Modeling the Culture of Online Collaborative Groups with Affect Control Theory

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Abstract. We review Affect Control Theory (ACT), a mathematically formalized theory that integrates sociological insights about the symbolic construction of the social order with psychological knowledge about cognitive-affective mechanisms, as a basis for equipping computational agents in social simulations with a sense of sociality. After explaining theoretical foundations and describing previous applications of ACT at the dyadic and group level, we describe a case study from an ongoing research project aimed at understanding self-organized online collaboration in software development with ACT-based social simulations.

Keywords: Culture, Affect, Group Dynamics, Digital Collaboration.

1 Modeling Culture: A Challenge for Social Simulation

Much recent discussion has revolved around the question of aligning social simulation with relevant theories in psychology and sociology. One aspect of this debate is how to implement behavior rules and decision-making algorithms that reflect psychological knowledge about bounded rationality, heuristics, emotions etc. [e.g., 1-3]. A second problem relates to sociality; i.e., modeling the emergence of a social order out of agent interactions, reflecting properties of human and primate groups such as fights about status, identity, group cohesion, or cultural rules about appropriate relationships [cf. 4].

In this paper, we outline how Affect Control Theory (ACT), an established social psychological theory of social interaction as emerging from an emotional desire to align one's identity with culturally shared beliefs about the social order [5-6], can be used to equip artificial computational agents with a sense of sociality. ACT, with its dual roots in psychology and sociology, speaks to the problems of psychologically realistic decision making and artificial sociality alike. We briefly review the theory and some of its applications before we describe ACT-based simulations of group dynamics in online collaborative networks. These simulations emphasize the aspect of hierarchical vs. egalitarian structures in such groups, an important and ubiquitous facet of work culture [7]. The goal of this paper is thus twofold: (1) to make the community of social simulation scholars aware of a theoretical tradition that we think very useful for grounding

agents in social psychology; and (2) to contribute toward understanding through social simulation contemporary, and increasingly relevant, forms of digital collaboration.

2 Affect Control Theory (ACT)

2.1 Intellectual Roots and Theoretical Components of the Theory

ACT links social perception with identity, behavior, and emotion in social interactions. The theory draws on symbolic interactionism [6, 8-10], proposing that people rely on culturally shared meanings for social concepts to efficiently interpret and respond to social events and anticipate the behavior and emotions of others [5-6]. We internalize these meanings as we are socialized into our culture, through language acquisition and our encounters with others, and they have tremendous influence on our interpretations of and responses to the world around us. We are motivated to maintain alignment between our interpersonal behavior and this basic cultural knowledge, and tend to behave in ways that are culture-maintaining.

The cognitive mechanism that produces alignment of interpersonal behavior with cultural meanings, according to ACT, is our desire to maintain coherent mental representations, a core psychological motive according to well-known classical theories of balance, cognitive dissonance, and -nowadays- parallel constraint satisfaction [11-14]. While these theories differ in scope and detail, the common denominator is that humans are assumed to seek states of mind where all elements of their cognitive representations have a good mutual semantic fit, while inconsistent mental models are perceived as aversive and motivate either reappraisals or changes of the situation.

From modern neuroscience we know that cognition is inseparable from affect [14-15]. Accordingly, ACT assumes that the alignment of social behavior with cultural norms is a subtle process, driven by affective processes and intuition more than by conscious thought. The theory uses cultural affective meanings associated with identity, behavior, and emotion labels to model how humans interpret and respond to social events. Meanings are measured on three universal semantic dimensions (referred to collectively as EPA) [16]: evaluation (good vs. bad), potency (weak vs. strong), and activity (calm vs. excited), corresponding to the basic dimensionality of human emotion and social interaction [17-18].

