical differentiation between, say, men and women in a given group affects the performance expectations that group members have for each other, if gender previously had no status value. If beliefs would affect performance expectations in the context in which they had been acquired, this might greatly contribute to the maintenance of the behavior interchange patterns that led to their emergence. In this way, status beliefs might contribute to their own reinforcement. For our core argument, such an additional reinforcing process is not necessary, because the argument relies on a reinforcing process induced by behavior interchange patterns alone. However, we cannot rule out the possibility that status beliefs might affect the performance expectations in the groups in which they have been acquired. We therefore also explore this possibility.

2.18 To do so, we implemented three versions of our model. Panel (a) in Figure 1 shows the model that enables us to test our basic argument. In this model, performance expectations are exclusively affected by behavior interchange patterns between individual group members. Status beliefs can emerge, but they do not affect performance expectations in the group in which they have been acquired. We call this the *basic interaction model*. Panel (b) shows a less conservative model in which status beliefs can affect performance expectations on top of behavior interchange patterns. We call this the *extended interaction model*. We assess the relative impact that behavior interchange patterns and status beliefs have on the likelihood with which consistent differentiation emerges by comparing the outcomes that the *basic interaction model* and the *extended interaction model* create with the outcome of a model in which performance expectations are unaffected by behavior interchange patterns and status beliefs. In this model, interactions essentially occur at random and this enables us to examine how much the behavioral principles that we study contribute to the likelihood that consistent differentiation emerges, over and above pure chance. This *random interaction model* is shown in panel (c). Earlier modeling work has used similar approaches to choose a baseline model for assessing how different social mechanisms affect social structures (cf. Skvoretz, Faust & Fararo 1996).

Modeling Task Focused Interaction

3.1 In this section we describe the agent-based model. It was implemented in NetLogo version 5.0.5 (Wilensky 1999). The model code can be downloaded here: https://www.openabm.org/model/4216/version/3. Table 1 and Table 2 provide an overview of the model's parameters and variables.

Table 1: Run-time settable model parameters

Parameter	Description
I	Number of agents in the group.
I_A, I_B	Number of agents in the group with the states A and B on the nominal social distinction N_i.
γ	Governs the effect that differences in agents' expectation standings E_i have on interaction probabilities in the group.
δ	Governs the effect that agents' expectation standings E_i have on the probability that the suggestion of a given agent i will be accepted/rejected by another agent j.
c	Threshold that r needs to pass for agents to acquire or maintain status beliefs.
a	Probability with which agents adopt a status belief when r ($-r$) passes the threshold c ($-c$).
l	Probability with which agents loose a status belief when r ($-r$) fails to pass the threshold c ($-c$).

Table 2: Agent-, dyad-, and group-level variables

Variable	Description	Level
N_i	Agent i's state on a nominal social distinction.	Agent
S_i	Agent i's status belief that indicates which state of N_i it believes to be associated with higher competence.	Agent
b_{ij}	A directed tie between i and j that represents a behavior interchange pattern between them. The direction and weight of b_{ij} indicates which of the two agents appeared more often in the higher competence role in their dyadic interactions.	Dyad
$\#neg_{ij}$, $\#pos_{ij}$	Pieces of information that agent i perceives to suggest that agent j is less (*neg*) or more (*pos*) competent than other group members.	Dyad
e_{ij}	Performance expectation that agent i has for agent j.	Dyad
e^*_{ji}	Average performance expectation that all group members have for agent i.	Group

E_i	Expectation standing that agent *i* has in the group.	Group
comp	Comprehensiveness of past interactions in the group that might be indicative of competence differences between members of the categories *A* and *B*.	Group
$\#b_{ij,A-}$, $\#b_{ij,A+}$, $\#b_{ij,A0}$	Number of behavior interchange patterns/ties b_{ij} in which members of category *A* took the lower (-), higher (+), or the same (0) competence role in their interactions with members of category *B*.	Group
cons	Consistency with which behavior interchange patterns/ties b_{ij} support different status beliefs.	Group
r	Measure of how much *comp* and *cons* together support different status beliefs.	Group

Agents and their characteristics

3.2 We assume groups with *I* individuals that are represented by agents *i*. There is one nominal social distinction N_i that separates agents into two categories, *A*s and *B*s ($N_i \in \{A;B\}$). This distinction can be imagined to represent gender with the categories man and woman, or skin-color with the categories white and black. The numbers of agents with each characteristic in a given group are indicated by I_A and I_B ($I = I_A + I_B$). Each agent has a status belief S_i related to this distinction that can take one of the three states *A*, *O*, and *B* ($S_i \in \{A;O;B\}$). When $S_i = A$ or $S_i = B$, agent *i* believes that agents with the corresponding state on N_i are more competent than agents with the other state; from here on we refer to agents with either state on S_i also as 'agents with status beliefs'. $S_i = O$ indicates that *i* does not believe that agents who differ in N_i also differ in competence; from here on, we refer to agents with this state on S_i also as 'agents without status beliefs'.

Performance expectations

3.3 Agents' performance expectations for each other can have two sources: behavior interchange patterns and status beliefs. In the *basic interaction model*, only behavior interchange patterns affect performance expectations. In the *extended interaction model*, behavior interchange patterns and status beliefs affect performance expectations. In the *random interaction model*, performance expectations are not affected by these factors and interactions occur at random.

3.4 A behavior interchange pattern is established between two agents whenever one of them accepts or rejects the suggestion of the other during discussion. For instance, when agent *i* for the first time directs a suggestion at agent *j* and *j* accepts this suggestion, a behavior interchange pattern becomes established in which *i* appears more competent than *j*. However, when *j* rejects this suggestion, *i* appears less competent than *j*. The more often their interactions cast one of them into the more competent position and the other in the less competent position, the more stable the behavior interchange pattern becomes and the more difficult it becomes to remove. That is, when in virtually all their past interactions agent *i* appeared more competent than agent *j*, a single interaction that contradicts this pattern is not enough to undermine the impression that *i* is generally more competent than *j*.

3.5 More technically, we model the structure of behavior interchange patterns in a group as a directed graph with weighted ties between agents. Whenever two agents interact for the first time, a tie b_{ij} is created between them. Initially b_{ij} is undirected and has a weight of 0. When the outcome of *i* and *J*s first interaction suggests that, say, *i* is more competent than *j*, b_{ij} becomes directed with *i* as the source and *j* as the sink and its weight becomes 1. Each subsequent interaction between *i* and *j* that supports the current behavior interchange pattern increases the weight of b_{ij} by 1; each subsequent interaction that contradicts the pattern decreases the weight by 1. When a tie takes the weight 0, which is the case when on average none of the two agents appeared more or less often competent, the tie becomes undirected again. When after this change one of the two agents appears in the higher competence role in the next interaction, the tie is assigned a new directionality and its weight is changed accordingly.

3.6 Status beliefs affect performance expectations (in the *extended interaction model*) so that, from *I*s point of view, expectations increase for those agents who belong to the category which it believes to be generally more competent. They decrease for those agents that belong to the category which *i* believes to be generally less competent. This also applies to *i* itself.

3.7 According to the expectation states framework, individuals tend to balance contradicting information from multiple behavior interchange patterns and status beliefs. In this balancing process, the weight of status beliefs is similar to the weight of a single behavior interchange pattern (Webster & Rashotte 2010). Furthermore, given a set of observations that suggest that a particular group member is (not) very competent, additional information that further supports this perception has a decreasing marginal effect on performance expectations. This has been referred to as the *attenuation effect* (Berger et al. 1977). Based on this, we calculate the performance expectation e_{ij} that agent *i* has for *j* at moment *t* as

$$e_{ij,t} = .8^{\#neg_{ij,t}} - .8^{\#pos_{ij,t}} \qquad (1)$$

where Eq. (1), $\#neg_{ij}$ and $\#pos_{ij}$ are pieces of information that, from *I*s point of view, imply that *j* has low or high competence respectively. Using $\#neg_{ij}$ and $\#pos_{ij}$ in the exponent with a base smaller than one implements the attenuation effect; the value of e_{ij} is restricted to the range $-1 < e_{ij} < 1$. Appendix A provides a detailed discussion of how we arrived at Eq. (1) based on existing research.

3.8 As indicated above, the three versions of our model differ in the pieces of information that affect performance expectations. In the *basic interaction model*, each behavior interchange pattern/tie b_{ij} in which *j* appears in the higher competence role increases the value of $\#pos_{ij}$ by one. Each pattern in which it appears in the lower competence role increases the value of $\#neg_{ij}$ by one. In the *extended interaction model*, $\#pos_{ij}$ additionally increases by one if *j* belongs to a social category that *i* believes to be generally more competent. Conversely, $\#neg_{ij}$ decreases by one if *j* belongs to a social category that *i* believes to be generally less competent. In the *random interaction model*, $\#neg_{ij}$ and $\#pos_{ij}$ are always equal to zero, so that all agents always have the same performance expectations for all group members.

3.9 Note that we assume that all agents perceive the behavior interchange patterns that develop in the group in the same way. In the *basic interaction model* the performance expectations that different group members have for a particular agent are thus the same. In the *extended interaction model*, these expectations can vary when there is variation in group members' status beliefs.

Performance opportunities and performance evaluations

3.10 Figure 1 illustrates that task focused interaction proceeds in two steps. First, one group member receives a performance opportunity in the form of directing a suggestion at another agent. Subsequently, the receiver of this suggestion makes a performance evaluation in which it either accepts or rejects the suggestion. Both the probability that a given agent makes a suggestion to a particular other agent and the probability that this suggestion is accepted or rejected by the receiver depend on the agents' relative expectation standings in the group. Those agents for whom group members on average have higher expectations than for the rest of the group are more likely to be involved in an interaction, either as the sender or receiver of a suggestion. They are also more likely to have their suggestions accepted by their interaction partners.

3.11 Technically, e^*_{ji} represents the average performance expectation that all group members, including *i*, have for *i*. We transform this value (non-linearly) to be positive and smaller thano 1.

$$E_{i,t} = \frac{\exp\left(e^*_{ji,\mathrm{t}}\right)}{1+\exp\left(e^*_{ji,\mathrm{t}}\right)} \qquad (2)$$

where E_i represents the expectation standing of agent *i* in the group. Based on this, in the *basic interaction model* and the *extended interaction model*, the sender of a suggestion is randomly selected from the set of all group members with a probability proportional to E^{γ}_i. Subsequently, the receiver of this suggestion is randomly selected from the set of remaining group members, also with a probability proportional to E^{γ}_i. In both cases, γ ($\gamma \geq 0$) is an exogenous weighting factor that enables us to control the extent to which interactions concentrate among the higher ranking group members. When $\gamma = 0$, performance expectations do not affect the interaction probabilities among agents and all group members are equally likely to be the sender or receiver of a suggestion. The larger γ becomes, the more likely it becomes that agents with higher expectation standings in the group become selected as senders or receivers of suggestions.[2] In the *random interaction model*, expectation standings have no effect on interaction probabilities and all agents are always equally likely to be selected as the sender or receiver of a suggestion.

