

The Sociological Concept of "Group": An Empirical Test of Two Models¹

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Two models of the structural form of small, informal groups are compared. One, derived by Winship, requires that patterns of social affiliation be strictly transitive. The other, based on Granovetter's ideas about weak and strong ties, requires only a special limited form of transitivity. When these alternative models are tested with data on human interaction, it turns out that the Winship model does not fit the data but that the model developed from Granovetter's work does.

I. INTRODUCTION

Over the years sociologists have distinguished various kinds, or what Simmel (1902) called "forms," of human groups. Among these, one form in particular has continued to interest investigators for more than a century. Groups that are relatively small, informal, and involve close personal ties—those that Tönnies ([1887] 1940) characterized as based on *Gemeinschaft*, Durkheim ([1893] 1933) portrayed as reflecting *solidarité organique*, and both Spencer ([1897] 1933) and Cooley (1909) described as *primary*—remain at the core of the discipline.

I am concerned here with groups of this kind, in which individuals are linked by regular interaction and by positive sentimental ties. In particular, I focus on the problem of specifying their structure.

Numerous attempts have been made to specify the structure of such groups in exact terms (Luce and Perry 1949; Festinger 1949; Luce 1950; Davis 1967; Alba 1973; Winship 1977; Seidman and Foster 1978; Mokken 1979; Seidman 1983*a*, 1983*b*; Borgatti, Everett, and Shirey 1990). None of these attempts, however, has succeeded in capturing sociologists' intuitive ideas about group structure. Typically, the groups uncovered by these models overlap too much to satisfy intuition. Moreover, they fail

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to display the internal structure that groups are generally believed to possess.

Homans (1950, p. 85) spelled out the sociological intuition about overlap. He suggested that, from an individual-centered perspective, groups would almost certainly overlap. Any particular individual would, for example, be likely to be a member of a group at work and another at home in a family setting. But Homans argued (see also Feld 1981) that sociologists do not focus on individuals, but on contexts. Sociological groups are located in particular contexts, like work or home, and are limited to particular time frames, like working hours or evenings. When groups are defined in terms of contexts, they usually overlap very little if at all. This view is widely shared: similar arguments about overlap have been made by Alba (1973), Alba and Moore (1978), Seidman and Foster (1978), Mokken (1979), King and Nakornchai (1982), Seidman (1983*a*, 1983*b*), Yan (1988), and Arabie and Carroll (1989).

Davis, Gardner, and Gardner (1941, p. 150) outlined the sociological intuition about the internal structure of groups. In their study of Southern women, they distinguished between "core members" who participated together most often, "primary members" who participated on some, but not all, occasions, and "secondary members" whose participation was infrequent. This kind of characterization of group structure is common (Lewin 1951, pp. 146–47; Homans 1950, p. 85; Shaw 1981, p. 8; Romney and Faust 1982).

But most attempts to specify group structure represent interpersonal linkages in binary, or on/off, terms. Such binary models are unable to capture the variation in peoples' tendencies to get involved with the group. Festinger (1949), Lévi-Strauss (1963), Hubbell (1965), Doreian (1969), Lorrain and White (1971), Alba (1973), Peay (1974, 1976), Seidman and Foster (1978), Marsden and Laumann (1984), and Yan (1988) have all commented on the limitations of binary models of group structure.

What is needed, then, is a representation that both eliminates overlap and permits the display of the internal structure of groups. Here, I describe and test two such models.

Of the models so far introduced, only the one proposed by Winship (1977) and later by Yee (1980) meets both of these conditions. I begin, in Section II below, by reviewing that model. In Section III, I show that Granovetter's (1973) ideas about weak and strong ties can also be used to develop a model of group structure that meets both of these conditions. There I derive a new model that provides an alternative to the one defined by Winship. Finally, in Section IV, I draw upon some available data to determine whether either of these competing models is satisfactory when it comes to representing the structure of empirical groups.

II. WINSHIP'S MODEL

As one of a family of distance models, Winship introduced a representation that specifies exactly the conditions that partition people into non-overlapping groups and at the same time permits the display of internal group structure. It begins with a set of individuals, $P = \{x, y, z, \dots\}$. These individuals are partitioned into a hierarchical structure by forming a nested sequence of k distinct levels of equivalence classes, E'_i, E''_i, \dots , $i = 0$ to k . At any given level i , the elements in P are partitioned in the usual way, so that E'_i, E''_i , and so on are mutually exclusive and collectively exhaustive. Thus, at any given level, any pair of objects x and y are either equivalent or they are not.