Unlike most other, predominantly qualitative, symbolic interactionist approaches, ACT employs mathematical formalization. Affective meanings are represented as vectors in the affective EPA space, based on empirical measures in large-scale surveys using the established semantic-differential technique [16]. Shared cultural knowledge expressed on EPA dimensions describes and differentiates social concepts, which possess characteristic patterns of affective meaning known as fundamental sentiments (**f**). These reflect how good, powerful, and active particular identities, behaviors, or emotions seem in general, outside of the context of social events. Perceptions shift, however, when concepts appear together within social events. Event-contextualized EPA meanings, known as transient impressions (τ) and modeled with regression equations [5], capture our interpretation of actors, behaviors, and other elements of a situation and predict our behavioral and emotional responses to unfolding events.

Our social actions are planned and carried out to either maintain situational meanings or to bring them back into <u>alignment with cultural expectations</u> about appropriate behavior and emotions for the identities involved in an event. When expectations are violated, we experience <u>deflection</u> (*D*), a sort of tension about the situation that signals a discrepancy between our current experiences and cultural expectations. In line with cognitive consistency theories (see above), people seek to minimize deflection by acting in ways that maintain cultural expectations about the situation. Deflection is calculated, in ACT, as the sum of the squared Euclidean distances between transient impressions τ of the identities and behaviors emerging from a situation (between a given "actor" and "object-person") and fundamental sentiments **f** for these event elements summed over EPA dimensions (with weights w_i):

$$D = \sum_i w_i (\mathbf{f}_i - \boldsymbol{\tau}_i)^2 \tag{1}$$

ACT's predictions accurately reflect behaviors and emotions experienced in a variety of real-world social interactions, including sentiments and social behavior in domestic partnerships [19], support groups [20], social movement organizations [21], and other interactional contexts. Scholars have found that the motivation to align situational behavior with cultural meanings explains phenomena as diverse as deference patterns based on persons' relative occupational prestige [22], leader responses to employee behavior [23], and the preference for interaction partners that provide identity-consistent feedback [24] – even patterns of interaction among nations [25].

2.2   Social Simulation Based On ACT

Given the mathematical formalization of ACT with linear algebra [5], using the theory as a basis for defining computational agents is straightforward. A variety of ACT-based computational models have been developed and applied in the past. ACT's classic simulation model, known as <u>INTERACT</u> [26], predicts the culture-specific social dynamics that arise from cultural meanings for identities and behavior by means of empirically parameterized regression models in conjunction with repositories of cultural sentiment data, generating testable predictions about behavioral and emotional responses to social events. Model predictions have been supported by survey, experimental, and naturalistic evidence from a research program spanning several decades [e.g., 23-25].

<u>BayesACT</u> is a more recent probabilistic generalization that combines the ideas and empirical strategies of the ACT research program with a Bayesian approach from artificial intelligence, modeling social dynamics as a partially observable Markov decision process [2, 27]. BayesACT agents can represent uncertain knowledge about identities as probability distributions in EPA affective space, model multiple identities in one person, and make improved inferences about identity as interactions unfold. Simulations show that even with large initial amounts of uncertainty, stable and orderly patterns of social interaction emerge after a few rounds of interaction, showing that affective coherence mechanisms can explain human interactions even in the absence of consensual symbolic knowledge about the social order [27].

<u>Group Simulator</u> (see Fig. 1) is a turn-based ABM that extends ACT to model group interactions [28, 29]. Users can set up identity profiles for each group member and model task groups of sizes ranging from three to twenty-five members.

Inheriting INTERACT's social-dynamics equations, Group Simulator predicts group members' behavioral and emotional responses to unfolding events based on the assumption that the agent experiencing the most social tension (i.e., deflection as per Eq. 1) will tend to be the next to act. It then calculates the most likely interaction partner by optimizing for the agent that will best confirm the sentiments associated with the actor's self-identity, the object-person's self-identity, and the behavior. In other words, the model simulates a relational process of mutually compatible meaning-making based on deflection-minimization as the optimization mechanism. Besides such identity-based tie formation, Group Simulator predicts the distribution of interpersonal behaviors across Interaction Process Analysis categories, a well-known taxonomy of group behavior [30]. Heise [28] validated Group Simulator's applicability for task groups by replicating empirical findings from a classic study of mock jury deliberations [31].

