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The Structural Balance Theory of Sentiment Networks: Elaboration and Test[1]

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Structural balance theory attends to a group's network of sentiments and posits that this network alters over time toward particular structural forms. Current work on the theory is focused on understanding the mechanisms that alter sentiments as a function of the configuration of sentiments in which they are embedded. Although the theory assumes tension reduction mechanisms, there has been no effort to directly measure and model the temporal changes of individuals' relational tensions that are predicted by the theory. This article elaborates and tests balance theory with an empirical analysis of its posited interpersonal tensions and their reductions via a sentiment conversion process. In addition, the authors open a new line of inquiry on the theory's scope conditions and point to a community commitment condition that is involved in the realization of structural balance. Their analysis draws on a unique suite of multiwave measures obtained from the Urban Communes Data Set.

Georg Simmel posed an interesting, seemingly simple, question: what are the implications of enlarging a dyadic relationship to a triad of individuals? His insight, which might be stated as "social structure matters," was that the

[1] Earlier versions of this article were presented at the annual meetings of the American Sociological Association in Chicago and the Sunbelt Conference of the International Network for Social Network Analysis in Newport Beach, California. We thank John Levi Martin and the *AJS* reviewers for insightful comments on prior drafts. Direct correspondence to Craig Rawlings, Department of Sociology, Northwestern University, 1810 Chicago Avenue, Evanston, Illinois 60208. E-mail: craig.rawlings@northwestern.edu

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enlargement of the smallest social group to a triad is a profound qualitative change of group condition that has ramifications for all three dyadic relationships and all three individuals (Simmel [1922] 1955, 1950 [ca. 1902–17]). Lines of investigation subsequent to Simmel's analysis of the triad have reinforced this insight. The triad cannot be understood as decomposable into three dyadic relationship systems but is itself a system in which the three dyadic systems are nested. Lines of investigation have generalized Simmel's analysis by nesting triads in a social network. As with Simmel, these lines of investigation attend to structural forms. In structural balance theory, which is the focus of this article, the network is composed of interpersonal sentiments. The theory applies to groups in which every individual has either a positive or a negative orientation toward every other individual of the group. In such groups, the configuration of sentiments in each triad can be classified as one of 16 possible types. Structural balance theory posits that some types of triads are forbidden and others are permitted on the basis of four rules. The theory shows that these rules have remarkable nonintuitive implications for the macrostructure of the group's sentiment network. Thus, Simmel's triad is the stepping stone to an understanding of the macrostructure organization of sentiment relations.

Structural balance theory has been elaborated over generations of investigators. It continues to advance in work by sociologists and investigators in the natural and engineering sciences with publications in premier general scientific journals, such as the *Proceedings of the National Academy of Sciences* (Antal, Krapivsky, and Redner 2005; Abell and Ludwig 2007; Szell, Lambiotte, and Thurner 2010; Marvel et al. 2011). The sustained and ongoing interest in this theory is its implication that a social network of interpersonal sentiments has a natural evolution toward particular generic forms of balanced social organization at the macrolevel. Yet puzzles remain. Current work on the theory is focused on understanding the mechanisms that alter sentiments as a function of the configuration of sentiments in which they are embedded.

Balance theory was initiated by Heider (1946). He analyzed a simple P-O-X system composed of two persons P and O, with a fixed symmetric positive or negative P-O relationship, who are oriented differently in sign to the same object X. Heider focused on P's response to different states of this constrained system. Newcomb (1961), attending to Heider's work, proposed an A-B-X system with more moving parts. The A-B sentiment symmetry constraint is relaxed, A or B's signed orientation to X may alter, and A or B's sentiments toward one another may alter. In Cartwright and Harary's (1956) advancement of balance theory, the object X is another individual, and all triads of individuals are nested in a sentiment network in which each individual has an alterable positive or negative sentiment toward every other individual. This is a system with many moving parts. It is in Cartwright and Harary's work that Simmel's triad surfaces in an especially interesting way and where the macrostructural implications of balance theory are formalized. The set of assumptions involved in their analysis is now referred to as the classic model of structural balance. Using the term "friend" to designate a positive sentiment and the term "enemy" to designate a negative sentiment, the classic balance model defines a sentiment network as balanced if it contains no violations of four assumptions:

(A1) A friend of a friend is a friend,
(A2) A friend of an enemy is an enemy,
(A3) An enemy of a friend is an enemy,
(A4) An enemy of an enemy is a friend.

In these terms, the assumptions are evocative of maxims that appear in various cultures. The four rules permit some types of triads and forbid others. Cartwright and Harary showed that only two generic forms of sentiment network macrostructure are possible under these rules. The sentiment network must be either a network of all-positive sentiments or a network of individuals partitioned into two cliques with all-positive within-clique sentiments and all-negative between-clique sentiments. This discovery has sustained the interest in balance theory.

Davis and Leinhardt (1972) generalized the Cartwright-Harary model. They formalized the distinction of 16 possible types of triads. Then, in a brilliant analysis, they arranged the four rules of the classic model as a tuple {A1, A2, A3, A4}—that is, an ordered set—and sequentially dropped assumptions to consider the macrostructure implications of the sequence of reduced tuples {A1, A2, A3}, {A1, A2}, and {A1}. They showed that each reduction includes the macrostructure implications of all larger tuples as special cases. One rule, denoted above as {A1} and referred to as the transitivity assumption, includes the macrostructure implications of the larger tuples as special cases. On the basis of this single rule, (1) all macrostructures have one or more cliques (the entire structure may be one clique) within which relations are all positive; (2) the relations between pairs of cliques are either all negative or asymmetric; (3) every member of a clique has an identical sentiment toward every member of the macrostructure; and (4) if cliques are joined by asymmetric relations, then a hierarchical form of macrostructure exists.

The empirical evidence on groups that has been amassed to assess balance theory presents strong support for the following restricted statements: (1) the probability of a positive $i \rightarrow k$ sentiment is more likely when a sequence $i \rightarrow j \rightarrow k$ of positive sentiments exists than when such a sequence does not exist, and (2) the probability of an intransitive triad (one of the seven types of triads that violate transitivity) is lower than the probability of a triad that is not intransitive (one of the nine types of triads that do not violate transitivity).

See, for example, the findings of Hallinan (1974), Sørenson and Hallinan (1976), Davis (1979), Hallinan and Hutchins (1980), Doreian and Krackhardt (2001), and Kossinets and Watts (2009). We believe that it is accurate to characterize all other predictions of the theory as being in an unsettled state.

Unresolved puzzles arise concerning the mechanisms that alter a sentiment network and put it on a trajectory toward structural balance. The theory suggests the existence of such a temporal evolution, but it does not specify the mechanism that alters sentiments. Empirical tests of whether such an evolution occurs require the collection of longitudinal data on networks of interpersonal sentiments, and such tests are rare. The few longitudinal studies that have been conducted have not connected the dynamics of sentiment change to the management of the relational tensions that the theory posits are associated with particular configurations of sentiments. Without the demonstration that such a mechanism exists, the validity of the theory may be questioned, and it has been. Feld (1981) and Feld and Elmore (1982) have suggested that relational tensions are not relevant and that the evidence on a transitivity bias in observed social networks is largely explained by the social-structural contexts ("foci") that give rise to clusters and inequalities in popularity, rather than by tension reduction responses to violations of balance theory rules.

We believe that relational tensions are associated with structural violations of the rules of balance theory and that the temporal evolution of a sentiment network is the epiphenomenon of responses to tensions that reduce violations of balance theory rules. But the available evidence to support this belief is scanty. Experimental social psychologists have investigated the extent to which certain imagined triads are perceived as stressful by subjects (Aderman 1969; Crano and Cooper 1973; Fuller 1974). This evidence suggests that, when subjects imagine being put in particular positions of various balanced and imbalanced triadic situations, they associate conditions of imbalance with more imagined unpleasantness than under more balanced conditions. These findings on imagined tensions have obvious limitations in terms of being extended to interpersonal tensions in naturally occurring groups, but they do suggest a plausible link between perceived imbalances and tension reduction motivations. They also do not attend to the question whether individuals' responses to perceived tensions are sentiment conversions that reduce violations of balance theory rules.

CONTRIBUTION

Recent theoretical work on balance theory mechanisms has reinforced a long-standing call for more empirical evidence on the dynamics of sentiment change that shift macrostructures toward generic forms of balance (Opp 1984). Although the theory assumes tension reduction mechanisms, there has been no effort to empirically investigate the linkages of sentiment structures and relational tensions. In this article, we report the first effort to directly measure relational tensions and model the linkages and temporal changes of individuals' sentiment structures and relational tensions. A suite of new findings are reported on a set of open questions. We do not know whether differences of exposure to violations of balance theory rules, which all balance theory models assume are a source of tension, are associated with individuals' perceptions of relational tensions and how such perceptions lead to observed sentiment conversions. Can temporal shifts toward structural balance emerge in the absence of individuals' perceptions of interpersonal tensions? Are all of the violations entertained in the four rules of the classic balance model similarly associated with perceived relational tensions and, in turn, with sentiment conversions? Does the empirical evidence favor automatic or deliberative (optimizing) sentiment conversion responses to perceived relational tensions? Furthermore, no evidence exists on the scope conditions of sentiment structure evolution; that is, are mechanisms that alter group macrostructures toward greater balance more likely under some group-level conditions than others?

We find systematic evidence of temporal reductions of violations of balance theory rules and linkages of structural violations with relational tensions. The evidence supports the assumption of purposeful actors, entailed in some of the recent work on mechanisms of sentiment network evolution, who alter sentiments on the basis of the relative tension reduction payoffs of converting particular sentiments. In addition, we open a new line of inquiry on the theory's scope conditions. We find that a community commitment condition is importantly involved in the realization of structural balance, whereby balance theory mechanisms depend on the extent to which a group is composed of individuals who are committed to the group as a social unit.