But in addition, in a hierarchical partitioning the equivalence of a pair of elements at some level, $(x, y) \in E''_i$ implies that they are equivalent at every higher level, $j > i$. Thus, two hierarchical equivalence classes at different levels, E'_i and E'_j cannot overlap except by containment; if

$$E'_i \cap E'_j \neq \emptyset,$$

then either

$$E'_i \subseteq E'_j,$$

or

$$E'_j \subseteq E'_i.$$

A hierarchical structure of partitions yields a tree—an ordered sequence of equivalence classes. At the lowest level, E_0 , each object is equivalent only to itself: each person stands alone as an individual. Equivalence classes define nested groups at intermediate levels. And, at the highest level, E_k , all objects are defined as members of a single equivalence class or overarching group.

In order to construct this kind of hierarchy we would need a quantitative measure of people's social affiliation—some sort of *social proximity function*. Let s be a social proximity function, a *mapping* from each ordered pair $\langle x, y \rangle \in P$ to an element in the real numbers in the interval between 0 and 1. Thus, for each ordered pair of elements $\langle x, y \rangle$ in $P \times P$, there is an associated real number, $0 \leq s_{xy} \leq 1$, based on some observable index of the frequency, amount, or depth of affiliation between person x and person y ; it is a measure of how close x and y are.

Social proximities can be used to organize a collection of people into hierarchical partitions only if those proximities are arranged in a form called *ultrametric*. And, to be ultrametric, the function s must meet three conditions:

$$s_{xy} = 1 \Leftrightarrow x = y, \tag{1}$$

each person must be closer to himself or herself than to anyone else;

$$s_{xy} = s_{yx}, \quad (2)$$

the proximity of one person to another must be the same as the proximity of that other to the original person;

$$s_{xy} \geq \min \{s_{xz}, s_{yz}\}, \quad (3)$$

in any triple of persons no pair may be less proximate than the minimum of the other two pairs.

This third condition can be understood as a generalized prohibition against intransitive triples. Consider a general procedure for dichotomizing s . One can begin with $s = 1$ and work down progressively until one hits its minimum value. At each level $s = i$, one can construct a binary relation R_i such that $s_{xy} \geq i \Leftrightarrow (x, y) \in R_i$; that is, only the pairs of people that are socially proximate at a level greater than or equal to i are in the relation at that level. Thus, there are as many dichotomizations as there are levels of s .

Condition (3) is no more and no less than a statement of the rule that no set of three individuals at *any* level of s can exhibit intransitivity. Specifically, it prohibits the case in which, at a given level, an individual x is linked to another y , y is linked to a third z , but x and z are not linked.

Winship's model, then, provides an explicit characterization of the intuitive concept of nonoverlapping groups with internal structure. It embodies the key ideas of the traditional sociological conception. And, at the same time, it yields an explicit, testable hypothesis about the patterning of social proximities.

Winship's model, however, is not the only formal model that can capture the essential features of the sociologists' intuitive notion of groups. In his article on weak and strong ties, Granovetter (1973) introduced an alternative conception of the patterning of proximities. In the next section I review that conception and use it to develop an alternative model of group structure.

III. A MODEL BASED ON WEAK AND STRONG TIES

Granovetter's ideas about the patterning of affiliation grew out of a statement by Rapoport (1954) that "the likely contacts of two individuals who are closely acquainted tend to be more overlapping than those of two arbitrarily selected individuals." Granovetter (1973) extended this idea. He began with Rapoport's notion of "closely acquainted" and distinguished between what he called "strong" and "weak" affiliative ties

linking people. By definition, strong ties are those in which individuals are closely affiliated, while weak ties involve less intimate connections.

Like Winship (1977), Granovetter was concerned with transitivity. But Granovetter qualified that notion. Following Rapoport's reasoning, he proposed that if an individual is *strongly* tied to two others, the two others should be *at least weakly* tied to each other; he was arguing, in effect, that a friend of a friend should be *at least* an acquaintance.