Master Urbane Zukunft

Städte der Zukunft modellieren, visualisieren, transformieren:

Das Beispiel Eberswalde

Projektkurs Sommersemester 2018
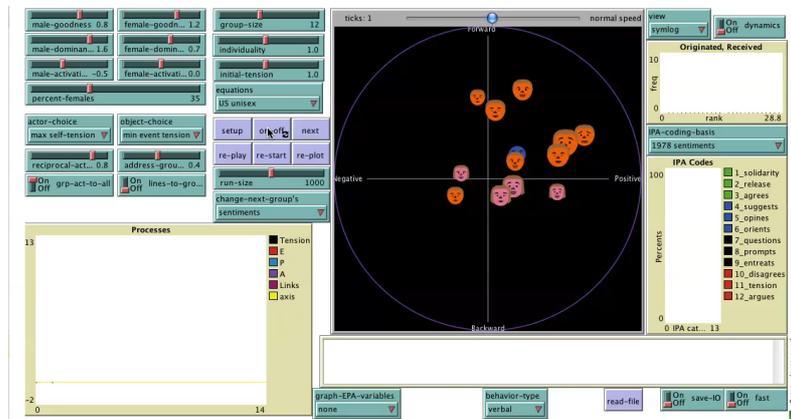
Fig. 1. Screenshot of Heise's Group Simulator Model [28,29].

3 Studying Online Collaboration with ACT

3.1 Hierarchy vs. Equality in Online Collaboration

As part of a larger, ongoing project aimed at studying open-source software development with ACT [2], we model the influence of work cultures on online collaborations using Group Simulator. The portrayal of online groups in the literature is conflicted. Some scholars emphasize the reputedly consensus-driven, egalitarian nature of open-source groups [32]; others note that successful online collaborations tend to be hierarchical and are often unable to reconcile the ideological expectations of egalitarian co-dependent collaboration with the reality of developing versatile, reliable, and profitable applications [33-34]. We contribute to the growing literature studying the power dynamics of online groups by examining how roles, identities, and relational norms such as the level of reciprocity and distribution of group member contributions simultaneously influence the expectations and behaviors of group members. In particular, we are

interested in comparing the social tension (deflection as per Eq. 1) experienced in hierarchical vs. egalitarian groups. We hypothesize that more egalitarian groups create more deflection because they lack the clear expectations and relational structures implied by the supervisor-subordinate role-sets [cf. 35] given in hierarchical settings. In contrast, egalitarian groups must repeatedly renegotiate who will take a leading role in the interaction, yielding more potential for the affective expectations of group members to be violated. Preliminary simulations with Group Simulator reported in [2] were in line with our hypothesis, here we expand on these results by studying in more detail how role identities are expressed over repeated group interactions. For example, does an agent broadcast their guidance to the entire group, work through a trusted intermediary, or through a series pairwise interactions? While reciprocation implies greater accessibility and, thus, a shallower power gradient between team members, the ability to address the group for prolonged periods underscores the social distance between the supervisor and her subordinates [36]. Consequently, when considering how a work culture is likely to influence interactions, we need to consider both the meanings of the work identities defining that culture (i.e., their evaluation, potency, and activity) and the impact of the relational norms governing turn-taking.

3.2 Procedure: Simulation Experiments

To examine how role configurations and relational norms influence the power dynamics of groups, we conducted two simulation experiments where we compared two role configurations. We refer to these group types as egalitarian and hierarchical, respectively. We address the role configurations featured in each experiment first. As implied by their names, the types differ from each other with respect to the group members' relative potency. We kept the evaluation and activity of the group members in both groups constant at a value of 1 to isolate the effects that relational norms have on power dynamics [but see 38]. The resulting egalitarian and hierarchical groups consist of identities roughly corresponding to EPA ratings for the identity *man* on one hand and the identities *boss* and *client* on the other, based on data from a U.S. cultural context [26].