Our findings are based on the unique suite of multiwave measures in the Urban Communes Data Set (Zablocki 1980; Martin, Yeung, and Zablocki 2001). Below, we describe the theoretical framework of balance theory, and the current work on it, in more detail. Then we lay out hypotheses, our measures and method, findings, and conclusions.

THEORETICAL FRAMEWORK

Rules of Structural Balance

Sentiments are an important special case of attitudes that are positive or negative cognitive orientations of some strength. Positive interpersonal sentiments and their relational correlates (sustained contact, reciprocity, trust, and influence) are the essential bases of small primary groups, and they form the backbone of larger social structures (Homans 1950; Granovetter 1973; Krackhardt 1992; Friedkin 1998; Lawler 2001; Martin 2009). The scope condition of balance theory is a group in which all individuals have a positive or negative orientation of some strength toward every other member of the group. This condition is more likely to be satisfied in small groups of mutually acquainted individuals than in large groups where ubiquitous mutual acquaintance is more problematic (Davis 1963). Balance theory relaxes the assumption of all-positive sentiments, and, in so doing, it allows the simultaneous existence of social cohesion and social conflict, that is, the ubiquitous duality that has stimulated the development of sociological theory since the inception of the discipline (Durkheim [1893] 1933). Balance theory suggests that stable macrostructures may exist that include both positive and negative interpersonal sentiments.

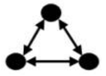
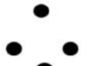
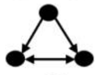
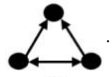
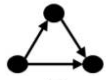
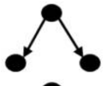
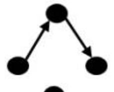
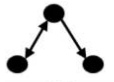
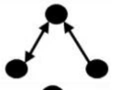
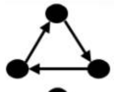
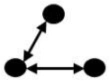
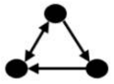
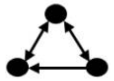
In the literature on balance theory, it is the structural form of a triad—that is, its configuration of positive and negative relations among three individuals—that determines whether the triad microstructure is balanced. The existence of a negative sentiment in the triad does not automatically define it as unbalanced. In turn, a balanced macrostructure may contain numerous triads in which there is one or more negative sentiments. It is the configuration of positive and negative sentiments in the microstructures of triads and in the macrostructure containing the triads that determines whether the network as a whole is in a state of structural balance.

The development of balance theory rests on its analysis of four maxims. The classic model of balance theory disallows ("forbids") any violations of the four rules. Generalizations of balance theory disallow a subset of these four rules. The clusters model forbids violations of {A1, A2, A3}, the ranked clusters model forbids violations of {A1, A2}, and the transitivity model forbids only violations of {A1}. This ordered relaxation of constraints allows the appearance of more constrained models as special cases. The transitivity model allows the other three models as special cases.[2]

Table 1 shows the 16 types of triads that are possible in any group of three or more individuals. The four rules of balanced sentiment structures "forbid" subsets of these 16 types, on the basis of the occurrence of at least one violation of the rules, and "permit" the remaining types. The convention is to represent the 16 types of triads in a simplified form: only positive sentiments are displayed, with the understanding that the absence of a positive sentiment implies the presence of a negative sentiment. These triads are characterized by three numbers, indicating the number of mutual (M), asymmetric (A), and null (N) ties, and symbols that discriminate triads with identical MAN numbers—transitive (T), up (U), down (D), and cyclic (C)—when required. Only two triads (300 and 102) do not violate any of the four rules, a condition that when stipulated for all triads in a group leads to the classic model's implication of united or bifurcated macrostructures.

[2] See Johnsen (1985) for a useful analysis of the logic involved in the sequence of the models.

TABLE 1
Four Rules of Structural Balance and Forbidden Triads

Triad Type	Triad Label	A4	A3	A2	A1
	300				
	102				
	003	Forbidden			
	120D			Forbidden	
	120U			Forbidden	
	030T	Forbidden	Forbidden	Forbidden	
	021D	Forbidden	Forbidden		
	021U	Forbidden	Forbidden	Forbidden	
	012	Forbidden			
	021C	Forbidden			Forbidden
	111U		Forbidden		Forbidden
	111D			Forbidden	Forbidden
	030C		Forbidden		Forbidden
	201		Forbidden	Forbidden	Forbidden
	120C		Forbidden	Forbidden	Forbidden
	210		Forbidden	Forbidden	Forbidden

For a particular group with n members, a "triad census" distributes the group's observed "n choose 3" triads among these 16 types. The number of triads that are distributed among these 16 types increases rapidly with the size of a group; for example, for groups of size 5, 10, 20, and 40, the number of triads is 10, 120, 1,140, and 9,880, respectively. Analyses of distributions of observed triads among the 16 possible types have regularly indicated a strong bias toward transitivity, which is the only rule that is assumed by all four models of structural balance. Note that in table 1, seven triad types violate transitivity at least once, and a triad may have as many as three violations of transitivity (as does the 030C triad). The remaining nine triad types are divided into two classes: transitive and vacuously transitive triads. The distinction is based on whether the configuration of sentiments in a triad contains a path involving all three members: $i \rightarrow j \rightarrow k$, or $j \rightarrow k \rightarrow i$, or $k \rightarrow i \rightarrow j$, and so on. If no such path exists in a triad, then the structural condition for a violation of transitivity does not exist, and the triad is defined as *vacuously transitive* because it does not violate transitivity.

Models of Structural Balance Mechanisms

What is the "force" that structural imbalance exerts on individuals? For social psychologists such as Heider and Newcomb, the force is intrapsychic and rests on the reduction of the tensions associated with cognitive dissonance. Such tensions are experienced as unpleasant feelings or stress that automatically encourage conversions of individuals' positive sentiments to negative sentiments and vice versa. For Simmel and structural sociologists, triads are structural forms with social capital, cohesion, and conflict implications. The structural form of a triad induces tensions that trigger efforts to alter the structural formation in which the individuals are embedded. Such efforts are not limited to individuals' conversions of their own sentiments; they may involve efforts to convert the sentiments of others in order to alter the structural form of a triad. In the triadic form, there is a third party implicated in each dyadic relation, who may take on roles (analyzed by Simmel) that are more or less consequential in reducing interpersonal tensions. For example, the third party of a dyadic relation in a triad may act to convert (influence) the sentiment of one member of the dyad. The key postulate of structural balance theory is that sentiment conversions have an endogenous foundation in the felt tensions induced by structural forms of a group's triads.

The direct source of every sentiment change is an individual who converts his or her positive sentiment toward another individual to a negative sentiment or vice versa (e.g., Hallinan and Hutchins 1980). These changes may or may not put the sentiment network as a whole on a trajectory toward a structure with no violations of balance rules. The potential difficulty involved in the existence of such a trajectory is that a change of sentiment, which eliminates a violation of one or more balance rules, may generate new violations of balance rules.[3] Under the scope restriction of the theory, which restricts its application to sentiment networks in which every individual has either a positive or a negative sentiment toward every other individual in the network, it follows that every individual is involved in numerous triads that may have various structural forms. The greater the size of the network, the greater the number of triads in which an individual is embedded. Each i to j sentiment (positive or negative) is contextualized by $n - 2$ other individuals. Each of these other individuals sets up an ijk triad with a particular configuration of sentiments, so that the i to j sentiment is embedded in a social environment of $n - 2$ sentiment configurations. Thus, the exposure to violations of balance theory rules implicates all those "n choose 3" ijk triads that contain the (i,j) ordered pair.

Current work on balance theory is concerned with temporal mechanisms that convert sentiments. Proposed temporal mechanisms of structural balance include processes that treat the group (or each individual in it) as an optimizing balance-seeking strategic actor who rewires the group's structure of sentiments to eliminate imbalance (Hummon and Doreian 2003; Wang and Thorngate 2003; Antal et al. 2005; Kulakowski, Gawronski, and Gronek 2005; Abell and Ludwig 2007; Montgomery 2009; Marvel et al. 2011; Van de Rijt 2011; Deng et al. 2012; see also Macy and Willer 2002). This work has concentrated on mechanisms that generate the classic model's postulated forms of structural balance, that is, a group with all-positive sentiment structure or a group with precisely two mutually antagonistic groups with all-positive within-group sentiments and all-negative between-group sentiments. For example, the "naïve model" of Antal et al. (2005) simulates sentiment conversions according to a "local triad dynamics" model in which individuals alter sentiments within those triads that violate any of the rules {A1, A2, A3, A4}. It is considered "naïve" or perhaps "myopic" because individuals alter one sentiment at a time on the basis of a random probability that does not take into account the likelihood that a sentiment conversion may actually increase an individual's total number of imbalanced triads. In contrast, other investigators have proposed "constrained triad dynamics" models in which individuals are only likely to convert sentiments if the conversion does not increase overall levels of imbalance for them. For example, Van de Rijt (2011)

[3] Sørenson and Hallinan (1976) detailed changing reports of friendship among a class of 28 sixth graders. Their analysis also showed that groups do not "hop" from unbalanced to balanced sentiment structures and that shifts toward greater balance involve transitions of particular ijk triads through states of intransitivity. Doreian and Krackhardt's (2001) reanalysis of Newcomb's longitudinal data on 17 members of a fraternity is also concerned with the process. Their findings were based on rank-order measures—rather than dichotomous measures—of positive sentiments, and they examined the likelihood of moving toward transitivity given various "pretransitive" triadic states.

has proposed a "best response dynamics" model in which individuals only alter particular sentiments if such change reduces the number of imbalanced triads to which they are exposed; the greater the individual's estimate of such payoffs, the more likely the sentiment conversion. The proposed mechanisms for the evolution of a group toward the macrostructures of the classic balance model differ in their assumptions and present unresolved puzzles that are stimulating additional work. For example, it has been noted that some mechanisms may generate structures that are "jammed" or "stuck" in imbalanced states such that individuals cannot alter sentiments without increasing structural imbalance. The movement in theory development on mechanisms has been toward greater realism and assumptions that attend to the social psychological foundations of individuals' decisions to convert particular sentiments.[4]

HYPOTHESES

Group-Level Temporal Declines of Imbalance

The current interest in specifying mechanisms of sentiment network evolution toward structural balance is well-founded if, indeed, groups do evolve in ways consistent with balance theory. The scarcity of longitudinal investigations of balance theory makes this an open question. We test whether a signal of such evolution exists in our data.