3.12 After the sender *i* and receiver *j* of a suggestion have been selected, in the *basic interaction model* and the *extended interaction model* the probability that *j* accept *I*s suggestion is equal to $E^{\delta}_i/(E^{\delta}_i + E^{\delta}_j)$. The probability that *j* will reject *I*s suggestion is equal to $1 - E^{\delta}_i/(E^{\delta}_i + E^{\delta}_j)$. In both cases, δ ($\delta \geq 0$) is an exogenous weighting factor that enables us to control the extent to which performance expectations affect interactions. When $\delta = 0$, differences in the performance expectations that group members have for *i* and *j* do not affect their interaction, so that *j* is equally likely to accept or to reject *I*s suggestion. The larger δ becomes, the more a difference between E^{δ}_i and E^{δ}_j to the advantage (disadvantage) of *i* increases the probability that *j* will accept (reject) *I*s suggestion.[3] Note that we use here the expectation standings (E_i) of *i* and *j*, rather than the performance expectations (e_{ij}) that *i* and *j* personally have for each other. This implements the notion that group members tend to take the performance expectations of other group members into account when interacting with each other. In the *random interaction model*, expectation standings have no effect on the outcomes of interactions, so that suggestions are always equally likely to be accepted or rejected.

Formation of status beliefs

3.13 Status beliefs can emerge from comprehensive and consistent behavior interchange patterns between members of different social categories. A comprehensive and consistent association between behavior interchange patterns and differences in the social distinction makes it possible that group members acquire corresponding status beliefs. However, if comprehensiveness and/or consistency are low, group members acquire no such beliefs and even might lose existing beliefs.

3.14 We capture the comprehensiveness of the observed structures with the measure *comp* ($0 \leq comp \leq 1$). This measure is calculated as the number of dyads of agents who differ in the social distinction and who have interacted already (i.e. the number of ties b_{ij} between group members who differ in N_i, regardless of the weight of these ties), divided by the total number of dyads of agents who differ in the social distinction (regardless of whether they have already interacted or not). With this approach, the interactions between two group members who differ in N_i provides only a fraction of the information that is potentially available for evaluating competence differences between members of the different categories in larger groups. Accordingly, if only two group members who differ in N_i have interacted so far, the value of *comp* will be low in larger groups. However, its value increases as the number of such interactions increases. It reaches its maximum when all members of the two categories in the group have interacted at least once with each other.

3.15 We capture the consistency of the observed interaction structures with the measure *cons* ($-1 \leq cons \leq 1$). This measure is based on the interactions that have occurred between agents who differ in the social distinction. It assesses whether agents who belong to category *A* appeared more often in the higher or lower competence role in their interactions with agents who belong to category *B*. More technically, we model *cons* as

$$cons_t = \frac{\#b_{ij,A-,t} - \#b_{ij,A+,t}}{\#b_{ij,A-,t} + \#b_{ij,A0,t} + \#b_{ij,A+,t}} \tag{3}$$

where $\#b_{ij,A-}$ and $\#b_{ij,A+}$ are the number of behavior interchange patterns/ties in which agents who belong to the category $N_i = A$ appear in the lower (−) or higher (+) competence role in their interactions with members of the category $N_i = B$ (as indicated by the directions of the ties between them); $\#b_{ij,A0}$ represents behavior interchange patterns which are balanced, so that both agents appear similarly competent. The closer *cons* comes to −1, the more often members of the category $N_i = A$ appear in the higher competence role; the closer it comes to 1, the more often members of category $N_i = B$ appear in the higher competence role.

3.16 Together *comp* and *cons* determine how strongly the structure of behavior interchange patterns in the group supports a status belief. We express this support with the measure r ($-1 \leq r \leq 1$), which relates to *comp* and *cons* in the following way:

$$r_t = \frac{r_{t-1} + (comp_t * cons_t)}{1 + comp_t} \tag{4}$$

Eq. (4) implies that r approaches its minimal or maximal value only when the structure of behavior interchange patterns is maximally consistent (*cons* = −1 or *cons* = 1) and maximally comprehensive (*comp* = 1). When $r = -1$, the observed structure maximally supports the belief that members of category $N_i = A$ are more competent than members of category $N_i = B$. When $r = 1$, the observed structure maximally supports the belief that members of category $N_i = B$ are more competent than members of category $N_i = A$. Note that Eq. (4) creates some time lag in the effect that observed behavior interchange patterns have on r. This implements the notion that when a particular status belief has been supported for some time, new information that contradicts it might initially be conceived as a merely coincidental deviation from well-established hierarchical structures (cf. Ridgeway 2000).

3.17 Finally, there is a chance that agents acquire (and maintain) a status belief when the observed structure of behavior interchange patterns sufficiently supports it. We assume that agents perceive a given belief as sufficiently supported when the value of r crosses the threshold c (with $0 < c \leq 1$), either in the negative or positive direction. For instance, when at time t the value of r is smaller than or equal to $-c$, then the belief $S_i = A$ is sufficiently supported and agents who currently hold no status belief acquire this belief with probability a (with $0 < a \leq 1$). Yet, when at time t the value of r is larger than $-c$, then the belief $S_i = A$ is not sufficiently supported and agents who currently hold this belief loose it with probability l ($0 < l \leq 1$). Similarly, when r is larger than or equal to c, then agents who currently hold no status belief adopt the belief $S_i = B$ with probability a; when r is smaller than c, agents who currently hold this belief loose it with probability l. This implies that agents who hold a status belief that is not sufficiently supported anymore always need to make the transition through $S_i = O$ before they can acquire a new belief.[4]

The temporal ordering of interactions

3.18 In our model, group interaction takes place in iterations that consist of five steps that emulate the cycles shown in Figure 1:

1. Update the performance expectations of all agents.
2. Select a sender and a receiver of a suggestion.
3. Determine the reaction of the receiver.
4. Update behavior interchange patterns.
5. Update status beliefs of all agents.

3.19 In the *basic interaction model*, the outcome of step (4) at t is the basis of step (1) at t+1. In the *extended interaction model*, the outcomes of steps (4) and (5) at t are the basis of step (1) at t+1. In the *random interaction model*, the outcomes of steps (4) and (5) do not feed back into step (1). Appendix B provides a description of the simulation process in pseudo-code.

Computational Experiments

4.1 We aimed to assess the proposition that task focused interaction in small groups has the tendency to create consistent hierarchical differentiation between members of different social categories and thereby leads to the emergence of status beliefs, even in groups larger than dyads. We assessed this proposition in two experiments. In the first (main) experiment, we assessed whether status construction processes can lead to the emergence of consistent hierarchical differentiation and status beliefs under realistic interaction conditions. We also assessed how emergence is affected by group size, the duration of group interaction, and the possibility that status beliefs affect performance expectations in the context in which they have been acquired. In the second experiment, we conducted sensitivity analyses in which we aimed to assess how much model outcomes depend on the exact selection of parameter values.

4.2 In all experiments, we focused on groups of sizes $I = 2$, $I = 4$, $I = 6$, $I = 8$, and $I = 10$. The members of these groups were equally divided into the two categories $N_i = A$ and $N_i = B$ (i.e. $I_A = I_B = .5I$) . Initially no agent held a status belief (i.e. all $S_i = O$) and no behavior interchange patterns were established between them. In real life, groups might interact over varying time frames. We let agents interact for 2,000 iterations. This seemed long enough to emulate groups that in real life would interact over a long period. Yet, to be able to inspect developments over shorter time frames, we recorded outcomes after each iteration.

4.3 In the first experiment, we fixed the parameters that govern the concentration of interactions among higher status group members (γ) and the effect that status differences have on the acceptance and rejection of suggestions (δ) to the values 2.5 and 1 respectively. In the *random interaction model* and the *basic interaction model* this parameterization creates interaction conditions that are in line with our theoretical arguments and observations in empirical research (for example see Balkwell 1991a; Skvoretz & Farraro 1996). That is, with this parameterization, differences in expectation standings among group members lead to differences in the probability with which they will be the initiator or receiver of a suggestion, to the benefit of individuals with higher expectation standings. Furthermore, the suggestions of individuals with higher expectation standings are more likely to be accepted than suggestions of individuals with lower expectation standings. We had no primary interest in the effects of the threshold parameter (c), the probability that agents acquire beliefs (a), and the probability that they lose beliefs (l). We therefore fixed these parameters at intermediate values of $c = a = l = .5$. We focused on three outcomes and compared them across all three model versions (i.e. *random interaction model*, *basic interaction model*, and *extended interaction model*). First, we assessed the extent of consistent hierarchical differentiation between members of different social categories with the absolute value of *cons*. Second, we assessed the stability of consistent hierarchical differentiation over time by the number of times the value of *cons* changed its sign during group interaction (i.e. how often *cons* changed from *cons* ≤ 0 to *cons* > 0 or from *cons* ≥ 0 to *cons* < 0). Third, we assessed the overall tendency for status beliefs to emerge with the largest share of group members that held the same status belief (i.e. the largest set of agents with the same state on S_i that is $S_i \neq O$).

4.4 In the second experiment, we first tested how variation in the parameters γ and δ affects model outcomes. We only examined this for the *basic interaction model* and the *extended interaction model*, given that these parameters have no effect on interactions in the *random interaction model*. Subsequently, we assessed how variation in the parameters c, a, and l affects the outcomes of the *extended interaction model*, given that this is the only model in which they can affect the interactions among agents.

4.5 In order to convey a better understanding of the dynamics that our model generates, we start with presenting the outcomes of two exemplary simulation runs. For these runs, we used the *extended interaction model* to illustrate the full range of dynamics that can occur.

Exemplary simulation runs

4.6 Figure 2 shows the outcome of two simulation runs that ended with some level of consistent hierarchical differentiation between the members of the two categories. In both runs, there were six group members who interacted for 200 iterations. The trace plot in panel (b) shows the development of consistent hierarchical differentiation between members of the two categories (*cons*) over time. Panels (a) and (c) show snapshots of the structure of behavior interchange patterns that developed in the two groups.

4.7 After the first ten iterations of the first run (shown in panel (a)), one member of category *B* appeared unambiguously more competent in its interactions with two members of category *A*. By contrast, other members of category *B* and members of category *A* appeared more, less, and equally competent in interactions with members of the respective other category. As the trace plot in panel (b) shows, an initial advantage for members of category *B* led to a high level of consistency. This consistency decreased when some behavior interchange patterns became established in which members of category *A* appeared more or equally competent as members of category *B*. However, the initial advantage of members of category *B* induced a corresponding status belief in some group members. These beliefs fed back into interactions, so that by iteration 200 more comprehensive structures had become established that still supported the belief $S_i = B$.

4.8 In the second run (shown in panel (c)), by iteration 10, the structure of behavior interchange patterns was less mixed than in the first run and was to the advantage of members of category *A*. Over time, this initial advantage became stronger.