Granovetter went on to suggest, moreover, that when one or both of the ties linking an individual to two others is weak—when they are only casual acquaintances—there will be no such pressure toward linking the two others. At this level, intransitive triples would be expected to occur.

Granovetter's ideas about tie strength and social structure can be modeled in a way that parallels Winship's model of hierarchical partitioning. Again let $P = \{x, y, z, \dots\}$ be a collection of individuals. And again define an index of affiliation-based social proximity s as above:

$$s_{xy} = 1 \Leftrightarrow x = y, \tag{4}$$

$$s_{xy} = s_{yx}. \tag{5}$$

But while the Winship model prohibited *all* intransitive triples, a model based on Granovetter's conception would prohibit only those containing two strong ties and one complete lack of tie. Thus, we would not expect the social proximities to be ultrametric, and condition (3) would not apply.

Instead, I will substitute a condition that prohibits some, but not all, intransitive triples. There must be some constant ℓ that divides weak and strong ties. Thus, there can be no triples of three individuals x, y, z in which x and y are tied more strongly than that constant, y and z are tied more strongly than that same constant, and x and z have no tie at all. So, based on Granovetter's conception, we can specify the required alternative:

$$\exists s = \ell \mid s_{xy} \geq \ell, \tag{3'}$$

and

$$s_{yz} \geq \ell \Rightarrow s_{xz} \neq 0,$$

where $s_{xy} = 0$ if and only if x and y have no affiliation.

This condition captures Granovetter's weaker version of Winship's prohibition against intransitive triples. I call triples that violate this rule G intransitive. The problem, of course, is to determine whether an appropriate value of ℓ exists so that Granovetter's condition is met.

To do this, one can again use the general procedure for dichotomizing introduced above. I proceed from top to bottom as before, beginning with $s = 1$ and dichotomizing at successively weaker levels of affiliation.

If this model is correct, the top levels—where the ties are strongest—will not exhibit any G intransitivity. We can continue working down, then, until we can proceed no further without encountering a G -intransitive triple. At that point, we have defined the critical level ℓ that distinguishes between strong and weak ties. Any pair of individuals who are linked at any proximity greater than or equal to ℓ are strongly tied. Any pair who are at any proximity less than ℓ , but greater than 0, are weakly tied. And the others are not tied.

If we dichotomize at level ℓ , and draw a graph at that level, we can see that some pairs of points are adjacent; they are directly connected by a line. Other pairs may be indirectly linked by a *path* beginning at one point, passing through one or more intermediaries, and finally connecting with the other. All points that are connected, either directly or indirectly are *reachable* from each other.

So, at level ℓ , the set P is partitioned into *components*, or subsets within which all points are reachable from each other. And, of course, components cannot overlap. No member of any component is linked to (is affiliated with) anyone outside that component at a level as great as ℓ . Therefore, as was the case for Winship's partitions, these subsets are nonoverlapping. And, as was the case for partitions, each component will contain one or more points. Only here, unlike partitions, the points in a component are not necessarily all directly connected to each other; here there may be triples that are—strictly speaking—intransitive.

But from the way we constructed the dichotomy it is clear that condition (3') holds and that none of these intransitive triples is G intransitive. One could simply add in the weak ties, those in the range $0 < s < \ell$, and that would automatically eliminate all of the intransitive triples created by the strong ties; all the missing third lines would be filled in. Thus, we know that in any subset that contains more than one individual, each subset member is related to (is directly affiliated with) *at least one* other subset member at a level $s \geq \ell$ and with *every* other member of that subset at a level $s > 0$.

But if one really did add the weak-tie lines to the graph, not only would one eliminate intransitive triples created by the strong ties, but one would take the risk of creating new intransitive triples. Indeed, in his own treatment of this structure Granovetter stressed the importance of intransitive weak ties as communication "bridges" linking the components described above.

So here then is an alternative model of group structure. Like Winship's model it captures the essential features of the intuitive conception of groups. And, also like Winship's model, it embodies a testable hypothesis about the patterning of affiliation. This new model makes less stringent demands on the data than those made by the Winship model. Nonethe-

less, it does require that there be no *G*-intransitive triples among the individuals who are affiliated at the closest levels. And that is a testable proposition.