HYPOTHESIS 1.—*Violations of each of the rules of balance theory decline over time.*

With this hypothesis, we examine temporal reductions of balance theory rule violations. A triad sentiment configuration (one of the 16 types of triads) may entail violations of more than one rule, but each rule (and not the triad that contains it) is the basis of balance theory's macrostructural implications. Each rule involves a specific assertion about the configuration of three sentiments among three individuals. We disentangle rule violations from the triads in which they occur. Balance theory does not, for example, assert that transitivity must increase. It asserts that violations of transitivity decrease. Violations of the transitivity rule may be reduced by shifts to vacuously transitive configurations, which lower the incidence of violations of the transitivity rule without increasing the incidence of transitive sentiments. Similarly, for the other rules, reductions of their violations are hypothesized. We expect to find varying levels of empirical support for the different postulated rules of balance. The available prior empirical evidence points to violations of the transitivity rule (A1) as most salient—that is,

[4] Leskovec has introduced an alternative to classic balance model predictions (see also Yap and Harrigan 2015). However, we note that this "status-based" approach is consistent with the more generalized balance models that allow for hierarchy formation.

all models of balance are reliant on this rule as an anchor for structuring sentiments. The theoretical logic of the generalizations of the classic model suggests that the rank order of rule salience may be {A1, A2, A3, A4}. Our findings on this hypothesis will put more empirical flesh on the relative salience of the rules that have been entertained.

We then seek to elaborate the foundations of the expected macrolevel shifts away from imbalance with a sequence of hypotheses on the microlevel tension reduction mechanism. The sequence begins with the experience of felt tensions as anchored on structural imbalances. These tensions motivate sentiment conversion processes that are oriented toward reductions in violations of balance theory rules. At the individual level, greater tensions motivate more structural conversions. The more such imbalances are reduced within the individual's triadic environment, the more tensions are reduced. Finally, we introduce the community-commitment condition that provides a scope condition for this tension reduction sequence.

Interpersonal Tensions and Violations of Structural Balance Rules

Balance theory posits that negative sentiments are not the exclusive or even primary sources of relational tension and that relational tension importantly springs from the particular structural configurations of sentiments. However, there is no current evidence obtained on groups in field settings that addresses this postulate. Here, we consider the rules of balance theory and investigate whether their violations are associated with relational tension:

HYPOTHESIS 2.—*The probability of an $i \rightarrow j$ relational tension increases with the extent to which the $i \rightarrow j$ sentiment is exposed to violations of balance theory rules.*

Relational tension may occur in both positive and negative sentiments, and this balance theory hypothesis states that the probability of relational tension is associated with the sentiment configurations in which an $i \rightarrow j$ sentiment is situated at a given time. We expect to find different associations of relational tension and the exposures to violations of particular balance theory rules. The theoretical logic of the generalizations of the classic model suggests that the rank order strength of these associations may be {A1, A2, A3, A4}.

Sentiment Conversions and Their Payoffs

Current works on the evolution of sentiment networks toward structures that do not violate the rules of balance theory have taken different positions on the mechanisms involved. Van de Rijt's best response dynamics model points to a deliberate process of sentiment conversion calculations of rule violation reduction payoffs. Montgomery (2009) considers the consequences of incomplete awareness of others' sentiments and proposes a mechanism in which best response calculations take into account only those triads in which the individual is involved.

This logic of the near- versus farsightedness of conversions can be extended by approaching projected payoffs as possibly differing for each member of the triad when considering a single sentiment conversion. What might present a payoff for one individual in terms of balancing his or her direct "friends" and "enemies" may be less beneficial or even generate imbalance from the standpoint of other group members. A "myopic" sentiment conversion calculus does not include the conversion's implications for other group members. There is no empirical evidence addressing the question whether individuals react "myopically" to violations of balance theory rules or whether individuals are more likely to convert sentiments with higher rule violation reduction payoffs than lower payoffs. Here, we investigate two hypotheses:

HYPOTHESIS 3a.—*The probability of an* $i \rightarrow j$ *sentiment conversion increases with the extent to which the* $i \rightarrow j$ *sentiment is exposed to violations of balance theory rules.*

HYPOTHESIS 3b.—*The probability of an* $i \rightarrow j$ *sentiment conversion increases with the payoff of that sentiment conversion in reducing the magnitude of exposure to violations of balance theory rules.*

These two hypotheses on sentiment conversions consider both reactions to violations of the four rules of balance as well as conversions that offer larger payoff reductions of balance theory rule violations. Again, we expect to find different associations depending on exposures to violations of particular balance theory rules and that the rank order strength of these associations may be {A1, A2, A3, A4}.

Individual-Level Exposures to Imbalance and Relational Tensions

Individuals make the decisions on sentiment conversions, and they differ in levels of exposure to violations of balance theory rules. The magnitude of individual-level exposure to imbalance is based on the subset of "n choose 3" ijk triads that contain a particular individual i. Individuals also vary in the extent to which their $n - 1$ bundle of sentiments toward others in the group are perceived as tense relations. The greater the size of an individual's bundle of tense relations, the greater the motivation to do something that will reduce these tensions. Balance theory posits sentiment conversion responses that reduce violations of balance theory rules. Our next hypotheses deal with temporal relationships between these two individual-level bundles of exposure to balance theory rule violations and relational tensions. We use the term "total" to refer to these bundles.

Hypothesis 4a.—*The greater an individual's total exposure to relational tension, the greater the individual's total reduction of exposure to violations of particular balance theory rules.*

Hypothesis 4b.—*Greater reductions of exposure to balance theory rules are associated with greater reductions of exposure to relational tension.*

The first hypothesis addresses the temporal linkage of an individual's states of tension and reductions of violations of balance theory rules. The second hypothesis addresses the strength of the association between changes of exposure to violations of balance theory rules and changes of exposure to relational tensions. Here, again, we expect to find different associations depending on exposures to violations of particular balance theory rules and that the rank order strength of these associations may be {A1, A2, A3, A4}.

Community Commitment Condition

Balance theory has only one scope condition—namely, a sentiment network in which every individual has either a positive or a negative sentiment about every other individual in the network. But we believe there may be group-level conditions that moderate whether the balance theory logic is realized. Our candidate for such a condition is whether the group is a community populated by individuals with a distinctive set of commitments to ideals or is a loose aggregation of individuals with no entailed commitments to the group as an entity. If it is the former, then individuals' orientations to the group should encourage an attention to structural problems. If it is the latter, then individuals should be less aware of and concerned with structural problems and their resolution. As Zablocki (1980) discusses in detail, there is considerable variation in how deeply individuals invest their selves in these communes—that is, individuals assign to the group a varying level of "power to shape [their] opinions, preferences, and judgements" (p. 267; see also Zablocki 1971, chap. 6). In more committed groups, individuals are more susceptible to interpersonal influence by remaining "constantly vulnerable in their inner most thoughts and feelings and constantly vigilant in probing the vulnerability of the other members" (Zablocki 1980, p. 326). This idea elaborates the structural approach of balance theory and suggests that individuals will be less responsive to violations of balance theory rules and relational tensions depending on whether the group is a committed community.

Hypothesis 5.—*Structural changes of sentiment networks are more likely to comport with balance theory rules in groups with a shared commitment to ideals than in groups without such commitment.*

We expect to find that reductions of violations of structural balance rules are more pronounced in groups whose members are voluntarily committed to maintaining membership in it, than in groups with low levels of membership commitment. Voluntary social groups may disintegrate, but in most voluntary social groups there are inflows of new members who are entertaining a commitment to the group, outflows of members who decide to leave it, and a stable membership component of members who continue to find value in their group membership. Evidence of balance theory logic should be clearest in the stable component of a group and be more or less in evidence depending on that core component's orientation to a set of ideals. Community commitment should heighten the degree of tension associated with violations of the rules of balance and the cognitive dissonance of being situated in unbalanced sentiment configurations. Without community commitment, individuals are more likely to be indifferent to the structural implications of their own interpersonal sentiments for third parties and for the group as whole.

DATA AND METHOD

The Urban Communes Data Set

Our database for testing these hypotheses is the Urban Communes Data Set (UCDS). The UCDS is a unique multiwave, multimethod study of relatively small, intentional communities in several major U.S. cities, beginning in the 1970s (for full description, see Zablocki 1980; also Martin et al. 2001). The intentional communities that are the focus of the UCDS study should be ones in which balance theory logic is manifested. However, there is considerable variation among the communes in their realizations of the social unit ideals on which they are formed. This variation allows a test of our community hypothesis. The UCDS study allows measures of our constructs and provides a number of advantages over data used in prior investigations of balance theory. First, the data are longitudinal so that it is possible to directly assess shifts toward or away from balance. We deal with the data on the first two waves of study (1974 and 1975).[5] Our dynamic analyses focus on the stable core components in communes, which are the only basis on which one can assess sentiment conversions. We omit from analysis communes with fewer than three stable members over the period. The remaining core components with complete survey data range in size (3–10), and the 129 individuals involved in them are distributed in 31 communes.[6] Second, these data contain measures of directed sentiments among commune members. All commune members were surveyed (with an 80% response rate) on

[5] The 1976 wave covers only a small number of communes, and the data for years subsequent to 1976 have yet to be released.

[6] Our sample has the following characteristics: 50% female, average age of 27, 76% without children, 64% college graduates, and 80% living in the commune for a year or less in the base year.

their relationships with every other member, including whether a particular relationship was "loving" or "hateful" and "tense, somewhat tense, or not tense," as well as a number of more nuanced sentiment indicators. With its multiple groups and measures, the UCDS data are an attractive platform for investigating balance theory. We note our agreement with Zablocki (1980, p. 6) that, while these communes are not "microcosms" of society, they do allow important insights into generic social processes.