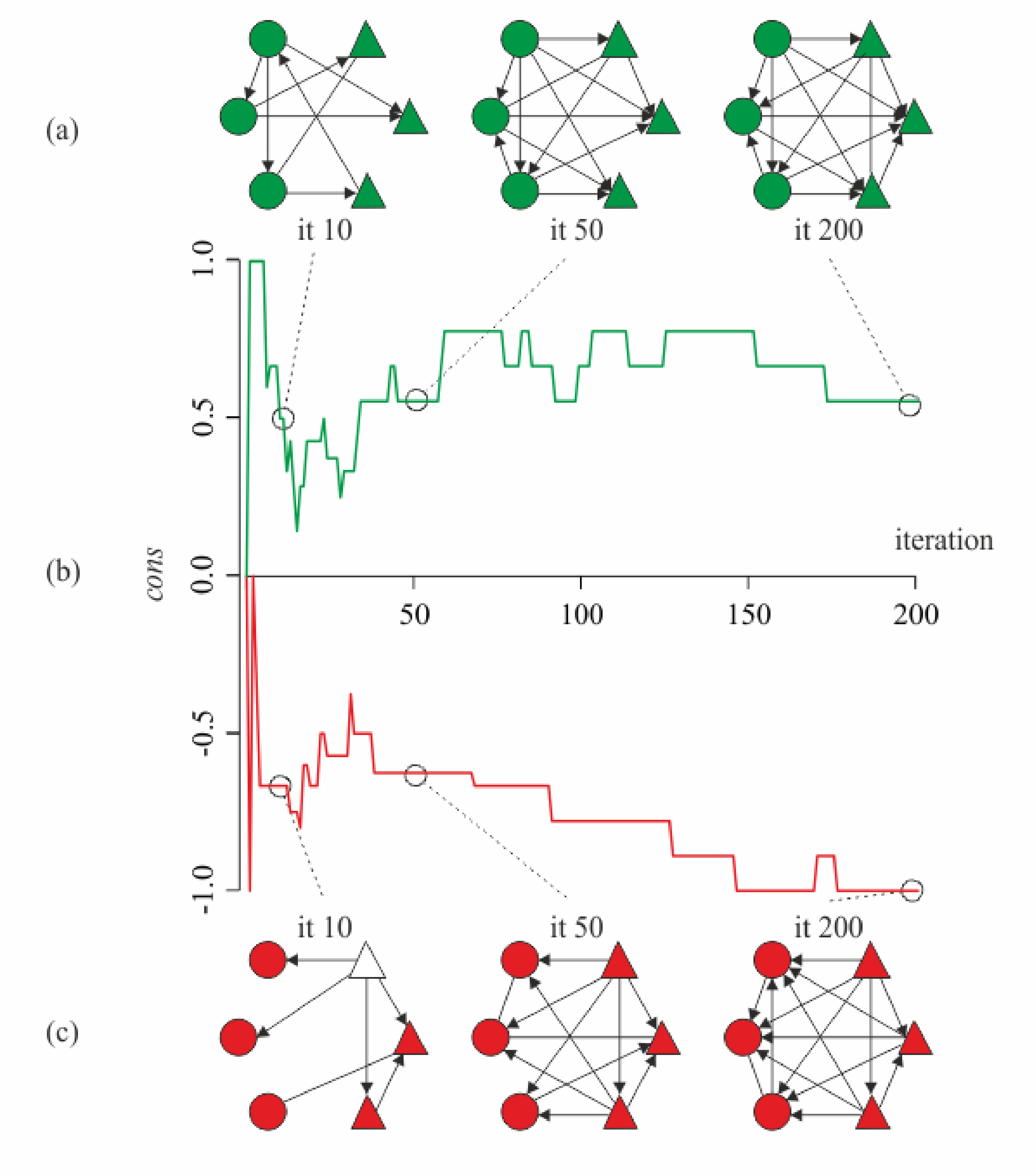


Figure 2. Development of consistency of hierarchical differentiation (*cons*) in two exemplary simulation runs in the *extended interaction model* over 200 iterations. Parameter setting: $I = 6$, $I_A = I_B = .5I$, $\gamma = 2.5$, $\delta = 1$, $c = a = l = .5$. Triangles and circles represent agents for which $N_i = A$ and $N_i = B$ respectively. Red, white, and green coloring of agents represent $S_i = A$, $S_i = O$, and $S_i = B$ respectively. A directed tie between agents indicates that a behavior interchange pattern (b_{ij}) had been established, in which the source appears in the higher competence role and the sink appears in the lower competence role; undirected ties indicate balanced interactions. Panels (a) and (c): snapshots of behavior interchange patterns; panel (b): level of consistent hierarchical differentiation between members of different social categories.

4.9 The outcomes of these exemplary simulation runs show that task focused interaction can over time lead to the creation of stable hierarchical structures. These structures can be aligned with differences in a social distinction among group members. Our computational experiments enabled us to assess how likely this is to happen and to assess whether this likelihood depends on group size, time frame, and on the version of the model that is used.

Outcome of main experiment

4.10 Figures 3 to 5 show the outcomes of our computational experiments that aimed at assessing the emergence of consistent hierarchical differentiation and status beliefs based on realistic interaction probabilities. The figures suggest that the behavioral processes that the *basic interaction model* and the *extended interaction model* implement have the tendency to induce consistent hierarchical differentiation between members of different social categories and this differentiation leads to the emergence of status beliefs. This tendency is stronger in smaller groups and in the early and late phases of group interaction. Especially for larger groups, the behavioral principles that the *basic interaction model* and the *extended interaction model* implement make an important difference. In larger groups, the *random interaction model* on average hardly leads to belief emergence. The *basic interaction model* and the *extended interaction model*, by contrast, generate substantial amounts of belief emergence.

4.11 To illustrate the foregoing results, consider first the relation between group size and consistent hierarchical differentiation shown in Figure 3. Increasing group size beyond size two had a strong negative effect on the average level of consistent hierarchical differentiation in all models. This negative effect was strongest in the *random interaction model*, followed by the *basic interaction model*, and the *extended interaction model*. In groups larger than dyads, the average level of consistent differentiation was initially higher in the *extended interaction model* than in the *basic interaction model*, but this difference decreased as group size increased. The difference disappeared almost completely for groups of size 10.

4.12 The generally negative effect of group size on the level of consistency can be attributed to the fact that in larger groups there is a larger possibility for interactions among members of different categories to contradict each other. Additionally, status accumulation tends to be weaker than in smaller groups. The reason is that in larger groups interactions are often spread over a larger number of individuals. This makes it less likely that few, highly dominant actors emerge who might strongly influence patterns of differentiation to the benefit of their own category. This is illustrated by Figure 4, which shows that the average number of sign changes in *cons* tended to be higher in larger groups. This indicates that the hierarchical structures that emerge in larger groups tend to be less stable than in smaller groups.

4.13 The convergence of the outcomes of the *basic interaction model* and the *extended interaction model* with increasing group size can be attributed to the fact that in larger groups status beliefs contribute relatively less to performance expectations. In a group of size four, for example, a single individual can appear in the higher competence role in up to 3 behavior interchange patterns. In a group of size ten, by contrast, this number increases to 9. Given the attenuation effect implemented in Eq. (1), the relative amount of information that status beliefs add to performance expectations in groups of size ten therefore tends to be lower than in groups of size four. Status beliefs thus tend to have less effect on hierarchy formation in larger groups than in smaller groups.

4.14 Figure 3 shows that there was an initial peak in consistency in the early phases of interactions in groups larger than two. In the *basic interaction model* and the *extended interaction model*, this peak was followed by a decrease and subsequent increase in consistency. In the *random interaction model*, the peak was followed by a decrease that led to a comparatively stable, low value of consistency. The initial peak that occurred in all models can be explained by the fact that in the early phases of group interaction only few group members will have interacted with each other. This leaves little room for interaction patterns that might contradict initial differentiation between members of the two categories. The longer the group interacts, however, the more likely there is contradicting information that leads to a decrease in consistency. The subsequent increase after this initial decrease in the *basic interaction model* and the *extended interaction model* is due to the fact that in these models status accumulation processes can occur over time. These processes tend to reinforce any slight advantage to the benefit of one category and thereby contribute to the consistency of observed behavior interchange patterns. In the *random interaction model* no such reinforcing processes exist and the average level of consistency thus tends to be low after some interactions have taken place.

4.15 Note that across model versions the level of consistent hierarchical differentiation was especially high in dyads. However, in the *random interaction model*, there was more fluctuation in this outcome over time than in the *basic interaction model* and the *extended interaction model*. The generally high level of consistency across model versions can be explained by the fact that in groups of size two any hierarchical differentiation is necessarily fully consistent with differences in the social distinction. The fluctuation in the *random interaction model* is due to the fact that interactions occur at random, which means that the history of interactions between group members sometimes will be balanced. This implies that occasionally there is no hierarchical differentiation between them and this tends to decrease the average absolute value of *cons* across simulation runs. The processes that the *basic interaction model* and the *extended interaction model* implement, by contrast, lead to more stability in hierarchical differentiation, even in groups of size two.

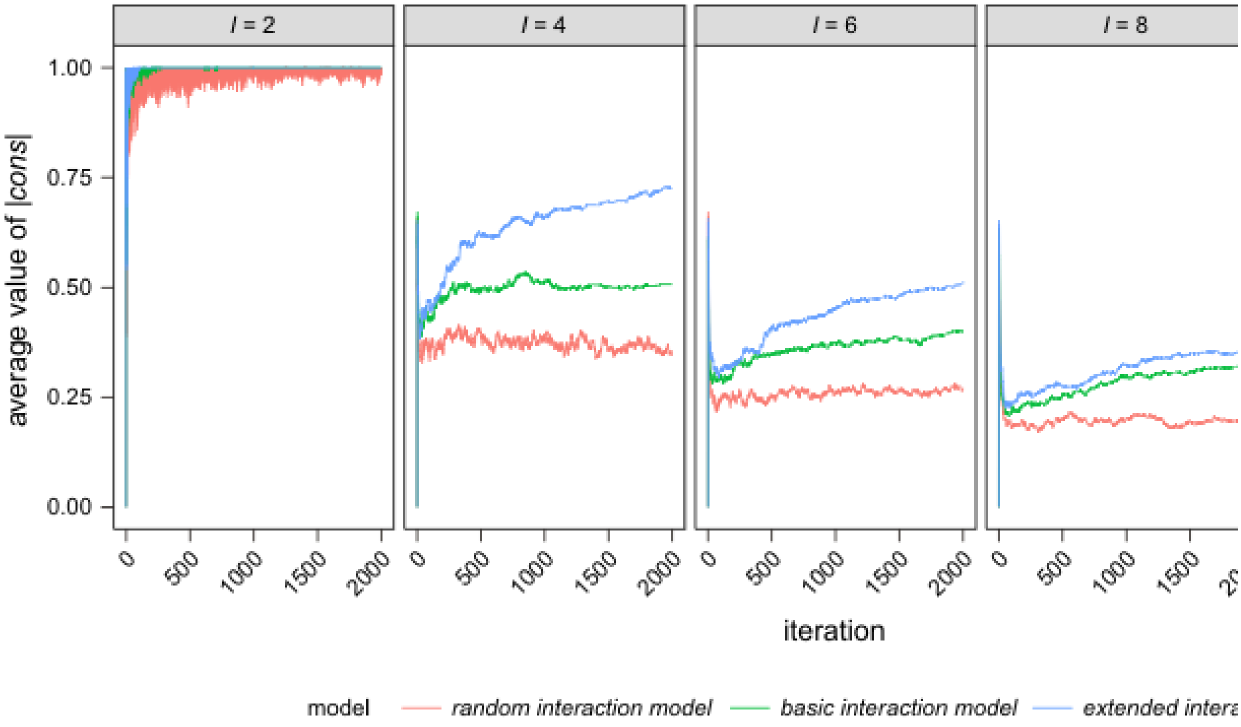


Figure 3. Average consistency of hierarchical differentiation (average value of |*cons*|) for different group sizes (*l*) in all model Parameter setting: $l_A = l_B = .5l$, $\gamma = 2.5$, $\delta = 1$, $c = a = l = .5$. Averages are based on 200 independent simulation