We compared the effect of addressing the group (as opposed to an individual group member) and reciprocation by conducting two simulation experiments. In the first experiment, we simulated egalitarian and hierarchical groups at different address-the-group probabilities. Specifically, we employed a 2X2X10 design, conducting 10 simulations (one for each 10th percentile increase in address-the-group probability) for each group type (egalitarian and hierarchical) and for two different seed numbers.[1] Each simulation consisted of approximately 200 simulated groups, comprised of 500 turns each. Reciprocity was held constant at 0.8 for these experiments, simulating commonly observed rates of reciprocity in discussion groups [37]. In the second simulation experiment, we varied reciprocity in an identical fashion, keeping the percentage of actions directed at the group constant at 0.4. For both experiments, we held group size constant at three; all other parameters were set at their default values as per [28]. Table 1 summarizes the role configurations (identity label and number of agents of this type), address-the-group percentages, and reciprocity rates featured in each experiment.

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[1] We replicated the experiment with multiple seed numbers to ensure that observed differences were not an artifact of using a given seed number.

Table 1. Simulation Description, Parameter Settings for Study 1 and 2.

Group	E	P	A	Label	Addressing Group %	Reciprocity %
Egalitarian	1	1.5	1	Man (3)	*Varying*	0.8
Hierarchical	1	2.5	1	Boss (1)	*Varying*	0.8
	1	0.5	1	Client (2)		
Egalitarian	1	1.5	1	Man (3)	0.4	*Varying*
Hierarchical	1	2.5	1	Boss (1)	0.4	*Varying*
	1	0.5	1	Client (2)		

Note: The identity labels come from U.S. sentiment data collected between 2002 and 2004 [26].

3.3 Results

We analyze the results of our two simulation experiments in two ways. First, we provide a high-level description of changes in group behavior in response to changes in relational norms by comparing the relative proportions of behaviors in egalitarian and hierarchical groups that fall into four broad types of group behavior identified by Robert Bales and colleagues over the course a thirty-year research program [28,30]. These types include: positive socio-emotive (e.g., raving about a repository's app), active task (e.g., reviewing pull requests), passive task (e.g., watching), and negative socio-emotive behaviors (e.g., rejecting pull requests) enacted by group members. Second, we examine how changes in relational norms influence the median level of deflection experienced by group members. These analyses allow us to demonstrate the varying degree of identity maintenance allowed by the different types of group norms.

Types of Activities. Fig. 2 compares the proportions of behaviors in each category enacted by egalitarian and hierarchical groups (the left and right columns respectively). The figure's rows correspond to changes in the percentage of behaviors addressed to the group, and the percentage of reciprocated behaviors (the top and bottom rows respectively). The x-axis indicates the percentage of behaviors addressed to the group or reciprocated. The y-axis indicates the percentage of behaviors in each behavior category, with the shading indicating the proportion of behaviors in that category. E.g., the first bar in the top left-hand quadrant indicates that groups of men who addressed the group approximately 1 out of 10 times tended to exhibit relatively few negative socio-emotive behaviors and passive task behaviors (6% each), and many more active task behaviors and positive socio-emotive behaviors (41% and 47% respectively).

We find that, for both egalitarian and hierarchical groups, the proportion of negative socio-emotive and passive task behaviors shrinks as the percentage of actions directed to the group increases, while the proportion of active task behaviors tends to grow. For hierarchical groups, the proportion of both negative socio-emotive and passive task behaviors tends to be greater than that of egalitarian groups, as well as the relative change in the proportion of active task behaviors. These trends are fairly intuitive when considering a few factors.

First, the two groups' role configurations directly influence the likelihood of each behavior type. In egalitarian groups, members' moderately positive identity profile makes more potent negative behaviors such as defying and arguing unlikely because

these behaviors tend to be quite negatively evaluated. In contrast, the power difference between clients and bosses makes it more likely that clients will both consult with bosses and, when acted on in ways perceived as aggressive, ignore and evade them.