Measures

Sentiment network.—Balance theory assumes a group of mutually acquainted individuals in which a positive or negative sentiment exists in every ordered pair of individuals. In the UCDS data, many relationships can be neatly classified as positive or negative on the basis of individuals' reports of "loving" or "hateful" sentiments toward particular others. There is, however, a subset of relationships that were not designated as entailing either love or hatred so that additional information is required to classify them. Moreover, individuals may differ in the meanings they apply to a particular sentiment, as when one person employs "loving" to describe all "friendships" but another reserves "loving" only for family and closest friends (see Yeung 2005; also Swidler 2001). The propensity for openly expressing love or suppressing feelings of hatred is likely to vary with group culture (see Zablocki 1980, chap. 4). Fortunately, the UCDS includes numerous relational variables that characterize the directed sentiments among commune members, and a number of these can be used to more accurately gauge the existence of an underlying positive/negative orientation among members.

We use six variables and latent class analysis (LCA) to classify the sentiment of every ordered pair as either positive or negative. LCA is equivalent to factor analysis, with the result being a probability of class membership for each observation rather than a location in continuous space determined by factors. LCA draws on the information in each individual's profile of sentiments to fit a predetermined number of unobserved classes to the data. The classification of a particular relationship as positive or negative is based on six ordinal responses (no, sometimes, and yes) to questions about the respondent's relationship with every other group member. Three questions allow the expression of a positive sentiment ("loving," "improving," and "exciting"), and three questions allow the expression of a negative sentiment ("hatred," "awkward," and "exploitative"). The LCA results and a validity check on its classification are located in the appendix.

Tension network.—Balance theory does not assume that negative sentiments are tense. Both positive and negative sentiments may or may not be tense, depending on the structural configurations of sentiments in which they are embedded. For this reason, we measure a tension network through a separate direct measure of relational tension in commune members' ordinal responses (no, sometimes, and yes) to a question whether "tension" exists in their relationships with every other group member. We categorize a relationship as tense if a respondent describes the relationship as "tense" or "sometimes tense." Thus, each positive or negative sentiment of the group's sentiment network is associated with a directed network of perceived relational tensions. Among the $i \rightarrow j$ positive sentiments observed among stable members, 36% in 1974 and 34% in 1975 were described as tense by i; among the $i \rightarrow j$ negative sentiments, 34% in 1974 and 41% in 1975 were described as tense by i. The presence of tensions in both negative and positive sentiments offers prima facie support for balance theory's assertion that tensions are distinct from signed relations.

Balance theory rule violations.—A triad sentiment configuration (one of the 16 types of triads) may entail violations of more than one rule, but each rule (and not the triad that contains it) is the basis of balance theory's macrostructural implications. We disentangled rule violations from the triads in which they occurred and counted violations of each rule in each $\{i,j,k\}$ tuple (i.e., an ordered set of three individuals) for the i of the tuple and for the $\{i,j\}$ ordered pair of the tuple. This approach allows an assessment of individuals' and their sentiments' exposures to particular rule violations, where the exposure is the precise number of each type of rule violation.[7]

Payoffs to sentiment conversions.—Every triad sentiment configuration contains six tuples, any one of which may violate one or more rules of balance. Each individual in the triad may be able to reduce the number of tuples violating balance through converting a specific sentiment (positive to negative or vice versa). However, a sentiment conversion may not reduce the number of tuples violating balance rules or may actually increase violations. According to balance theory, individuals should be able to project payoffs to reductions for themselves or other members of the group. Each individual in the triad has two tuples originating from that individual (e.g., *ijk* and *ikj*) that may present violations of one or more balance rules and four tuples not originating from that individual (e.g., *jki*, *jik*, *kij*, *kji*) that may also present violations. A given sentiment conversion may have a projected payoff from the standpoint of the individual converting his or her sentiment, but the same conversion may not entail any payoff for the other triad members or may in fact lead to increases in imbalance from at

[7] We tested models using proportions and found similar results. We believe counts are more consistent with balance theory. Proportions for larger groups will necessarily reduce the weight of imbalanced relations' effects on individual tensions and conversion probabilities, and such group weighting is not a postulate of balance theory. We do control for confounding effects of group size.

least one of their standpoints. To gauge how optimal versus myopic the conversion process is, we decompose the total projected payoffs of each sentiment conversion into a component for each ego (Payoff for Ego) and a component for the total additional projected payoffs for others (Payoff for Alters). These variables take the value zero when there is no projected payoff or a projected increase in violations. The payoff variables are the total number of balance-violating tuples that would be reduced for ego and alters, respectively, if that sentiment were converted.

Community commitment.—The groups vary in their levels of community commitment. All groups were explicitly formed around a collective identity and the goal of fostering community. However, some groups have pronounced characteristics of gemeinschaft, and others are "crash pads" in which members "do their own thing," with little community commitment to the group as a social unit (see Zablocki 1980, chap. 5). Drawing on Kanter's (1972) view of "service" communes during this same period, and Vaisey's (2007) similar concern with more community-like groups in these same data, we categorized each commune as either a high or a low community-committed group. Because most of the communes were newly founded, very few had institutionalized commitment mechanisms, and indeed some moved dramatically toward charismatic authority in seeking stability of consensus (Zablocki 1980, pp. 285–89). The high community-committed groups have the following features set as judged by the UCDS field setting investigators: (1) the overall purpose of the commune is transcendent, (2) the legitimation of commune leadership is partly or wholly charismatic, (3) some or many rules exist that govern members' conduct and behavior, and (4) a strong feeling exists among the members that the commune is a "We." Nine of the 31 communes have all of these features, and we take them to be high-commitment communities.[8]

Control variables.—To account for possible size-related factors, dyadic models control for the total number of triads that contextualize an *ij* sentiment relation in the base year, and individual-level models include the total number of each commune's stable core members. Additionally, dyadic models control for whether the sentiment relation is positive or negative, and individual-level models control for each individual's total number of positive sentiments toward other commune members.

Hypothesis 1.—We examine balance theory rule violations among the stable core over two years (1974–75). Given the noted newness and plastic-

[8] We were able to partially validate our commune-level measure as indicating varying commitment levels by examining individual-level differences in response to a question concerning whether the respondent would "accept $10,000 to leave the commune." While 91% of high-commitment commune members would reject the offer outright, only 61% of those in low-commitment communes would do so.

ity of these groups, this short temporal window should be adequate in gauging balance theory predictions of structural transformations. Because we observe sentiment relations among the same set of individuals over time, the total number of triads is stable, and any change in rule violations results from sentiment conversions. Consequently, a reduction in balance theory rule violations among this stable core is evidence in favor of the hypothesis. To provide some continuity with prior cross-sectional research on structural balance, we include statistical tests for each year that assess the significance of the observed yearly proportions of violations of each balance theory rule. We do so by constructing distributions of these proportions on 1,000 networks for each commune in which each individual member's reported bundle of sentiments about the other members of the commune is randomized. The convention in such tests is to account for possible group-level differences in dyadic factors such as sentiment reciprocity by constraining the randomizations to have the same distributions of mutual, asymmetric, and null ties as the observed communes (Wasserman and Faust 1994, pp. 592–98).[9] Results produce distributions of 1,000 random "worlds," each containing 31 networks with the same dyad censuses as observed communes, and are described by box-whisker plots. The observed proportion of particular rule violations is displayed relative to these distributions in order to provide more insight into the departure from random expectations for each rule violation in a given year.

Hypothesis 2.—Here we test whether the probability of an $i \rightarrow j$ relational tension increases with the extent to which the $i \rightarrow j$ sentiment is exposed to violations of balance theory rules. The units of analysis are $i \rightarrow j$ sentiments. The dependent variable is a binary variable indicating the presence/absence of an i to j tension at time t. The predictor is the ij exposure to violations of particular balance theory rules. As this is the only nonlongitudinal prediction, we examine imbalances and sentiments among all members present in the 31 selected communes in the base year. Among those "n choose 3" ijk triads, there are $n - 2$ triads that contain a particular ij ordered pair. Each of these $n - 2$ triads is associated with six tuples (ijk, ikj, jki, jik, kji, kij) that may or may not present a violation of one or more of the rules of balance. A particular $i \rightarrow j$ sentiment is increasingly exposed to violations of a particular rule as the number of its violations increases in the tuples of the $n - 2$ triads in which the sentiment is embedded. The total number of

[9] Random networks can be conditioned on a number of structural features. A less constrained approach would simply randomize on the basis of network density. One reviewer suggested a more constrained approach that would condition random networks on the degree distributions of the commune. To our knowledge there has been no demonstration to prefer one approach over another, and the vast majority of studies we cite here use some form of the U|MAN distribution as the baseline for randomizing networks.

violations for each rule of balance among all commune members are the predictors of relation tensions.

Dyadic data contain inherently interdependent observations. In our data, the same individuals are observed across sentiment relations, and the same pairs (dyads) appear as both ij and ji directed relations. The modeling challenges of such dyadic data structures have generated various strategies suited to different research goals (e.g., Kenny, Kashy, and Cook 2006; Snijders, van de Bunt, and Steglich 2010). A common concern is the possibility that dyads bias standard errors downward, and because this bias can come from multiple sources of repeated observations, standard fixed- and random-effects models provide insufficient solutions. We therefore follow the strategy of using multiway clustering in order to estimate standard errors, using the estimation procedures outlined in Cameron, Gelbach, and Miller (2011), an approach that is being employed in a growing number of network analytic studies of dyads (Dahlander and McFarland 2013; Kleinbaum, Stuart, and Tushman 2013; Rawlings et al. 2015). For hypothesis 2, we estimate a logistic regression predicting the probability of an i to j tension $\Pr(T_{ij} = 1)$:

$$\ln\left(\frac{\Pr(T_{ij} = 1)}{1 - \Pr(T_{ij} = 1)}\right) = \alpha + \beta_1 I_{ij} + Z\beta + e_{ij}, \tag{1}$$

where α is a baseline logit of tension when predictors are zero, I_{ij} is the number of imbalanced tuples according to each balance theory rule in which the dyad ij is located, Z is a set of controls, and e_{ij} is an error term that is multiway clustered for each ij dyad.