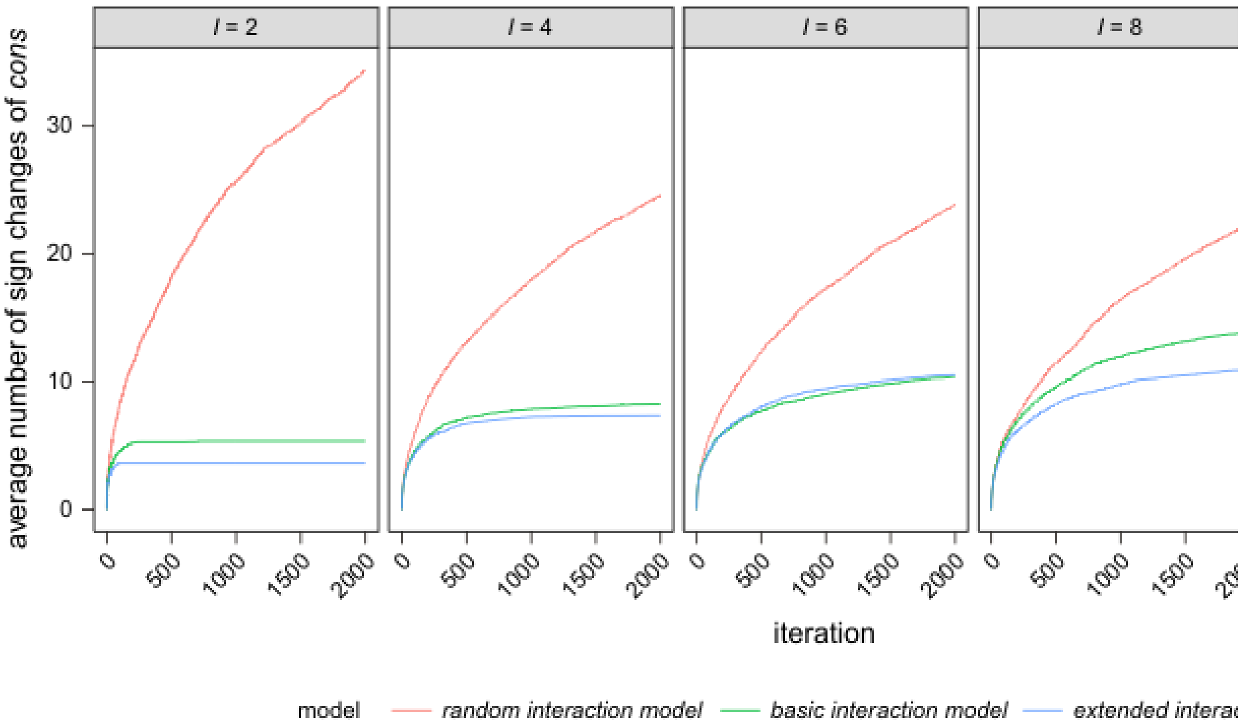


Figure 4. Average number of changes in the sign of *cons* for different group sizes (*l*) in all model versions over 2,000 iterations. 2.5, $\delta = 1$, $c = a = l = .5$. Averages are based on 200 independent simulation runs per conditior

4.16 Consider next the average largest share of agents that held a status belief, shown in Figure 5. The results parallel the results for the level of consistent hierarchical differentiation shown in Figure 3, given that belief emergence is linked to the level of consistent hierarchical differentiation. That is, the largest share of agents who hold a status belief shortly peaked in the early phases of the simulation process. In the case of the *random interaction model*, this peak was followed by a decrease that, over time, leveled off to a stable, low value. In the cases of the *basic interaction model* and the *extended interaction model*, by contrast, the peak was followed by a temporary decrease and a subsequent increase. Over time, the increase leveled off to a stable value that was higher than in the *random interaction model*. The most striking finding is the fact that in larger groups, the *random interaction model* on average hardly led to the emergence of status beliefs. By contrast, in the *basic interaction model* and the *extended interaction model*, there was a substantial probability that agents acquire status beliefs, especially in later stages of group life. This implies that, given the parameterization chosen here, the behavioral process that these models implement make the emergence of status beliefs more likely.

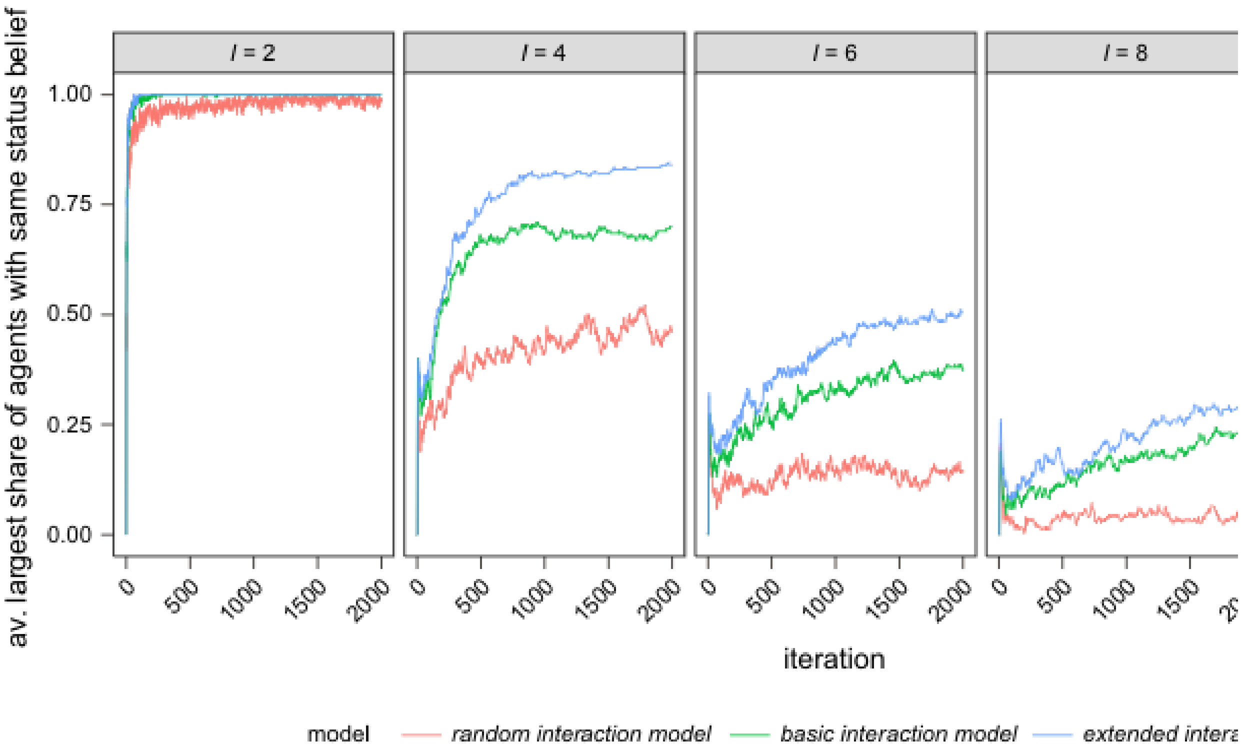


Figure 5. Average largest share of agents with the same status belief ($S_i = A$ or $S_i = B$) for different group sizes (l) in all mode

Parameter setting: $l_A = l_B = .5l$, $\gamma = 2.5$, $\delta = 1$, $c = a = l = .5$. Averages are based on 200 independent simulation

Outcome of sensitivity analyses

4.17 Figures 6 and 7 show the outcome of our sensitivity analyses that focused on the parameters that govern the concentration of interactions among higher status group members (γ) and the effect that status differences have on the acceptance and rejection of suggestions (δ). For brevity, we only show the average absolute level of consistency of hierarchical differentiation and the largest share of agents with the same status belief after 2,000 iterations. Furthermore, the results in terms of consistency (Figure 6) and belief emergence (Figure 7) are very similar, because belief emergence is linked to consistency for a given set of values for c, a, and l. We therefore only discuss the results for the consistency of hierarchical differentiation in detail. For illustrative purposes, we also show the outcome of the *random interaction model* after 2,000 iterations from the main experiment. Note that in this model interaction dynamics cannot be affected by the parameters γ and δ. We therefore use the same comparison value across different conditions given a certain group size l.

4.18 Figure 6 suggests that in dyads the parameters γ and δ had little effect on model outcomes. Only when δ was 0, the average absolute level of *cons* tended be somewhat lower than 1. The reason is that in this case, differences in expectation standings between group members cannot affect the likelihood with which they will accept/reject each other's suggestions. This means that the outcome of their interactions is determined completely at random. As a consequence, the behavior of the *basic interaction model* and the *extended interaction model* becomes similar to the behavior of the *random interaction model*. Figure 6 suggests that this similarity also occurs in groups larger than two. That is, when $\delta = 0$, the outcomes of the *basic interaction model* and the *extended interaction model* hardly differed from the outcomes of the *random interaction model*. The value of γ had no effect on this similarity. It should be noted though that such a parameterization would be inconsistent with the theoretical assumptions that we want to implement with this model, given that under this condition differences in expectation standings among group members do not affect the likelihood with which their suggestions will be accepted.

4.19 When the value of δ was larger than 0, the *basic interaction model* and the *extended interaction model* created higher levels of consistency than the *random interaction model*. Furthermore, the difference between the *basic interaction model* and the *extended interaction* model depended on how much δ was larger than 0, especially in larger groups. The potential reasons for this are the weaker tendency towards status accumulation in larger groups and the relatively smaller differences that status beliefs create in expectation standings in such groups. Under such conditions, even small status differences (as induced by status beliefs) need to have a strong impact on interactions (i.e. higher values of δ are required) in order to increase consistency.