Second, although the group's role configuration sets basic expectations, the increasing percentage of behaviors directed towards the group also affects the proportion of behaviors in each category. Group members have fewer opportunities to immediately and efficiently resolve interpersonal tensions as the percentage of behaviors directed towards the group increases. Consequently, the agent must act primarily in ways that affirm the entire group's identity. If we evaluate the group as being good and potent, then we will tend to act in ways that support this collective identity. As a result, we see increasingly homogenous behaviors because the identity demands of the group begin to supersede the identity demands of any particular group member.
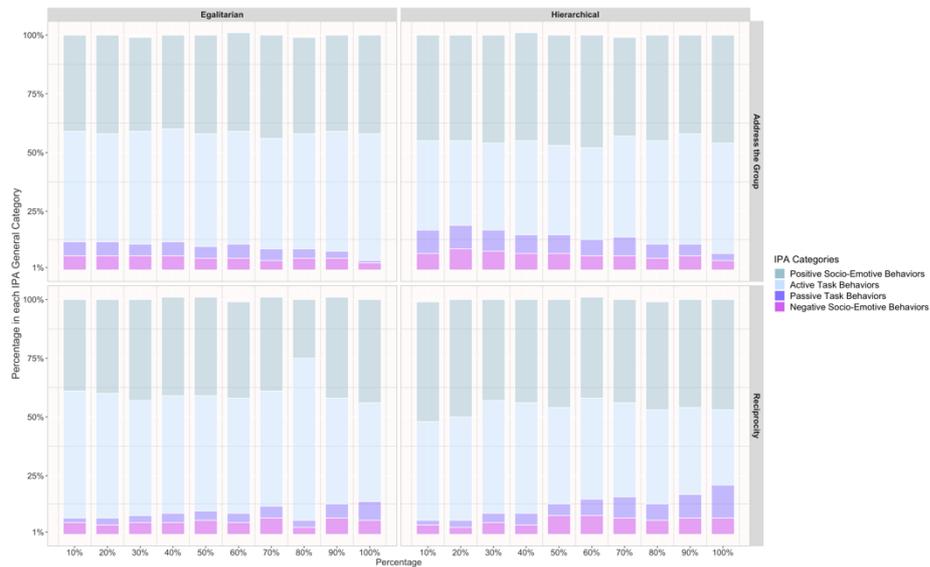

Figure 2. Predicted Percentages of Socio-Emotive and Task Behaviors as the Percentage of Actions Addressed to the Group and Reciprocity Change.

Fig. 2 also indicates that norms governing reciprocity also influence the likelihood of different types of behaviors occurring during the group interaction. The bottom two graphs suggest that groups with a stronger expectation that actions will be immediately reciprocated tend to exhibit more diverse sets of behaviors than groups with lower reciprocation rates, with hierarchical groups tending to exhibit greater diversity than egalitarian ones because a greater variety of behavior affirms the group members' respective identities. Bosses can affirm their identity by joking with, directing, or advising the group; clients by asking questions and consulting. In contrast, men affirm their identity by doing the same things: joking with, directing, and generally thumping each other on the back. This difference in the variety of behaviors that affirm the role expectations of the group is indicated in Fig. 2 by the relative distribution of behaviors in each category.

Although Fig. 2 indicates that strong reciprocation norms have generally the opposite effect of strong norms to direct actions towards the group, it also indicates that norms governing reciprocity can have an even greater impact on the variety of behaviors enacted by the groups. Reciprocity influences the variety of behavior sequences a group is likely to enact because reciprocation norms govern a wider range of potential alters. While norms governing the proportion of actions directed towards the group influence how many actions are directed towards one potential alter (the group), reciprocation norms influence whether the agent will address the group as well as anyone else. As the norm to reciprocate approaches 100%, there is a greater likelihood that the interaction will be dominated by chains of relatively homogeneous reciprocated events. Examples from daily life include chains of seemingly unending pleasantries, affirmations, questions and responses and, more alarmingly, escalating patterns of abuse. Because our egalitarian and hierarchical groups consist of good and at least moderately potent identities, the majority of behaviors even at high rates of reciprocity are positive socio-emotive and active task behaviors in the simulations presented here.