Hypotheses 3a and 3b.—Hypothesis 3a is a test of whether sentiment conversion is predicted by exposure to violations of balance theory rules. Hypothesis 3b is a test of whether sentiment conversion is predicted by the payoff of conversion in reducing the magnitude of exposure to violations of balance theory rules. The units of analysis are $i \rightarrow j$ sentiments. The dependent variable is a binary variable indicating the sentiment conversion event. For hypothesis 3a, the focal predictor of sentiment conversion is as in hypothesis 2, that is, the ij exposure to violations of particular balance theory rules in the base year. For hypothesis 3b, the focal predictors are the payoffs of converting that sentiment, that is, the number of the violations of a particular rule that would be eliminated were i to convert the i to j sentiment (positive to nonpositive or vice versa). We further decompose the payoffs into two components for each ego and alters as described above. For the tests, we estimate logistic regression models predicting the conversion of sentiments between $t = 1$ and $t = 2$ as follows:

$$\ln\left(\frac{\Pr(C_{ij} = 1)}{1 - \Pr(C_{ij} = 1)}\right) = \alpha + \beta_1 I_{ij1} + Z\beta + e_{ij}, \tag{2}$$

where α is a baseline logit of an ij sentiment persistence into time $t = 2$ when predictors are zero. For hypothesis 3a, I_{ij1} is the time $t = 1$ exposure to violations of particular balance theory rules among all $n - 2$ triads in the base year. For hypothesis 3b, I_{ij1} contains the projected payoffs of a conversion based on the base year sentiment configuration. Controls are contained in Z, and e_{ij} is an error term that is multiway clustered for each ij dyad.

Hypotheses 4a and 4b.—The hypotheses deal with changes in individuals' levels of exposure to violations of particular balance theory rules and relational tensions, respectively. The unit of analysis is the individual. Hypothesis 4a is a test of whether an individual's time 1 total exposure to relational tensions predicts the individual's total reduction of exposure to violations of particular balance theory rules between time 1 and time 2. The dependent variable is therefore a change score of the difference in i's total exposure to particular balance theory rules among the stable core members of the commune. Higher scores indicate greater reductions of violations ($\Sigma I_{j1} - \Sigma I_{j2}$). To test this hypothesis, we estimate ordinary least squares (OLS) regression models with standard errors clustered within the 31 communes. Written at the level of individual i within commune c, the model for hypothesis 4a takes the form

$$\left(\sum I_{j1} - \sum I_{j2}\right) = \alpha + \beta_1 X_{j1} + Z_{j1}\beta + e_c, \tag{3}$$

where α is a baseline average i's change in the total number of particular rule violations when other predictors are at zero, X_{j1} is the number of an individual's relational tensions with stable core members at time $t = 1$, and Z contains controls. Hypothesis 4b is a test of whether changes of exposure to violations of balance theory rules predict changes of exposure to relational tensions. The dependent variable is a change score of the difference in i's exposure to relational tensions ($\Sigma T_{j1} - \Sigma T_{j2}$). Higher scores indicate greater reductions of tensions. The focal predictor is the change of individual i's exposure to violations of particular balance theory rules ($\Sigma I_{j1} - \Sigma I_{j2}$). To test this hypothesis, we estimate OLS regression models with standard errors clustered within the 22 communes. The model takes the form

$$\left(\sum T_{j1} - \sum T_{j2}\right) = \alpha + \beta_1\left(\sum I_{j1} - \sum I_{j2}\right) + Z_{j1}\beta + e_c, \tag{4}$$

where the notation is consistent with that described in equation (3).

Hypothesis 5.—This hypothesis states that structural changes of sentiment networks are more likely to comport with balance theory rules in groups with a shared commitment to ideals than in groups without such commitment. All tests of hypotheses 1–4 will involve a test of this hypothesis by running separate models for high- and low-commitment communes.

Descriptive Statistics

Table 2 shows descriptive statistics for the variables used in the analysis.

RESULTS

Our results attend to the separate implications of the four maxims of balance theory and the salience of these rules in high- and low-commitment communes. A triad sentiment configuration (one of the 16 types of triads) may entail violations of more than one rule, but each rule (and not the triad that contains it) is the basis of balance theory's macrostructural implications. We disentangle rule violations from the triads in which they occurred. This approach allows an assessment of exposure to particular rule violations, where the exposure is the precise number of such violations to which an individual i or an $i \rightarrow j$ sentiment is exposed.

The classic model of balance theory posits that all four rules are salient, that their violation is associated with tension, and that the evolution of sentiment networks is an evolution in which violations of these rules are eliminated. Generalizations of balance theory have relaxed the classic postulate that all four rules are salient. All generalizations maintain the first rule of structural balance, and our results confirm that this rule is a secure foundation of structural balance theory. However, we find that the salience of this and other rules of structural balance depends on whether group membership entails a low or high commitment to the group as a social unit. In addition, our results will point to an unexpected (not hypothesized) distinction of the {A1, A3} rules and the {A2} rule. The former anchor an individual on friendship relations (an individual's set of friends), and the latter, on an enemy relation (the individual's set of enemies). The calculus of balance in the core component of high-commitment communes tends to be anchored on positive ties, whereas in low-commitment groups the calculus includes an orientation to negative ties in the core component.

Reductions of Balance Theory Rule Violations

The findings presented in figures 1 and 2 are, we believe, unique. They indicate that temporal reductions of balance theory rules depend on whether the sentiment network involves a group with a high commitment to the group as a social unit. In addition, they support the theoretical generalizations of the classic balance model, all of which permit violations of the A4 rule ("an enemy of an enemy is a friend"). Furthermore, these findings support the importance of the A1 rule ("a friend of a friend is a friend") that all balance theory models assume; the temporal reduction of violations of this rule appears to be the main moving part of sentiment network evolution.

TABLE 2
DESCRIPTIVE STATISTICS FOR VARIABLES USED IN STATISTICAL MODELS

Hypothesis/Variable	Mean	SD	Min	Max
H2 high:				
ij tension	.23	.42	0	1
Total violations of A1	4.57	3.99	0	25
Total violations of A2	3.78	3.69	0	20
Total violations of A3	8.64	7.20	0	28
Total violations of A4	1.52	4.26	0	38
ij positive tie	.80	.40	0	1
Total triads for dyad	13.90	4.13	4	24
N	984			
H2 low:				
ij tension	.36	.48	0	1
Total violations of A1	3.85	2.90	0	14
Total violations of A2	3.93	3.39	0	16
Total violations of A3	4.87	3.61	0	18
Total violations of A4	2.00	4.14	0	22
ij positive tie	.71	.46	0	1
Total triads for dyad	7.41	2.65	3	11
N	947			
H3a–3b high:				
Sentiment conversion	.19	.39	0	1
Total violations of A1	3.66	3.12	0	13
Total violations of A2	3.26	3.29	0	16
Total violations of A3	6.08	4.94	0	20
Total violations of A4	.36	1.50	0	11
A1 payoff for ego	.32	1.48	0	12
A2 payoff for ego	.35	1.66	0	15
A3 payoff for ego	2.43	2.83	0	13
A4 payoff for ego	.10	.52	0	4
A1 payoff for alters	.71	.86	0	4
A2 payoff for alters	.70	.86	0	4
A3 payoff for alters	.63	2.14	0	14
A4 payoff for alters	.09	.49	0	4
ij positive tie	.91	.29	0	1
Total triads for dyad	12.81	4.49	4	24
N	161			
H3a–3b low:				
Sentiment conversion	.21	.41	0	1
Total violations of A1	3.00	2.60	0	11
Total violations of A2	3.07	2.96	0	15
Total violations of A3	4.19	4.11	0	18
Total violations of A4	2.17	4.35	0	22
A1 payoff for ego	.35	1.04	0	9
A2 payoff for ego	.37	1.17	0	11
A3 payoff for ego	1.49	2.23	0	11
A4 payoff for ego	.76	1.68	0	8
A1 payoff for alters	.53	.88	0	4
A2 payoff for alters	.53	.88	0	4
A3 payoff for alters	.60	1.62	0	9
A4 payoff for alters	.33	.77	0	4
ij positive tie	.75	.44	0	1
Total triads for dyad	6.52	2.65	3	11
N	326			

TABLE 2 (*Continued*)

Hypothesis/Variable	Mean	SD	Min	Max
H4a–4b high:				
A1 reduction	−.80	6.17	−24	10
A2 reduction	−5.15	8.94	−29	10
A3 reduction	−3.50	12.46	−33	33
A4 reduction	−1.50	3.99	−16	0
Total tensions	1.20	1.27	0	4
Tension reduction	−.05	1.52	−4	3
Total positive ties	3.68	1.58	0	6
Commune size	7.34	2.16	3	10
N	40			
H4a–4b low:				
A1 reduction	−.25	7.35	−20	20
A2 reduction	−.02	9.26	−24	28
A3 reduction	−2.14	7.67	−22	12
A4 reduction	1.73	7.22	−16	26
Total tensions	1.29	1.19	0	5
Tension reduction	−.15	1.05	−2	4
Total positive ties	2.74	1.55	0	7
Commune size	5.57	1.62	3	8
N	89			

NOTE.—H = hypothesis; high = high-commitment communes; low = low-commitment communes.