4.20 Furthermore, the value of γ generally had little effect on model outcomes. A possible reason for this is that values of $\delta > 0$ make it more likely that agents who have a status advantage will maintain this advantage in subsequent interactions. Thus, any interaction across the boundary of the social distinction that involves status advantaged and status disadvantaged actors is likely to bolster existing status differences. As a consequence, it matters relatively little whether or not interactions are concentrated among higher status group members.

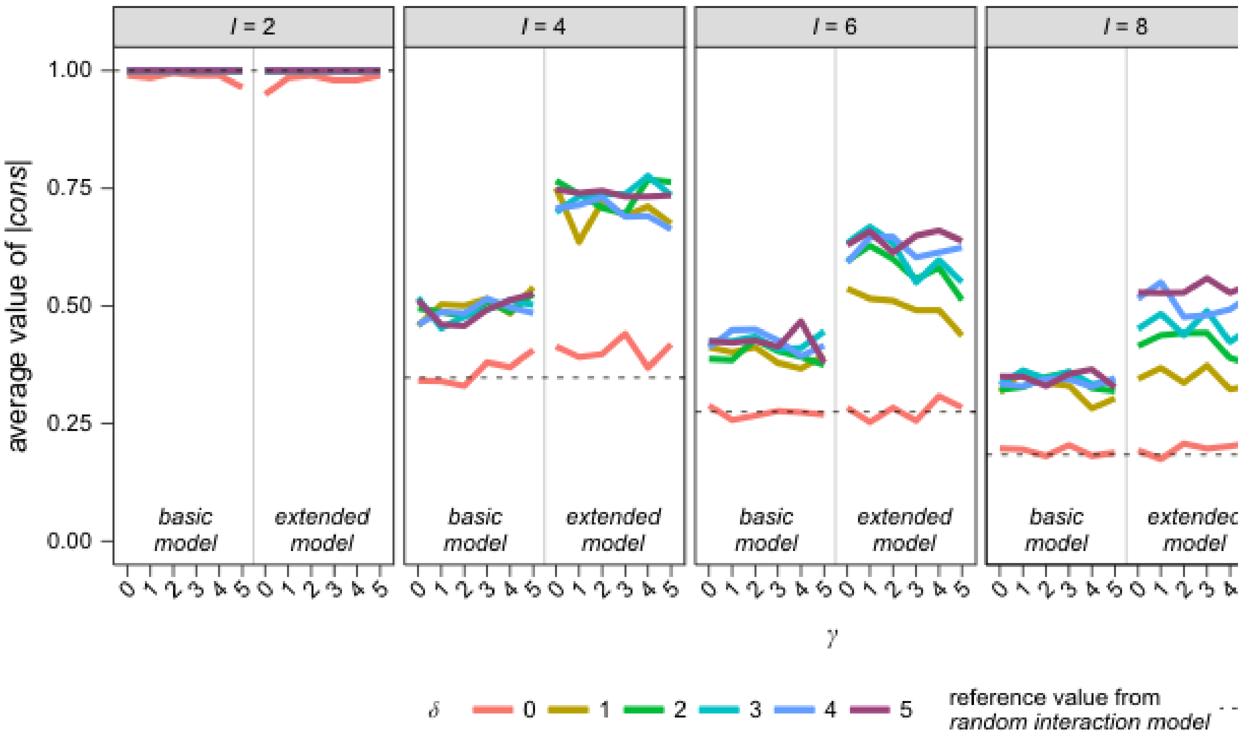


Figure 6. Average consistency of hierarchical differentiation (average value of |*cons*|) for different group sizes (l), different leve among higher status group members (γ), and different levels of the effect that status differences have on the acceptance and reje *interaction model* and the *extended interaction model* after 2,000 iterations. Parameter setting: $l_A = l_B = .5l$, $c = a = l = .5$. Averag simulation runs per condition. The dotted line provides the average outcome of the *random interaction model* after 2,000 iterat reference value.

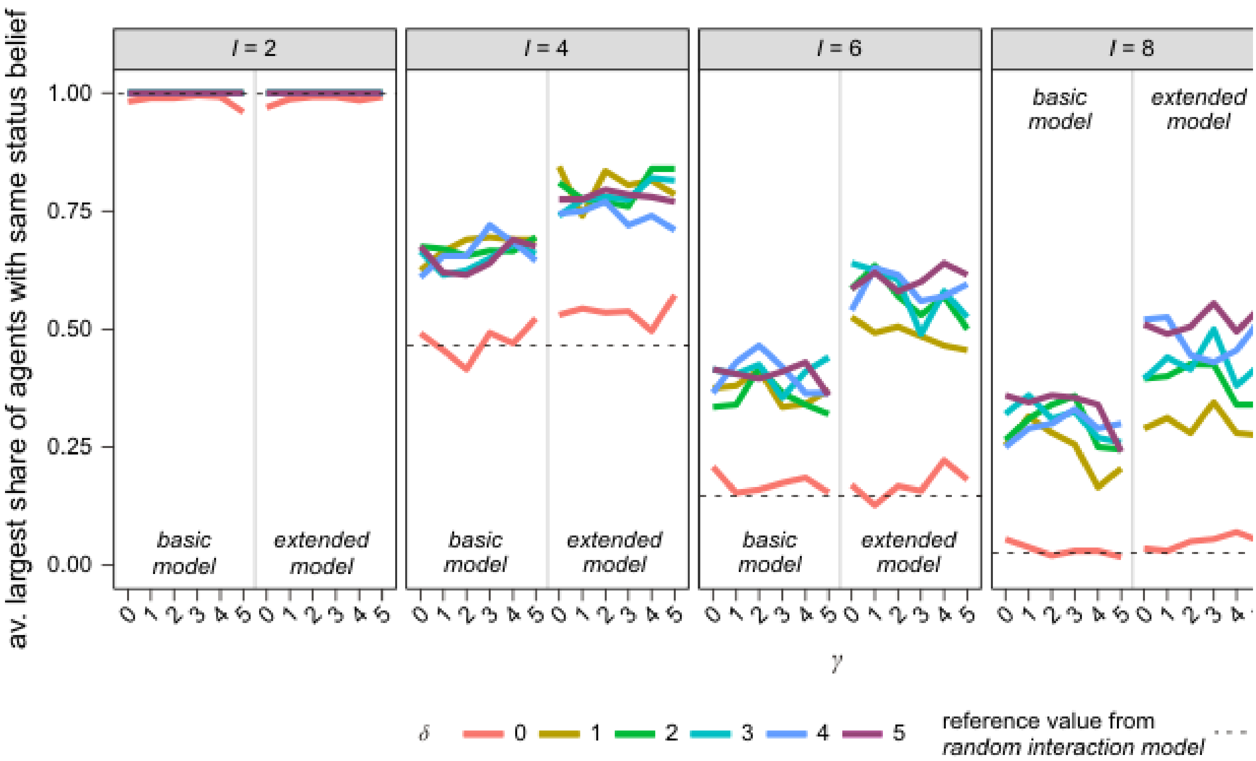


Figure 7. Average largest share of agents with the same status belief ($S_i = A$ or $S_i = B$) for different group sizes (I), different leve among higher status group members (γ), and different levels of the effect that status differences have on the acceptance and reje *interaction model* and the *extended interaction model* after 2,000 iterations. Parameter setting: $I_A = I_B = .5I$, $c = a = l = .5$. Averag simulation runs per condition. The dotted line provides the average outcome of the *random interaction model* after 2,000 iterat reference value.

4.21 Figures 8 and 9 show the effect that variation in the threshold parameter (c) and in the parameters that govern belief acquisition (a) and loss (l) had on model outcomes. In the case of consistency (Figure 8) we also show the outcome of the *random interaction model* after 2,000 iterations from the main experiment. Again, this comparison value is stable across conditions for a given group size I, given that c, a, and l cannot affect interactions in this version of the model. In the case of the largest share of agents with the same status belief (Figure 9), by contrast, we show comparison values from simulation runs based on the *random interaction model* at different values of c, a, and l. The reason is that these parameters can affect belief emergence in this model, even if beliefs cannot affect interactions.

4.22 The results shown in Figure 8 suggest that only c had an effect on model outcomes in terms of consistent hierarchical differentiation, by reducing the average absolute level of *cons*. The reason is that when c is high, the consistency of hierarchical differentiation in a group needs to be high before agents can acquire status beliefs. When a group has reached this state, there is little room left for status beliefs to contribute to even higher levels of consistency. Similarly, the results shown in Figure 9 suggest that that only c had an effect on model outcomes in terms of belief emergence. Generally, the more consistent hierarchical differentiation needs to favor one of the two categories before agents can acquire (or maintain) status beliefs, the less likely beliefs are to emerge in both the *random interaction model* and the *extended interaction model*. Yet, at a given level of c, the processes that the *extended interaction model* implements still made belief emergence more likely than in the *random interaction model*, unless both group size and the threshold parameter were comparatively large/high (i.e. $I = 10$ and $c = .75$).

4.23 Taken together, the results of our sensitivity analyses suggest that our main findings hold over a large area of the parameter space. If δ is larger than 0, the *basic interaction model* and the *extended interaction model* tend to create higher levels of consistency than the *random interaction model*. The larger δ becomes, the stronger this tendency becomes in the *extended interaction model* compared to the *basic interaction model*, especially in larger groups. Higher values of c tend to decrease the levels of consistency and belief emergence in the *extended interaction model*, but still this model tends to show higher average levels of both outcomes than the *random interaction model* for most parameter combinations.