Identity Maintenance: We next analyze Group Simulator's predictions about the level of deflection experienced by group members and the evaluation and potency of their behaviors to establish the link between the patterns we observed in Figure 2 and the symbolic identity-maintenance processes that generated them. We focus here on evaluation and potency because these two affective dimensions most directly influence the power dynamics of groups. The group's identity is an important part of these simulations. We assume that the group's identity is a combination of the identities of its members. The group's sentiment in each turn is the mean of its members', meaning its sentiments like the agents' changes over the course of the interaction. In addition, we assume that by acting on the group agents are simultaneously acting upon the other group members. Consequently, actions directed to the group affect all agents' sentiments.
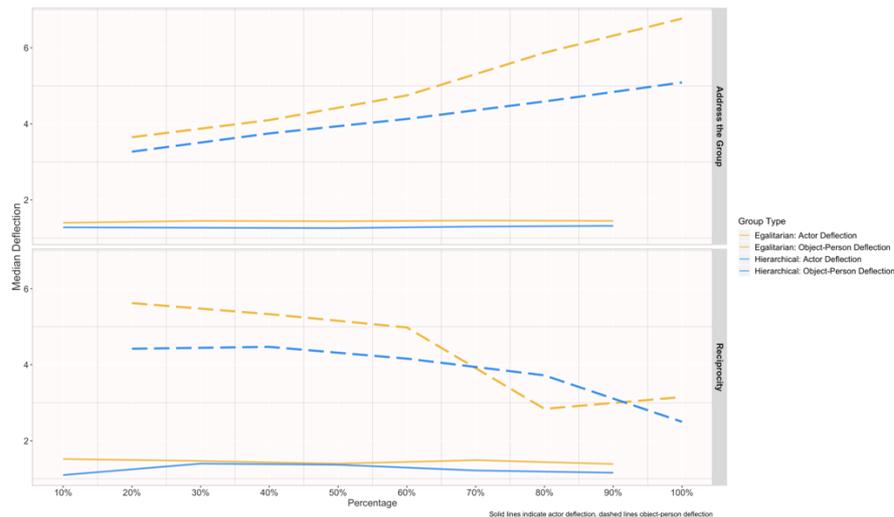

Fig. 3. Predicted Median Group Member Deflection as the Percentage of Actions Addressed to the Group and Reciprocity Change.

Figure 3 compares the level of deflection experienced by actors and object-persons in egalitarian and hierarchical groups. The x-axis indicates the percentage of behaviors either addressed to the group (the top panel) or reciprocated (the bottom panel). The y-axis indicates the median level of deflection experienced by group members. The lines indicate actors (solid lines) and object-persons (dashed lines) in egalitarian (gold lines) and hierarchical (blue lines) groups.

We focus on deflection because deflection minimization is the driving mechanism behind Group Simulator's predictions. Recall that deflection arises from the discrepancy between our expectations of a situation and our impressions of it. In particular, expectations regarding how we should be treated given our role's evaluation and potency govern the exercise of power in groups. The expectation that people will act in ways that are attuned to the potency of the person with whom they are interacting is an important interaction norm in groups. Good people are not bullies. There is also a strong expectation that powerful people will act in powerful ways. Although being the object of an interaction generally results in a loss of perceived potency, this loss is far less if the actor plays an important role in the group. ACT researchers have identified these norms and others, evident as interaction terms in the theory's impression change equations, repeatedly in empirical studies of impression formation [5, 38].

These cultural expectations largely explain observed differences in the level of deflection experienced by actors and object-persons in egalitarian vs. hierarchical groups. The loss of perceived potency explains why an agent experiences more deflection as the object of an interaction than when it is an actor. The moderating influence of the actor's potency largely explains why agents in egalitarian groups experience more deflection under most conditions. Our simulated men experience slightly more deflection from acting in dominant ways towards peers, and significantly more deflection from being acted upon in a dominant way. In addition, there are more interaction norms governing the behaviors of hierarchical groups than egalitarian ones. Although on one level this means that interactions in hierarchical groups are more regulated, it also means that interactants are more likely to act in predictable ways. For example, although the cultural expectation that good people act in good, powerful ways guides the behavior of the men in our egalitarian groups, the simultaneous expectation that powerful people act in good ways that respect the autonomy of the object-person does not have the same force as in the hierarchical groups.