The box-and-whisker plots of figures 1 and 2 represent the distributions of the proportion of rule-violating triads in 1,000 random "worlds" of 31 networks simulated with the same dyad censuses as those in the actual high- and low-commitment communes. The boxes contain 75% of the proportions, and the endpoints of the whiskers are the thresholds for a 95% confidence interval (i.e., indicators of the top and bottom 2.5% of proportions obtained from the simulations). The single displayed points are the observed proportions of violating triads at each time period. We must take an observed proportion of rule violations as significantly departing from random expectations if it lies outside the whisker plot for that rule in a given year. If an observed proportion of violations of a rule is to the right of the whisker plot, then an unambiguous structural bias of violation of that rule is indicated. Such bias only occurs for rule A4 ("an enemy of an enemy is a friend"). It is eliminated in the second time period of the high-commitment communes but not in the second period of low-commitment communes. There is no evidence consistent with temporal mechanisms that reduce violations of the A4 rule. In contrast, if an observed proportion of violations of a rule is to the left of the whisker plot, then an unambiguous structural bias of non-violation of that rule is indicated. Such bias occurs for rules A1–A3 in the first time period of both the low- and the high-commitment groups. Results

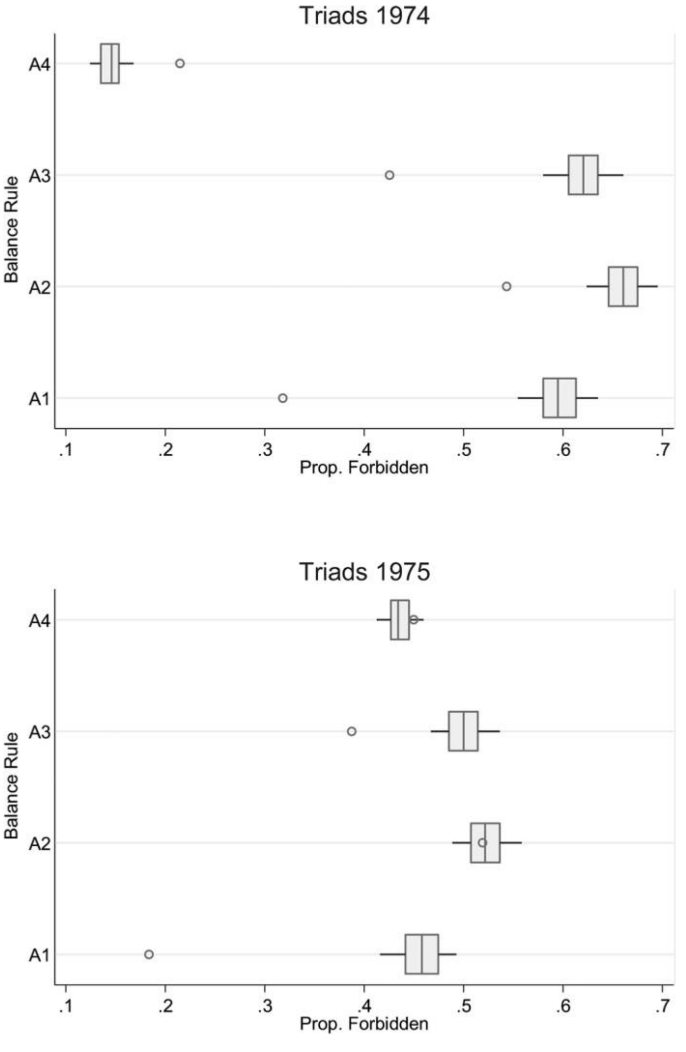


FIG. 1.—High-commitment communes: shifts in the proportion of triads violating four rules of balance.

indicate a generally lower proportion of violations of balance theory rules in high-commitment communes.

Hypothesis 1 concerns reductions in rule violations over time. Evidence of a temporal restructuring of sentiment networks is much more pronounced in the high-commitment communes and, in particular, to corrections of violations of the A1 transitivity rule (“a friend of friend is a friend”). In high-commitment communes, intransitive triads were around 31% of to-

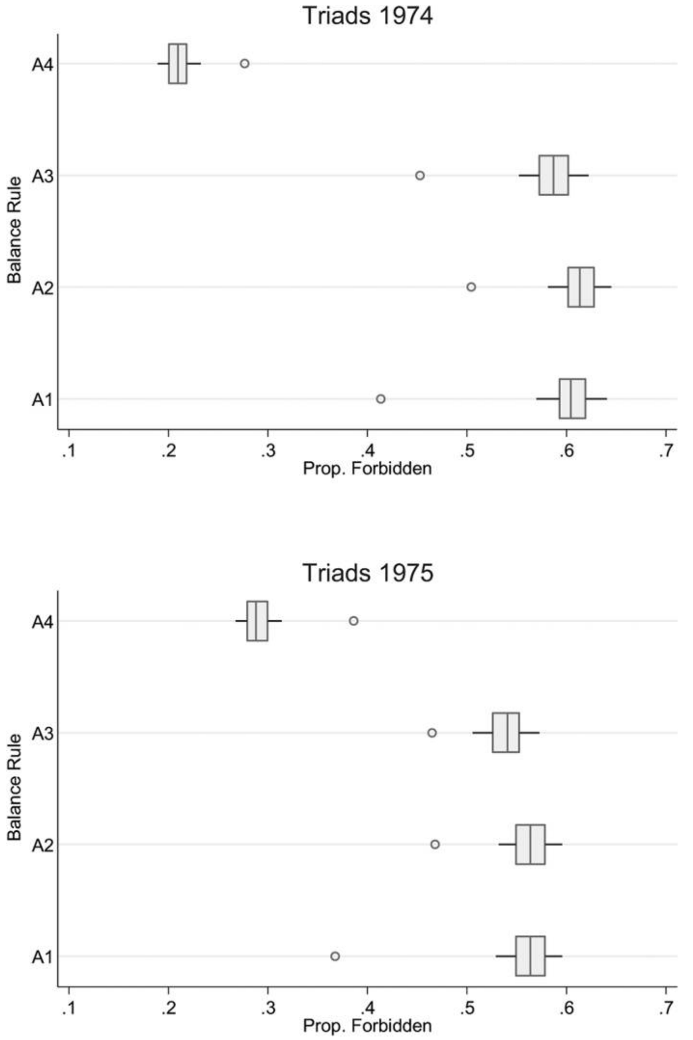


FIG. 2.—Low-commitment communes: shifts in the proportion of triads violating four rules of balance.

tal triads in 1974 and 19% in 1975, while in low-commitment communes, these were roughly 41% in 1974 and 38% in 1975. In high-commitment communes, corrections of intransitivity do not appear to compete with corrections of other rules; that is, their violations appear to be permitted. Hence, we read these data as indicating the merits of the transitivity model that permits violations of the A2–A4 balance rules and focuses on a group dynamic that reduces violations of A1.

Interpersonal Tensions and Sentiment Conversions

Table 3 shows results from logit models predicting the likelihood of relational tensions among commune members as a function of exposure to configurations of sentiments violating each of the rules of balance. The unit of analysis is (i,j) ordered pairs. We attend to the net associations of each type of rule violation with relational tension. In high-commitment communes, the greater the exposure of an (i,j) ordered pair to violations of A1, A2, and A3, the greater the likelihood that i reports the relationship with j as tense. Each violation of A1 is associated with an 8.4% increase in the odds of relational tension ($\exp[.081] = 1.084$), each violation of A2 is associated with an 8.9% increase ($\exp[.085] = 1.089$), and each violation of A3 is associated with a 4.7% increase ($\exp[.046] = 1.047$). There is no association for violations of A4. Table 3 also shows that the associations for violations of A3 are nonexistent in low-commitment communes, and in low-commitment communes violations of A4 are associated with fewer relational tensions. It seems clear again that, with respect to A4, balance theory expectations are not being met and that other balance theory expectations are restricted to or more pronounced in groups in which there is a high commitment to the group as a social unit.

Table 4 shows results from logit models predicting the likelihood of an $i \rightarrow j$ sentiment conversion as a function of exposure to configurations of

TABLE 3

Hypothesis 2: Logit Models Predicting the Likelihood of Relational Tensions

	High-Commitment Communes				Low-Commitment Communes			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Violations of A1	.08** (.03)				.10* (.04)			
Violations of A2		.09*** (.02)				.09** (.04)		
Violations of A3			.05** (.02)				−.03 (.03)	
Violations of A4				.02 (.02)				−.10** (.04)
ij positive tie	.20 (.23)	.19 (.23)	.38 (.30)	.14 (.31)	.20 (.19)	.26 (.19)	.11 (.20)	−.34 (.21)
Total triads for dyad	−.13*** (.03)	−.12*** (.03)	−.13*** (.04)	−.10** (.03)	−.13* (.05)	−.13** (.05)	−.04 (.05)	−.07 (.05)
Constant	−.05 (.47)	−.07 (.47)	−.16 (.48)	−.03 (.49)	−.16 (.34)	−.13 (.35)	−.21 (.35)	.39 (.36)
N	984				947			

Note.—Degrees of freedom = 3; SEs are in parentheses.
* $P < .05$.
** $P < .01$.
*** $P < .001$.