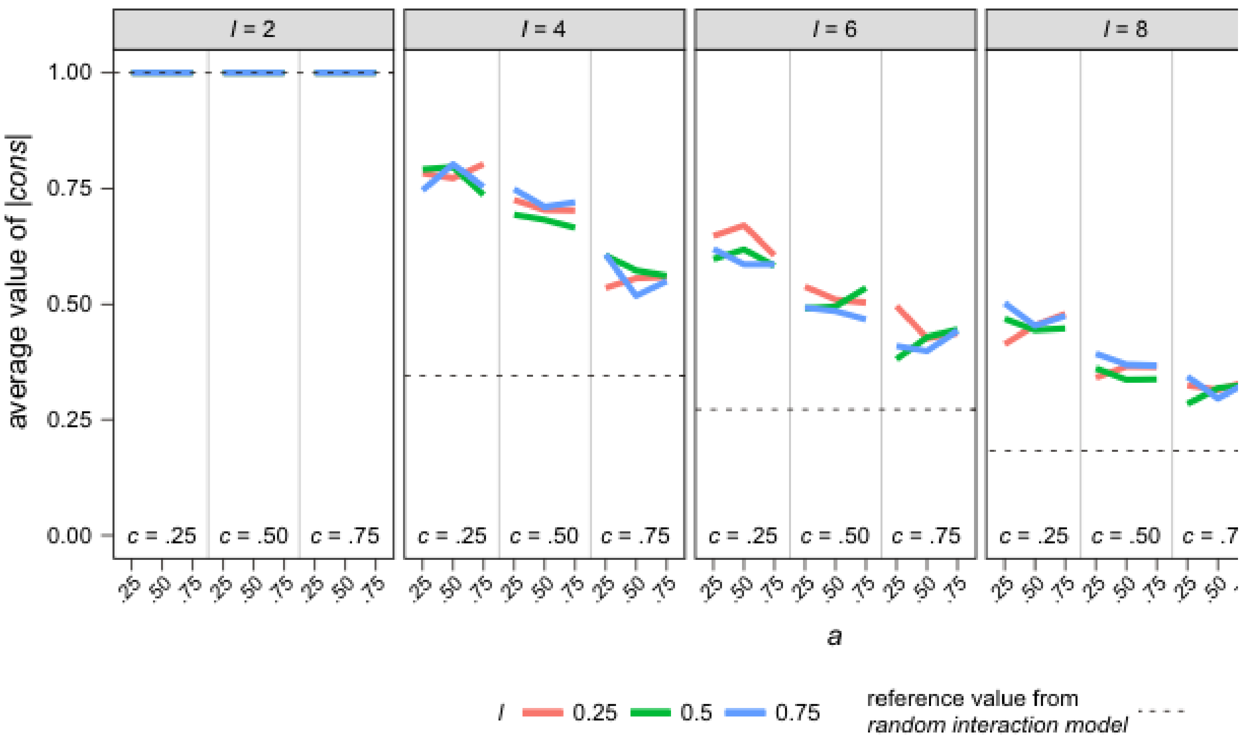


Figure 8. Average consistency of hierarchical differentiation (average value of |*cons*|) for different group sizes (I), different levels ((c), and different probabilities that belief acquisition (a) or loss (l) occur in the *extended interaction model* after 2,000 iterations. 2.5 and $\delta = 1$. Averages are based on 200 independent simulation runs per condition. The dotted line provides the average outc after 2,000 iterations in the main experiment as a reference value.

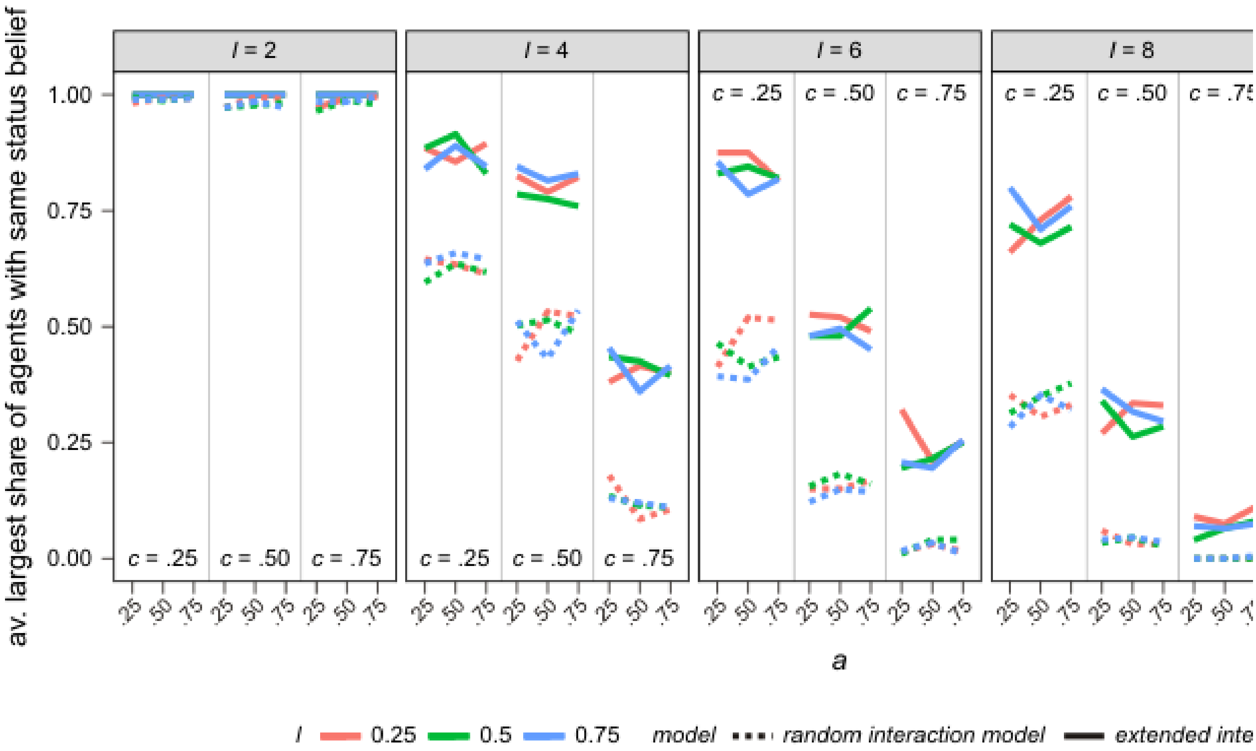


Figure 9. Average largest share of agents with the same status belief ($S_i = A$ or $S_i = B$) for different group sizes (l), different l
acquisition (c), and different probabilities that belief acquisition (a) or loss (l) occur in the *random interaction model* and the *exte*
iterations. Parameter setting: $l_A = l_B = .5l$, $\gamma = 2.5$ and $\delta = 1$. Averages are based on 200 independent simulation

Discussion and Conclusion

5.1 We contributed to research on the social construction of status characteristics by investigating how interaction in task focused groups larger than dyads can create the conditions necessary for the emergence of status beliefs. Earlier research suggests that the observation of consistent hierarchical differentiation between members of two different social categories can create the belief that members of one category are more competent than members of the other category, even when this objectively is not the case. Based on related research in the expectation states framework, we have developed an agent-based computational model that enabled us to examine the conditions under which task focused interaction might spontaneously create such consistency and thereby might lead to the emergence of stats beliefs.

5.2 Our computational experiments suggest that small group interaction might have a tendency to spontaneously create consistent hierarchical differentiation between members of different social categories, even in groups larger than dyads. This tendency might even exist when status beliefs do not affect performance expectations in the contexts in which they have emerged. Moreover, the emergence of consistent differentiation might be more likely in smaller groups than in larger groups, and in groups that interact for a very short or very long time. Finally, as groups become larger, the reinforcing effect that newly created status beliefs can have on consistent hierarchical differentiation might become weaker.

5.3 Our study shows that task focused interaction in small groups might be a potent force in the creation of status beliefs, also if groups contain more than two members. Future research can build on and extend our model in several ways. First, we have not investigated the mechanisms related to status beliefs crossing group boundaries. Future research might investigate how the processes involved in the creation of status beliefs, as presented here, relate to their diffusion throughout society. To this end, the simulation model could be extended to include a larger number of agents that can join/leave different groups of different sizes for different durations.

5.4 Second, in line with existing research in SCT, we have focused on social distinctions that create two categories of individuals. In real life, group members might be differentiated by social distinctions that create more than two categories and this might increase the complexity of the interactional dynamics that unfold. Extending our model to allow for more than two categories could provide researchers with a lever to study the implications of this additional complexity. However, it is important to note that to date there is little knowledge about the cognitive processes that underlie status construction processes in the presence of more than two categories. Including the notion that there can be more than two categories should therefore proceed in close interaction with empirical research.

5.5 Third, similar to earlier models of hierarchical differentiation in small groups (e.g., Skvoretz & Fararo 1996), in our model a single interaction between two group members can be sufficient to establish a behavior interchange pattern between them and thereby can potentially lead to the formation of status beliefs. It is an empirical question how many interactions between two individuals it takes before individuals actually perceive competence differences between them. Future research could conduct detailed empirical experiments to directly calibrate this (and other) model aspect(s). Yet, since earlier models using similar assumptions generated hierarchical structures congruent with empirical data (Skvoretz & Fararo 1996), this simplifying assumption seems sufficient for our purposes.

5.6 Finally, a central outcome of interest in earlier work on hierarchy formation in small groups is the formation of transitive hierarchies (e.g., Skvoretz & Fararo 1996; Skvoretz et al. 1996). In our work, we have explored the possibility that status beliefs might affect the interactions in the very group context in which they had been acquired. Future research might provide interesting new insights into how this possibility might affect the formation of fully transitive hierarchies in groups whose members are differentiated in a salient social distinction. It seems likely that in such groups, the reinforcing effects of status beliefs, once they have emerged, also facilitate the emergence of fully transitive structures.

Appendix A: Formal representations of performance expectations

6.1 In empirical research, formal representations of the formation of performance expectations are based on graph representations in which individuals are differentially linked to task outcomes. Such representations were introduced by Berger et al. (1977); Fisek et al. (1991) subsequently incorporated behavior interchange patterns, and Ridgeway (2000) incorporated elements of status construction. The notation that we use here in this appendix is slightly different than in the main part of the article to facilitate comparison with the original formulations.

6.2 Panels (a) and (b) of Figure A1 show an elementary group task situation that includes two persons *i* and *j* who differ in their status beliefs. The task is represented by *T* and its possible outcomes, success (*T*(+)) and failure (*T*(-)). To achieve success, the task requires one instrumental ability (*C**), whereas group members can either possess the high state (*C**(+)) or the low state (*C**(-)) of this ability (e.g., high vs. low mathematical skills in the case of a math problem). The relevance of *C** for *T* is indicated by a tie between their different states, so that the high state of *C** is connected to success and its low state is connected to failure. Furthermore, there is a nominal characteristic (*N*) that distinguishes group members into two categories (*Na* and *Nb*) which can be thought of as gender (man/woman) or skin color (white/black). Panel (a) shows the situation from *I*'s point of view; *i* holds the belief that members of category *Na* are more competent than members of category *Nb* (resulting in corresponding perceptions of highly, i.e. *Na*(+), and lowly, i.e. *Nb*(-), evaluated states of the characteristic). For *i*, *Na*(+) and *Nb*(-) thus induce differences in generalized performance expectations (*Γ*) that connect both persons via *C** to task outcomes. However, as illustrated in panel (b), *j* does not believe that *N* signifies differences in competence. For *j*, *Na* and *Nb* are thus neither evaluated differently, nor connected to the task.