Relational norms influence the likelihood of experiencing deflection by regulating opportunities to resolve situational tensions through action. A strong norm to address the group produces more deflection than a weak norm for two reasons. First, when an agent addresses the group it influences everyone else by making the rest of the group an object. Consequently, the rest of group experiences some loss of perceived potency, with the magnitude of that loss being a function of their relative potency. Clients in our simulation have a greater expectation of enduring the boss's jokes and of receiving advice so they experience less deflection than men when as the object of others' behavior. In addition, as the norm to address the group approaches 100%, bosses are more likely to be the actor, meaning that hierarchical groups as a whole are likely to experience lower levels of deflection than egalitarian groups because the interaction is more aligned with the agents' role expectations. Nevertheless, the slope of the object-deflection line suggests that a strong norm to address the group is likely to result in accumulating levels of deflection that addressing the group increasingly cannot resolve.

Second, a strong norm to address the group means that agents must act in ways that affirm the group's identity. Because the group's identity is an emergent property of the agent's identities, affirming the group's identity is often also affirming their own. Nevertheless, when group norms allow some mixture of collective and dyadic interactions, a strong norm to address the group means that any deflection resulting from a dyadic interaction will require either more turns before the agent can resolve the deflection through a pairwise interaction or by addressing the group. Addressing the group is often an inefficient way to resolve high levels of deflection because the group's identity is often too good, too potent, or both.

Reciprocation norms also regulate opportunities to resolve social tension. Lower reciprocity rates mean fewer opportunities to quickly resolve interpersonal tension arising from being acted upon. Nevertheless, the effect of strong reciprocation norms does not simply mirror the effect of strong norms to address the group because reciprocation norms influence both the likelihood of addressing the group and the other group members. Hierarchical groups experience less deflection as the reciprocity rate increases because then bosses and clients fall into their roles and more perfectly attune their behaviors to each other. Egalitarian groups exhibit a slightly different pattern. There seems to be an "interaction sweet-spot" in our simulations between a reciprocity rate of 70% and 80%. In this range, there is both a high enough reciprocity rate to efficiently resolve interpersonal tensions but enough opportunities to address the group to break sequences of disconfirming behavior by either addressing the group or the third group member. Because being either the actor or the object-person in an egalitarian group causes deflection, egalitarian groups can never achieve the same level of attunement over the course of pairwise interactions, but our simulations suggest that a mixture of relational norms can help reduce the overall level of deflection these groups experience.

4   Discussion

Our simulations demonstrate how role configurations and relational norms influence group behavior by setting role expectations and moderating the extent to which group members can affirm their roles. We find that hierarchical groups tend to experience less deflection. In addition, we find that relational norms that allow group members to efficiently resolve deflection through reciprocation, while also allowing them to disrupt sequences of disconfirming behaviors by addressing the group or another group member are likely to be important for both egalitarian and hierarchical groups, but particularly so for egalitarian groups where there are no clear role expectations establishing dominance patterns.

It is important to note that although there is decades worth of research examining the operation and maintenance of status hierarchies [39], there are far fewer generative models of these dynamics [40], and no other model to our knowledge that applies an identity maintenance perspective. This work highlights two avenues of future research. First, although hierarchical groups may make interactions more predictable, they do not necessarily make them more fulfilling. Preliminary simulation results indicate that, in many instances, people experience more negative emotions in hierarchical groups, suggesting new questions regarding the relationship between identity maintenance and emotion in groups. Second, although promising, affect control theory's emphasis on

interaction at the dyadic level limits its ability to model groups. The theory predicts how people respond to being the actor or object-person in an event but not an observer. This has implications for our findings, especially our reciprocity findings, because while these findings likely reflect the state of the agents acting and reciprocating, we have no predictions about the state of the other agents, and thus of the group as a whole. Consequently, a more robust application of the theory will need to consider the deflection experienced by actors and object-persons as well as observers.

Acknowledgements

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