Winship himself suggested that the demand for complete transitivity required by his model implied social arrangements that were not "typical." But that question, and the parallel one for the Granovetter-based model, are essentially empirical problems. They can be addressed only by testing the models with systematic data on social proximities. Only by examining such data can we determine whether the conditions specified by either of these models are seen in actual human social arrangements. That is my next task.

IV. A SYSTEMATIC TEST OF THE TWO MODELS

In order to test whether either of these models corresponds to the human social world, we need systematic information about people's affiliation patterns in particular social contexts. We know that affiliation includes both interaction and positive sentiment, but it is generally agreed that interaction is a necessary, if perhaps not sufficient, condition for affiliation (Cooley 1909, p. 24; Homans 1950, p. 84; Olmstead and Hare 1978, pp. 10–11; Shaw 1981, p. 8). For the present purpose, then, I searched for data sets that provided records of relatively long-term interaction.

I was able to locate seven such data sets: (1) Old South (Davis, Gardner, and Gardner 1941), (2) Lunch (Freeman 1987), (3) Beach (Freeman, Freeman, and Michaelson 1988), (4) Karate (Zachary 1977), and (5) Frat, (6) Tech, and (7) Office (Bernard and Killworth 1977; Bernard, Killworth, and Sailer 1980). These seven data sets represent a broad spectrum of different ways of recording social proximity. However, they are all based—directly or indirectly—on tabulations of interaction. The ways in which interaction was observed, the ranges of variation in interaction, and the numbers of individuals involved are all summarized in figure 1.

The Winship model specifies that there be *no* intransitive triples at any level of interaction. If any are observed, we should reject the model. In practice, of course, there is apt to be a certain amount of error in observing and recording the data. That being the case, we should probably be willing to accept a small number of intransitive triples in any particular data set. It is difficult to specify exactly how many intransitive triples would be acceptable, but their number should certainly be relatively small.

Counts of the numbers of intransitive triples at each level for each of the seven data sets are shown in figure 2. On the face of it, the numbers of intransitive triples recorded in the table are so large that we simply cannot reasonably conclude that they stem from errors in observing or

Data Set	Number	Range	What was observed
Old South	18	0- 7	Number of informal social events jointly attended
Lunch	28	0- 10	Number of informal lunches jointly attended
Beach	52	0-205	Number of minutes observed in conversation
Karate	34	0- 7	Number of contacts observed in non-club contexts
Frat	58	0- 30	Number of conversations observed in the public areas of the house
Tech	34	0- 14	Number of conversations observed in the workplace
Office	40	0- 16	Number of conversations observed in the workplace

FIG. 1.—Numbers of individuals, ranges of variation, and what was observed in seven data sets.

recording data in a situation where there is no intransitivity. Indeed, the data suggest quite dramatically that human interaction frequencies do not fit the Winship model.

As they are represented by Winship's model, then, groups simply do not appear in the world of experience. The available data on interaction suggest that intransitivities are always present and present in considerable number.

Let us now turn to the alternative model based on Granovetter's weak and strong ties. It will be easiest to illustrate how this model may be tested by beginning with an example. The Old South data provide records of women's coattendance at a series of small, informal social events. We will examine these data from the perspective of this model.

None of the triples of women who coattended four or more social events is G intransitive. There are, however, G intransitivities in the triples of women who coattended three or fewer events. In this case, then, $\ell = 4$, and I will consider any pair of women who coattended four or more events to be strongly tied.

Figure 3 shows the strong ties linking these 18 women. In the figure there are two large groups and three singletons. If we compare this structure with that described in the ethnographic report, it turns out that the group containing women 1-9 (with the exception of woman 8) corresponds to Davis, Gardner, and Gardner's Clique I. Moreover, the group made up of women 10-16 corresponds to their Clique II.