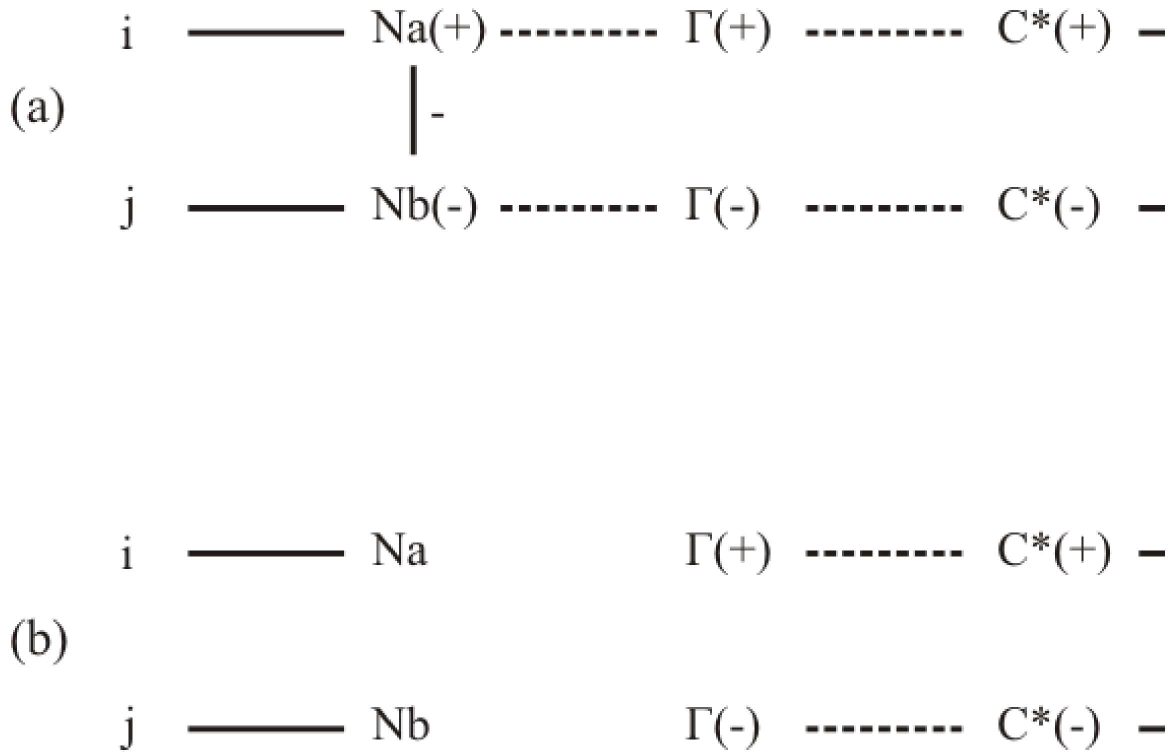
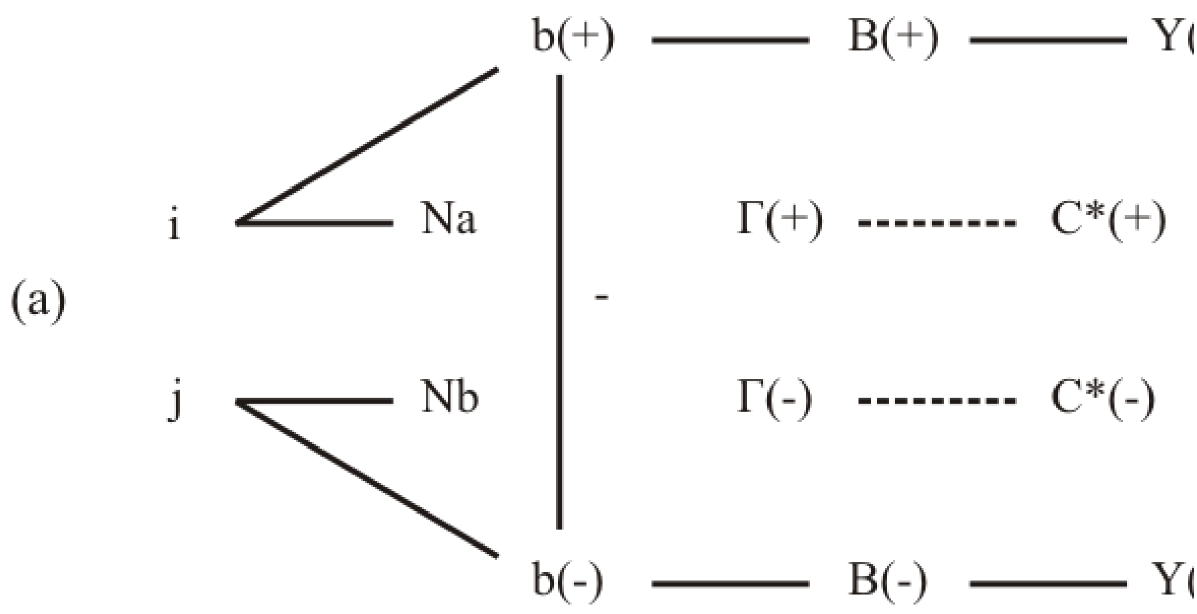


Figure A1. Graph representations of status structures in two person group task situation. Individuals are represented as *i* and *j*. with two states (*Na* and *Nb*). Panel (a): individual *I*s point of view; *i* perceives *N* as a status characteristic so that it is connec expectations *Γ* which are connected to differences in the task ability *C** that is required for the task *T*. Panel (b): individual *J*s poin status characteristic.

6.3 Fisek et al. (1991) incorporated into this behavior interchange patterns, as illustrated in panels (a) and (b) of Figure A2. Imagine that *i* and *j* already worked for some time on the common task and that during their interactions *j* consistently accepted *I*s suggestions, whereas *i* consistently rejected *J*s suggestion. This observation activates in both individuals the perception of a behavior interchange pattern (*b*) in which *i* holds the positively evaluated state (*b*(+)), whereas *j* holds the negatively evaluated state (*b*(-)). These states activate like-signed status typifications (*B*(+), i.e. leader, and *B*(-), i.e. follower) that connect both individuals via abstract task abilities (*Y*) to task outcomes.



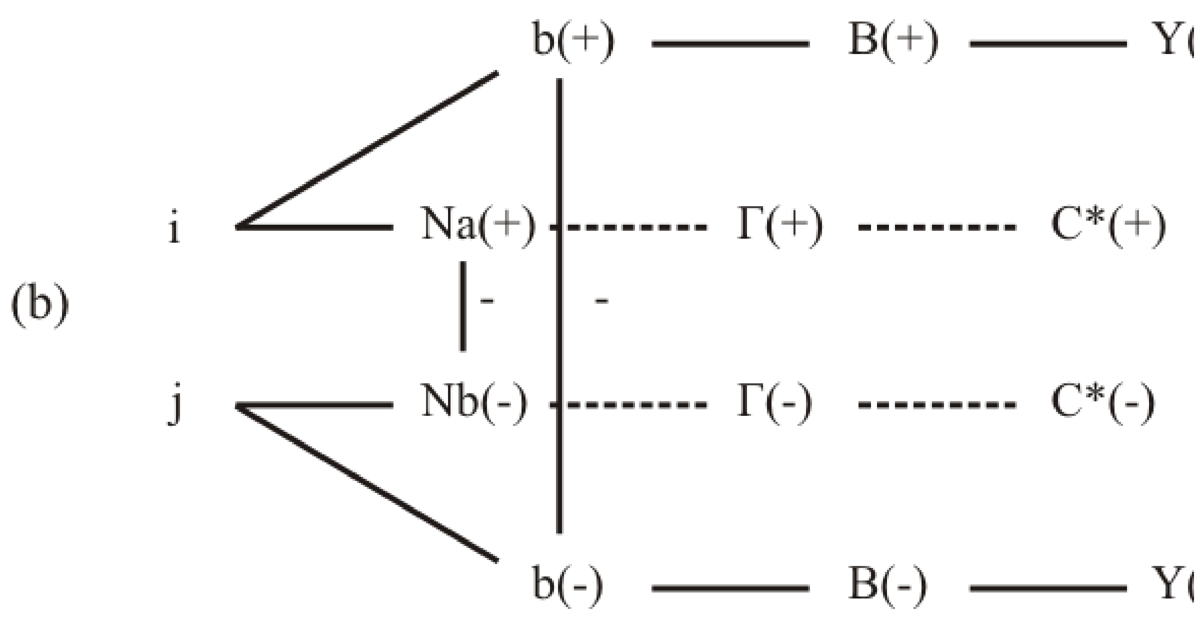


Figure A2. Graph representations of status structures in two person group task situation in which behavior interchange patterns individual *i* appears in the superior role (*b*(+)) in her interactions with *j*. Panel (b): the observation that *i* appears in the superior ro that *N* is connected to *T*, given that *i* and *j* differ in *N*.

6.4 Finally, as illustrated in panel (b) of Figure A2, Ridgeway (2000) suggested that the link between different states of *N* and *Γ* can become activated by the observation of behavior interchange patterns between individuals who differ in *N*. In Figure A2 this is the case, given that *i*, who is *Na*, holds the positive element of a behavior interchange pattern with *j*, who is *Nb*. This potentially induces in both *i* and *j* the belief that *Na*s are generally more competent than *Nb*s. In total there are three different beliefs possible, leading to the following evaluations of *N*: *Na*/*Nb*, *Na*(+)/*Na*(-), *Na*(-)/*Na*(+).

6.5 Berger et al. (1977) developed a method with which the relative performance expectations that group members have for each other can be estimated from graph structures. The first step consists of counting the number of positive and negative paths of various lengths (l) that connect individuals to task outcomes. Path signs are determined by multiplication of the signs of all ties that link a given person to task outcomes and the sign of the task outcome to which it is connected, whereas all ties are assumed positive unless they are explicitly negative. In panel (a) of Figure A1, i is connected to T by two positive paths of length 4 and 5, whereas j is connected to T by two negative paths length 4 and 5. Note that there is a negative dimensionality tie between *Na* and *Nb*.

6.6 In a second step, these paths aggregate to performance expectations for, for instance, actor i (e_i) by the rule (cf. Berger et al. 1977; Fisek et al. 1991):

$$e_i = e_i^+ + e_i^- \qquad \text{(A1)}$$

with

$$e_i^+ = 1 - [1 - f(l)] \ \ldots \ [1 - f(n)] \qquad \text{(A1a)}$$

and

$$e_i^- = -\{1 - [1 - f(l')] \ \ldots \ [1 - f(n')]\} \qquad \text{(A1b)}$$

6.7 where e^+_i and e^-_i represent the combined sets of positive and negative paths. The precise numerical values with which paths of different length enter (A1a) and (A1b) are determined by the function $f(l)$. Although several functional forms have been specified in the literature, the values they predict for paths of a given length differ only marginally. All functional forms have in common that longer paths contribute less to the formation of performance expectations than shorter ones, and this diminishing effect increases the longer the paths become. Paths longer than 6 are generally assumed to provide no performance relevant information for individuals and are therefore neglected. We rely here on the functional form suggested by Balkwell (1991b), because the values it predicts are in good accordance with empirical data. Thus, we assume that $f(4)$ = .150380, and $f(5)$ = .049779. In order to obtain Eq. (1), it is helpful to note that Eq. (A1a) and Eq. (A1b) are equivalent to

$$e_i^+ = 1 - \left(1 - f(2)\right)^{l2_i^+} \left(1 - f(3)\right)^{l3_i^+} \ldots \left(1 - f(L)\right)^{lL_i^+} \qquad \text{(A2a)}$$

and

$$e_i^- = -\left[1 - \left(1 - f(2)\right)^{l2_i^-} \left(1 - f(3)\right)^{l3_i^-} \ldots \left(1 - f(L)\right)^{lL_i^-}\right] \qquad \text{(A2b)}$$

where lL^+_i and lL^-_i indicate the number of positive and negative paths of a given length (Balkwell 1991b). Given that we only consider nominal characteristics and behavior interchange patterns, the only paths that can be obtained are of the lengths 4 and 5. We can thus reduce the foregoing equations to

$$e_i^+ = 1 - \left(1 - f(4)\right)^{l4_i^+} \left(1 - f(5)\right)^{l5_i^+} \qquad \text{(A3a)}$$

and

$$e_i^- = -\left[1 - \left(1 - f(4)\right)^{l4_i^-} \left(1 - f(5)\right)^{l5_i^-}\right] \qquad \text{(A3b)}$$