TABLE 4
HYPOTHESIS 3A: LOGIT MODELS PREDICTING CONVERSIONS OF SENTIMENTS ON THE BASIS OF PRIOR LEVEL OF IMBALANCE

	HIGH-COMMITMENT COMMUNES				LOW-COMMITMENT COMMUNES			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Violations of A1 . . .	.20*				.15*			
	(.08)				(.07)			
Violations of A2 . . .		.06				.18**		
		(.07)				(.07)		
Violations of A3 . . .			.12*				.00	
			(.06)				(.05)	
Violations of A4 . . .				−.54**				−.01
				(.20)				(.05)
ij positive sentiment.	−2.06	−2.47*	−1.74	−4.29***	−1.39***	−1.40***	−1.37***	−1.43**
	(1.18)	(1.16)	(1.18)	(1.21)	(.39)	(.40)	(.39)	(.52)
Total triads for dyad.	.05	.08	.07	.120*	−.10	−.14	.00	.00
	(.06)	(.05)	(.06)	(.05)	(.07)	(.08)	(.08)	(.06)
Constant	−1.24	−.68	−1.75	.83	−.25	−.13	−.40	−.33
	(1.29)	(1.19)	(1.30)	(1.21)	(.48)	(.49)	(.49)	(.57)
N	161				326			

NOTE.—Degrees of freedom = 3; SEs are in parentheses.
* $P < .05$.
** $P < .01$.
*** $P < .001$.

sentiments violating each of the rules of balance. The unit of analysis is (i,j) ordered pairs of directed sentiments. We attend to the net associations of each type of rule violation with sentiment conversion. In high-commitment communes, the greater the exposure of an (i,j) ordered pair to violations of A1 and A3, the greater the likelihood of an $i \rightarrow j$ sentiment conversion. Each violation of A1 is associated with a 22% increase in the odds of sentiment conversion (exp[.199] = 1.22), and each violation of A3 is associated with a 13% increase (exp[.121] = 1.129). There is a negative association for violations of A4, such that each instance of a rule violation decreases the likelihood of sentiment conversion by 72% (exp[−.543] = −1.72). In low-commitment communes, significant associations occur for exposure to violations of A1 and A2, but our figure 2 results for the low-commitment communes indicate that these sentiment conversions are associated with only small decreases in the total proportions of triads that violate the A1 and A2 rules.

Table 5 shows results from logit models predicting the likelihood of an $i \rightarrow j$ sentiment conversion as a function of a conversion's payoff in reducing violations of particular rules in the triads in which the $i \rightarrow j$ sentiment is embedded. The unit of analysis is (i,j) ordered pairs of directed sentiments. Payoff is the number of a rule's violations that would be resolved by a particular $i \rightarrow j$ sentiment conversion, decomposed into components for reduc-

TABLE 5
HYPOTHESIS 3B: LOGIT MODELS PREDICTING CONVERSIONS OF SENTIMENTS ON THE BASIS OF THE PAYOFFS IN REDUCING IMBALANCE

	HIGH-COMMITMENT COMMUNES				LOW-COMMITMENT COMMUNES			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A1 payoff for ego	.24 (.25)				.30 (.16)			
A1 payoff for alters	.92*** (.25)				.32 (.18)			
A2 payoff for ego		−.09 (.16)				.51** (.16)		
A2 payoff for alters		.35 (.33)				−.16 (.23)		
A3 payoff for ego			.14 (.08)				−.15 (.09)	
A3 payoff for alters			.02 (.21)				.06 (.16)	
A4 payoff for ego				−.64 (.43)				−.35 (.18)
A4 payoff for alters				−.81 (.87)				.67 (.37)
ij positive sentiment	−3.10* (1.33)	−3.26** (1.19)	−2.98 (1.77)	−4.24*** (1.19)	−1.47*** (.43)	−1.02* (.42)	−.96* (.48)	−1.51* (.59)
Total triads for dyad	.06 (.06)	.09 (.06)	.09 (.06)	.121* (.05)	−.05 (.08)	−.03 (.08)	.01 (.08)	.01 (.06)
Constant	−.56 (1.52)	−.18 (1.13)	−.50 (1.57)	.74 (1.29)	−.31 (.50)	−.61 (.52)	−.63 (.48)	−.33 (.58)
Number of dyads	161				326			

NOTE.—Degrees of freedom = 4; SEs are in parentheses.
* $P < .05$.
** $P < .01$.
*** $P < .001$.

tions from the standpoint of each focal ego's position in all triads and for rule violation reductions in the group's triads apart from ego's payoff. The concept of a payoff calculus has been introduced in the literature to distinguish myopic responses to exposure to structural imbalance from optimal responses preferentially converting sentiments on the basis of the net effects of their conversion. We attend to the net associations of sentiment conversion and conversion payoffs for each type of rule. In high-commitment communes, sentiment conversions operate much less "myopically" than in low-commitment communes. Each projected payoff reduction of A1 violations for the group is associated with a 251% increase in the odds of sentiment conversion ($\exp[.92] = 2.51$). In low-commitment communes, conversions operate more "myopically" and only for violations of A2. Each projected ego's payoff in reducing violations of A2 ("a friend of an enemy is an enemy") is associated with a 67% increase in the odds of sentiment conversion ($\exp[.511] = 1.67$). Thus, the emerging pattern of results indicates unambiguous support for the calculus of A1 and A3 that anchors an individual on existing friends in high-commitment communes and an increased anchorage of orientation to enemies in low-commitment communes.

Individual Bundles of Tensions and Imbalances

Table 6 presents results from regressions predicting changes of individual total exposure to violations of particular balance theory rules as a function of individual total exposure to interpersonal tensions in the base year. The payoff calculus that applies to converting particular sentiments, if it is driven by relational tensions, should be manifested in significant total reductions of individuals' exposure to violations of particular balance theory rules as a function of the size of their base year bundles of relational tensions. Controlling for the number of an individual's positive sentiments, and commune size, the results of table 6 indicate that the size of an individual's base year bundle of tense relations predicts the total reductions of A1 in high-commitment communes. Each additional felt tension during the base year is associated with an additional 1.074 fewer intransitive triads in the following year. In contrast, in low-commitment communes, felt tensions are associated with an inhibited capacity to reduce total violations of A1 and A2 (i.e., the more tension, the greater the increase in imbalance).

The results of table 7 further secure the postulate of a dynamical system in which change in individuals' total exposure to violations of particular balance theory rules predicts change in their total exposure to relational tensions. Reductions in violations of A1, A2, and A3 are strongly associated with reductions in total tensions in high-commitment communes. Total reductions in A4 violations are not significant in high-commitment communes and are associated with increased tensions in low-commitment communes.

DISCUSSION

Structural balance theory presents a fascinating set of propositions on the expected dynamics of sentiment networks based on four maxims that appear in various cultures. The theory has triggered a rich literature and efforts to

TABLE 6

Hypothesis 4a: OLS Regression Models Predicting Reductions of Individuals' Violations of Balance Theory Rules

	High-Commitment Communes				Low-Commitment Communes			
	A1 Violations (1)	A2 Violations (2)	A3 Violations (3)	A4 Violations (4)	A1 Violations (5)	A2 Violations (6)	A3 Violations (7)	A4 Violations (8)
Total tensions 1974	1.07**	.63	1.35	.07	−.97*	−1.73*	−.41	−.76
	(.32)	(.74)	(1.40)	(.44)	(.37)	(.68)	(.60)	(.67)
Total positive ties 1974	−2.42***	−3.74*	−4.60	−1.26	.46	1.19	1.40	−2.56*
	(.46)	(1.61)	(2.15)	(.81)	(1.03)	(1.32)	(1.08)	(1.23)
Commune size	−1.38	−2.03	−4.85	−.40	−.63	1.72	−14.86**	12.50*
	(1.78)	(4.72)	(6.56)	(1.97)	(6.47)	(9.49)	(4.57)	(5.55)
Constant	7.05**	9.67*	16.14	3.40	.13	−2.07	3.42	2.29
	(1.88)	(3.45)	(7.51)	(2.30)	(4.53)	(4.95)	(3.38)	(1.28)
N	40				89			

Note.—Degrees of freedom = 3; SEs are in parentheses.

* $P < .05$.

** $P < .01$.

*** $P < .001$.

TABLE 7
HYPOTHESIS 4B: OLS REGRESSION MODELS PREDICTING REDUCTIONS OF TOTAL INDIVIDUAL TENSIONS

	HIGH-COMMITMENT COMMUNES				LOW-COMMITMENT COMMUNES			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A1 reduction	.15**				.01			
	(.03)				(.01)			
A2 reduction		.09**				.01		
		(.02)				(.01)		
A3 reduction			.05*				.02	
			(.02)				(.01)	
A4 reduction				.12				−.04**
				(.07)				(.01)
Total positive ties 1974	.35*	.33	.24	.17	.11	.10	.09	−.01
	(.15)	(.17)	(.21)	(.18)	(.09)	(.09)	(.08)	(.12)
Commune size	−.46	−.54	−.47	−.68	−.11	−.12	.13	.41
	(.49)	(.64)	(.74)	(.82)	(.54)	(.54)	(.56)	(.61)
Constant	−.67	−.34	−.34	.11	−.37	−.36	−.43	−.30
	(.36)	(.60)	(.68)	(.79)	(.25)	(.25)	(.26)	(.25)
N	40				89			

NOTE.—Degrees of freedom = 3; SEs are in parentheses.
* $P < .05$.
** $P < .01$.
*** $P < .001$.

specify the mechanisms that alter sentiment structures toward structural balance. Longitudinal studies, which might better secure an understanding of these mechanisms, are scarce. The key tension reduction basis of sentiment network evolution away from violations of balance theory rules has remained untested in field settings. Our findings broaden and deepen the empirical analysis of the balance-theoretic approach to sentiment network change and introduce new factors related to mechanisms and scope conditions. Our main conclusions are as follows.

First, there appears to be no support for the salience of the A4 balance rule ("an enemy of an enemy is a friend"). This rule is dropped in all three generalizations of the classic model. Our findings are consistent with several studies that have found a lack of support for the classic model's predictions concerning 003 triads in settings outside balance theory's scope conditions, ranging from online communities (Leskovec, Huttenlocher, and Kleinberg 2010; Szell et al. 2010) to groups of wild mammals (Ilany et al. 2013). The current activity of developing dynamical models of sentiment network evolution concentrates on the discovery of mechanisms that generate the networks postulated by the classic model. We suggest that the mathematical modeling of sentiment network evolution would be better concentrated on the generalizations of balance theory, where violations of the A4 rule are permitted.