6.8 Substituting Balkwell's (1991b), path weights into these equations and substituting the resulting equations for e^+_i and e^-_i into Eq. (A1), we obtain

$$e_i = 1 - (1 - 0.150380)^{l4_i^+} (1 - 0.049779)^{l5_i^+} - \left[1 - (1 - 0.150380)^{l4_i^-} (1 - 0.049779)^{l5_i^-}\right] \qquad \text{(A4)}$$

which can be simplified to

$$e_i = -0.84962^{l4_i^+} 0.950221^{l5_i^+} + 0.84962^{l4_i^-} 0.950221^{l5_i^-} \qquad \text{(A5)}$$

6.9 Finally, in our model, a connection to a positive status element (i.e. N(+) and b(+)) always induces one positive path of length 4 and one positive path of length 5; a connection to a negative status element (i.e. N(-) and b(-)) always induces one negative path of length 4 and one negative path of length 5. As a consequence, $l4^+_i = l5^+_i$ and $l4^-_i = l5^-_i$. It is therefore sufficient to simply count the number of positive ($\#pos_i$) and negative status elements ($\#neg_i$) to which a given i is connected (i.e. the number of N(+)/b(+) or N(-)/b(-) to which a tie from i exists) and substitute the resulting numbers into the following equation:

$$e_i = 0.807327^{\#neg_i} - 0.807327^{\#pos_i} \qquad \text{(A6)}$$

When generalized to the case in which each group member can hold a private expectation for each group member that can differ from that of other group members, we obtain Eq. (1) in the main part of the article. For simplicity, we rounded the value of .807327 to .8.

Appendix B: Pseudo-code

Initialization

```
Create agents one at a time.

For each agent, determine the performance expectations e_ij that it has
     for all group members, including itself.

Create variables that store the values of comp, cons, and r.

Create an auxiliary variable largest_share_of_believers that stores the
     information about the largest share of agents that hold the same
     state on S_i which is different from O.

Create an auxiliary variable changes_cons that stores the information
     about the number of times that cons has changed its sign over the
     course of the simulation. Set the value of changes_cons to 0.

Create an auxiliary variable number_iterations that stores the number of
     iterations that have already been conducted. Set the value of
     number_iterations to 0.
```

Execution

```
While number_iterations ≤ max_number_iterations:
{
     For each agent, update its performance standing Ei in the gro

     For each agent, create a temporary variable Eγi that stores t
         value of Ei, weighted with γ as an exponent.

     Randomly select one agent for being interactant_1, with a
         probability proportional to Eγi over all agents.

     Randomly select one agent for being interactant_2 from the se
         of agents that excludes interactant_1, with a probability
         proportional to Eγi over all agents in this set.

     For both interactant_1 and interactant_2, create a temporary
         variable Eδi that stores the value of Ei, weighted with δ
         an exponent.

     Randomly select interactant_1 or interactant_2 for appearing
         the higher competence role in their interaction, with a
         probability proportional to Eδi over both agents; assign 
         respective other agent the lower competence role.

     Update the behavior interchange pattern/tie bij between
         interactant_1 and interactant_2, based on the outcome of
         their interaction.

     Calculate comp, cons, and r.

     For each agent, update its status belief Si.

     For each agent, update the performance expectations eij it ha
         for all group members, including itself.

     If cons has changed its sign compared to the last iteration,
         increase the value of changes_cons by 1.

     Calculate largest_share_of_believers.

     Report comp, cons, changes_cons, r, largest_share_of_believe

     Increase number_iterations by 1
}
```

Notes

[1]Ridgeway and Balckwell (1997) have developed a model of status construction theory that also accommodates groups larger than dyads. However, in this model status beliefs cannot emerge without an objective association between the social distinction and valuable resources. Our modeling efforts focus on the spontaneous emergence of status beliefs in the absence of such an association.

[2]This approach to modelling the distribution of dyadic interactions in discussion groups is a simplified version of the approach presented by Skvoretz and Farraro (1996) for studying the emergence of hierarchies in real life groups.

[3]This approach to modelling dyadic interaction is a simplified version of approaches used to estimate acceptance and rejection rates in dyadic interactions as, for example, presented by Balkwell (1991a; see his Eq. (7) on page 359).

[4]This approach to modeling changes in status beliefs is similar to the approach used by Mark et al. (2009). Note that agents always perceive the observed structure of behavior interchange patterns in the same way, but that this does not necessarily imply that they always hold the same status belief. Instead, belief acquisition is a stochastic process, in which two agents might or might not acquire the same belief given the same observation of behavior interchange patterns.

References

BALES, R. F. (1950). *Interaction Process Analysis: A Method for the Study of Small Groups*. Cambridge, MA.: Addison-Wesley.

BALES, R. F. (1970). *Personality and Interpersonal Behavior*. New York: Holt, Rinehart and Winston.

BALKWELL, C., & Balswick, J. (1981). Subsistence economy, family structure, and the status of the elderly. *Journal of Marriage and Family*, *43*(2), 423–429.

BALKWELL, J. W. (1991a). From expectations to behavior: An improved postulate for expectation states theory. *American Sociological Review*, *56*(3), 355–369.

BALKWELL, J. W. (1991b). Status characteristics and social interaction: Assessment of theoretical variants. In E. J. Lawler, B. Markovsky, C. L. Ridgeway & H. A. Walker (Eds.), *Advances in Group Processes*, *8*, 135–176.

BERGER, J., Fisek, M. H., Norman, R. Z., & Zelditch Jr, M. (1977). *Status Characteristics and Social Interaction: An Expectation-States Approach*. New York: Elsevier.

BERGER, J., Rosenholtz, S. J., & Zelditch Jr, M. (1980). Status organizing processes. *Annual Review of Sociology*, *6*, 479–508.

BIELBY, W. T., & Baron, J. N. (1986). Men and women at work: Sex segregation and statistical discrimination. *American Journal of Sociology*, *91*(4), 759–799.

BONABEAU, E. (2002). Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences of the United States of America*, *99*(Suppl. 3), 7280–7287.

CORRELL, S. J., & Ridgeway, C. L. (2003). Expectation states theory. In J. Delamater (Ed.), *Handbook of Social Psychology* (pp. 29–51). New York: Kluwer Academic/Plenum Publishers.

DRISKELL Jr., J. E. (1982). Personal characteristics and performance expectations. *Social Psychology Quarterly*, *45*(4), 229–237.

FISEK, M. H., Berger, J., & Norman, R. Z. (1991). Participation in heterogeneous and homogeneous groups: A theoretical integration. *American Journal of Sociology*, *97*(1), 114–142.

HENDRIX, L., & Hossain, Z. (1988). Women's status and mode of production: A cross-cultural test. *Signs*, *13*(3), 437–453.

JACKSON, L. A., Hunter, J. E., & Hodge, C. N. (1995). Physical attractiveness and intellectual competence: A meta-analytic review. *Social Psychology Quarterly*, *58*(2), 108–122.

LYNN, F. B., Podolny, J. M., & Tao, L. (2009). A sociological (de)construction of the relationship between status and quality. *American Journal of Sociology*, *115*(3), 755–804.

MACY, M. W., & Flache, A. (2009). Social dynamics from the bottom up: Agent-based models of social interaction. In P. Hedström & P. Bearman (Eds.), *The Oxford Handbook of Analytical Sociology* (pp. 245–268). Oxford: Oxford University Press.

MARK, N. P., Smith-Lovin, L., & Ridgeway, C. L. (2009). Why do nominal characteristics acquire status value? A minimal explanation for status construction. *American Journal of Sociology*, *115*(3), 832–862.

MEEKER, B. F. (1994). Performance evaluations. In M. Foschi & E. J. Lawler (Eds.), *Group Processes: Sociological Analyses* (pp. 95–117). Chicago: Nelson-Hall.

NOSEK, B. A., Banaji, M. R., & Greenwald, A. G. (2002). Math = male, me = female, therefore math ≠ me. *Journal of Personality and Social Psychology*, *83*(1), 44–59.

PHELPS, E. S. (1972). The statistical theory of racism and sexism. *The American Economic Review*, *62*(4), 659–661.

RIDGEWAY, C. L. (1991). The social construction of status value: Gender and other nominal characteristics. *Social Forces*, *70*(2), 367–386.

RIDGEWAY, C. L. (2000). The formation of status beliefs: Improving status construction theory. *Advances in Group Processes*, *17*, 77–102.

RIDGEWAY, C. L., Backor, K., Li, Y. E., Tinkler, J. E., & Erickson, K. G. (2009). How easily does a social difference become a status distinction? Gender matters. *American Sociological Review*, *74*(1), 44–62.

RIDGEWAY, C. L., & Balkwell, J. W. (1997). Group processes and the diffusion of status beliefs. *Social Psychology Quarterly*, *60*(1), 14–31.

RIDGEWAY, C. L., & Correll, S. J. (2006). Consensus and the creation of status beliefs. *Social Forces*, *85*(1), 431–453.

SKVORETZ, J., & Fararo, T. J. (1996). Status and participation in task groups: A dynamic network model. *American Journal of Sociology*, *101*(5), 1366–1414.

SKVORETZ, J., Faust, K., & Fararo, T. J. (1996). Social structure, networks, and E-state structuralism models. *Journal of Mathematical Sociology*, *21*(1–2), 57-76.

STEELE, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology*, *69*(5), 797–811.

STOVER, R. G., & Hope, C. A. (1984). Monotheism and gender status: A cross-societal study. *Social Forces*, *63*(2), 335–348.

WAGNER, D. G., & Berger, J. (2002). Expectation states theory: An evolving research program. In J. Berger & M. Zelditch (Eds.), *New Directions in Contemporary Sociological Theory* (pp. 41–76). Lanham: Rowman & Littlefield.

WEBSTER Jr., M., & Hysom, S. J. (1998). Creating status characteristics. *American Sociological Review*, *63*(3), 351–378.

WEBSTER Jr., M., & Rashotte, L. S. (2010). Behavior, expectations and status. *Social Forces*, *88*(3), 1021–1049.

WILENSKY, U. (1999). *NetLogo*. http://ccl.northwestern.edu/netlogo/. Evanston, IL: Center for Connected Learning and Computer-Based Modeling, Northwestern University.