Second, the salience of balance theory rules depends on a community commitment condition. Whether a group has social-unit characteristics of gemeinschaft matters. Balance theory effects are dramatically attenuated in communes without a transcendent purpose, a charismatic leadership foundation, a system of norms governing conduct and behavior, and a palpable we-the-commune solidarity. Groups with such characteristics encourage resolution of the structural tensions entailed in violations of balance theory rules. Moreover, our evidence suggests that the calculus of balance in high-commitment communes tends to be anchored on friendships, whereas in low-commitment groups the calculus includes an orientation to enemies. High community commitment elevates the salience of the {A1, A3} rules that anchor an individual on friendship relations (an individual's set of friends). Low community commitment elevates the salience of the {A2} rule that anchors an individual on enemy relations (the individual's set of enemies). Deeper investments of the self and rituals of social solidarity help to coordinate reductions in imbalance by addressing and resolving interpersonal tensions, such that individual payoffs in sentiment conversions matter less than the total payoff for the group. Our findings suggest caution in inferring a tension reduction mechanism as driving shifts toward balance in longitudinal studies in all but the most committed community-like groups. Absent such conditions, other cognitive mechanisms not entailing interpersonal tensions (e.g., Brashears and Brashears 2013), spatiotemporal factors, and status seeking may still affect sentiment change in ways that achieve some greater level of balance. But without a stronger set of community structures and moral substance, these changes are less likely to be systematic for the group as a whole and therefore less likely to lead toward pronounced shifts toward collective balance.

Third, we find systematic evidence of temporal reductions of violations of balance theory rules and linkages of structural violations with relational tensions. Relational tensions encourage reconfigurations of sentiments, and the reconfigurations of sentiments are not haphazard. They reduce violations of balance theory rules and relational tensions. Our evidence supports the assumption of purposeful actors, entailed in some of the recent work on mechanisms of sentiment network evolution, who alter sentiments on the basis of the relative payoffs of converting particular sentiments. Our results indicate that some microlevel shifts toward balance occur even in the absence of interpersonal tensions; however, these are relatively weak and do not add up to pronounced global shifts toward balance. We believe this is consistent with a dual processing of structural imbalance in which only imbalances that rise to the level of deliberative awareness will instigate sentiment conversion strategies that effect collective shifts toward balance.

Fourth, although our findings are consistent with Simmel's attention to structural forms, they also are consonant with Heider's focus on individuals' responses to the structural forms in which they are situated. Each individual is embedded in a local structural environment. The sentiment networks of balance are complete—that is, every individual has a positive or negative sentiment about every other individual. Hence, the local environment of each individual is defined by all the violations and nonviolations of rules of balance theory to which the individual is exposed on the basis of the individual's sets of friends and enemies. How an individual processes this complex environment and why an individual chooses to convert some sentiments and not others are nontrivial questions. But it appears that advancements on these questions are feasible. An intimate relationship exists between individuals' total bundles of relational tensions and total exposure to violations of balance theory rules, such that more tensions precipitate larger temporal reductions of exposure to violations, and larger temporal reductions in exposure to violations produce greater reductions in total tensions. We do not, of course, assert that interpersonal tension is the only factor generating such structural dynamics or that all tensions arise from violations of balance theory rules. However, our findings offer a consistent set of confirmations of the core postulates of balance theory at the levels of groups, dyads, and individuals.

The difficulties of pursuing empirical investigations on sentiment network evolution should be apparent. Such work involves collecting longitudinal data on the state of the network at two or more time periods. Obtaining data at numerous time periods is desirable. However, the practical difficulties involved in assembling such data sets are considerable. The problems are compounded by temporal instabilities of the membership (i.e., node set) of a group. The tests of our temporal hypotheses require a core component of stable members. The members of these core components should be especially attentive to each other and to balance theory logic. Our analysis of the sentiment dynamics of these components assumes that the sentiments of individuals, who are not members of the commune's core component, are noise with respect to the sentiment dynamics within the core. This assumption may be false. Analysis of balance theory logic on sentiment conversions of new members requires a longer temporal sequence of observations than our available data provide. Open questions arise on balance-theoretic socialization of new members and whether this socialization is constrained by sentiment structure of core members.

There is also important work to be done on attrition. A large number of the roughly 60 communes in the original survey were disbanded between 1974 and 1976, and Zablocki (1980) reported that these disbanded communes had higher densities of positive sentiments than enduring communes. It may be that the more consequential difference between these disbanded groups and those that survived is the structural configuration of interpersonal sentiments rather than their volume of positive sentiments (see Bradley 1999). Some of these groups may have been more successful in resolving violations of salient rules of balance than others. But in their reductions of tensions, balance theory allows resolutions that present an all-positive sentiment network, mutually antagonistic subgroups, and hierarchical structures without mutually agonistic subgroups. The implications of these realizations for the endurance of the group over time is an open question that importantly informs an understanding of sectarian processes.

The social psychology involved in sentiment network evolution may be more complex than balance theory suggests. Issues of group identification appear to be involved. The centralities of individuals in a sentiment network also may be important. Studies of cognitive social structures suggest that having a denser network of ties will lead to more accurate perceptions of the sentiment structure (Krackhardt 1987; see also Bondonio 1998). And, while pressures to form cognitively consistent sentiments toward objects may be universal (Homans 1950; Osgood and Tannenbaum 1955; Festinger 1957; Greenwald et al. 2002; Martin 2002), the rules of balance theory may be linked to an underlying moral order that shapes what is considered the correct content and structure of feelings toward others in the group. For example, social relations among highland New Guinea tribes suggest an underlying moral order with a close resemblance to Heider's initial vision of a "with us or against us" world (see Hage 1976). Higher commitment communities are more likely to provoke tensions and to reveal imbalances, but they are also more likely to provide formal and informal opportunities to address such interpersonal tensions and thus to resolve them more quickly. Kanter's (1972) classic study of American communes, which draws on historical data and ethnographic evidence, suggests that a domain of structural and cultural forces larger than balance theory logic may be relevant. Zablocki's (1980) study of these urban communes is similarly concerned with a broader suite of mechanisms, such as processes generating the "charisma" or "alienation" features of the burgeoning intentional community movement of that era. Brint (2001) builds conceptually on Kanter's view, while Vaisey (2007), also using the UCDS, adjudicates the extent to which structural factors and shared moral order separately and in combination generate a stronger sense of identity and purpose. All of these studies suggest that a more complex structural social psychology is involved in understanding sentiment network evolution. But with these caveats in mind, balance theory provides a remarkably sustained and empirically supported basis of advancing our understanding of sentiment networks.

APPENDIX

Deriving Positive/Negative Sentiment Relations

The LCA of sentiment relations suggests that a three-class model is a significant improvement over the two-class model, but a four-class model gives much less improvement in the Akaike information criterion and Bayesian information criterion. Such an "elbow" in fit statistics indicates a reasonable final model. As with factor analysis, LCA then provides a set of weights for each of the input variables that can be used to interpret each class. The LCA also classifies each observation—in this case, latent *ij* interpersonal sentiments—into the class with the highest posterior probability on the basis of the manifest profile of sentiments.

TABLE A1
Results of Latent Class Analysis

	1974			1975		
	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Loving—no	.48	.03	.08	.46	.00	.04
Hateful—no	.87	.93	.70	.94	.99	.84
Exciting—no	.75	.19	.14	.89	.35	.14
Improving—no	.45	.07	.06	.40	.07	.06
Exploitative—no	.81	.89	.68	.93	.98	.73
Awkward—no	.55	.71	.16	.66	.80	.26
Loving—sometimes	.38	.03	.55	.45	.04	.58
Hateful—sometimes	.10	.04	.29	.05	.00	.15
Exciting—sometimes	.21	.26	.74	.09	.24	.71
Improving—sometimes	.14	.04	.31	.23	.04	.28
Exploitative—sometimes	.10	.03	.28	.04	.01	.24
Awkward—sometimes	.29	.22	.80	.24	.16	.68
Loving—yes	.14	.95	.37	.09	.95	.38
Hateful—yes	.03	.04	.01	.01	.01	.01
Exciting—yes	.04	.54	.12	.02	.41	.15
Improving—yes	.41	.89	.63	.37	.88	.66
Exploitative—yes	.09	.08	.04	.02	.01	.03
Awkward—yes	.16	.07	.04	.10	.04	.06

Table A1 shows the weights for the three classes derived from the LCA. In both 1974 and 1975, we see that sentiments fall into one class that is clearly nonpositive, if not necessarily consciously antagonistic (class 1). Although not filled with "hatred" toward one another, individuals within even these communal settings have sentiments that are clearly not loving, not improving, and not exciting. In contrast, a second class of sentiments is clearly positive and heavily weighted toward being loving, exciting, improving, without hatred, not exploitative, and not awkward (class 2). A third class is also largely positive—sometimes loving, sometimes exciting, and improving—but also shows some signs of strain in being sometimes awkward and to a lesser extent sometimes hateful or exploitative (class 3). These latent sentiments may not be precisely the kind of positive and negative orientations we might find in other contexts, but in the context of communes, results are largely confirmatory of a dichotomous orientation of individuals toward one another.

On the basis of these weights, we label sentiments in both classes 2 and 3 as "positive" and those in class 1 as "negative." We examine the construct validity of this decision by analyzing a subsample of our data set who answered the question, "If this commune did not exist, would you want to have a close relationship with this person?" This question was only asked of communes located in the Boston area, preventing its use as an additional indicator of a positive sentiment relation. However, this question affords a check on the convergent validity of our measure, using logistic regression to predict a positive (or qualified positive) response to the question of remaining friends on the basis of our division of sentiments into positive and negative ties as a single dichotomous predictor. We find strong validation for our construct among the subsample of 2,423 sentiment relations in Boston in 1974 and 1,197 in 1975. For 1974, the predicted probably of someone within a latent positive sentiment wanting to remain friends is .77 ($\beta = 1.88$, $P < .001$), while the predicted probability of someone with a latent negative sentiment wanting to remain friends is .33 ($\alpha = -.69$, $P < .001$). For 1975, coefficients are similar with predicted probabilities of wanting to remain friends as .71 for positive ties versus .30 for negative ties ($\beta = 1.74$, $P < .001$; $\alpha = -.82$, $P < .001$).

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