Strength	Number		Strength	Number		Strength	Number
6	2	Old South	30	0	Frat	44	65
5	0		26	0		43	69
4	28		25	0		42	71
3	76		23	2		40	72
2	201		20	2		39	76
1	146	19	8	36		84	
		18	7	35		108	
9	0	17	11	34		109	
8	2	16	15	33		125	
7	2	15	30	32		156	
6	7	14	57	31	159		
5	23	13	58	30	173		
4	31	12	108	29	196		
3	30	11	154	28	209		
2	44	10	238	27	209		
1	283	9	324	26	214		
		8	422	25	218		
		7	639	24	252		
10	0	6	949	23	265		
8	2	5	1443	22	273		
7	11	4	2272	21	284		
6	28	3	3863	20	316		
5	43	2	6598	19	339		
4	81	1	10013	18	361		
3	145			17	397		
2	269			16	423		
1	1038			15	491		
		130	3	14	505		
		121	6	13	508		
13	0	110	7	12	586		
12	0	109	11	11	622		
11	1	90	11	10	665		
10	3	86	16	9	730		
9	6	83	22	8	793		
8	12	81	27	7	853		
7	12	79	35	6	998		
6	18	78	35	5	1254		
5	35	76	44	4	1454		
4	103	75	44	3	1730		
3	257	73	45	2	2110		
2	579	69	45	1	2897		
1	1764	67	47				
		66	50				
		58	50				
5	7	55	52				
4	33	52	50				
3	123	46	55				
2	324	45	65				
1	393						

FIG. 2.—Tie strength and numbers of intransitive triples in seven data sets

It is clear that the structure shown in figure 3 corresponds quite closely to that described in the ethnographers' accounts. As they are presented, however, the groups of figure 3 include triples that are, strictly speaking, intransitive. The triple containing women 3, 7, and 9 is a case in point. But it must be remembered that, though they are intransitive, they are not *G* intransitive. Thus, there is a weak tie linking woman 7 and woman 9. And, correspondingly, there are weak ties linking every unlinked pair of points within each of the groups in the figure.

But, if we add *all* the weak ties, we not only complete the two groups, we introduce a huge number of bridges between them and between the isolates and the groups. The weak ties are shown, along with the strong

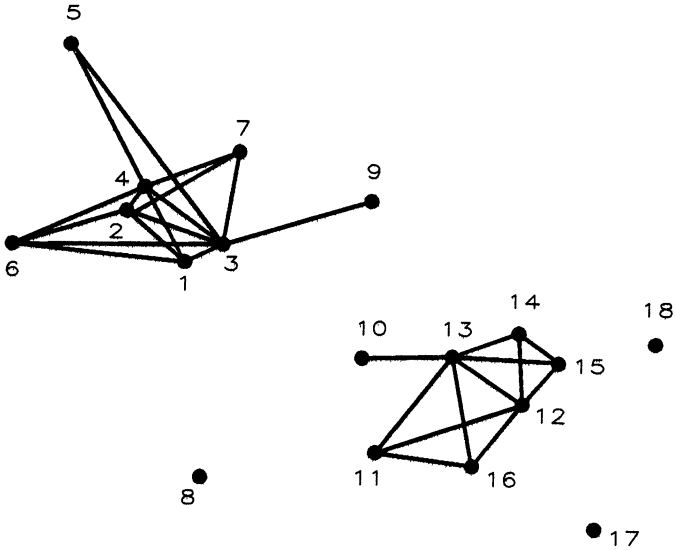


FIG. 3.—Strong ties in the Old South data set

ones, in figure 4. The Old South women are organized into two groups, but those two groups are intimately linked together by the weak ties that bridge both groups. Overall, then, the model suggested by the Granovetter conception of groups seems to be able to uncover the structure of groups in the Old South data quite well.

This same procedure was applied to all seven of the data sets used here, and the applications met with varying success in uncovering group structure. Acceptable triples are those that meet the Granovetter criterion, the one in which two pairs are linked by strong ties ($s \geq \ell$) and the third pair is linked by at least a weak tie ($s > 0$). To the extent that such triples are found at high interaction levels, the data fit the model. But if those individuals who are involved in the most frequent interactions are linked in a way that exhibits unacceptable (G -intransitive) triples, the data do not contain groups in the Granovetter sense.

Table 1 shows the numbers of acceptable triples at each proximity level (working down from the highest level) for each of our seven sets of data. Four of the data sets, Old South, Frat, Lunch, and Beach, display relatively large numbers of acceptable triples before an unacceptable one is found. But two data sets (Tech and Karate) have G -intransitive triples at even the highest levels of social proximity. And, in the case of the Office data, only four acceptable triples are recorded before a G -intransitive triple is encountered.

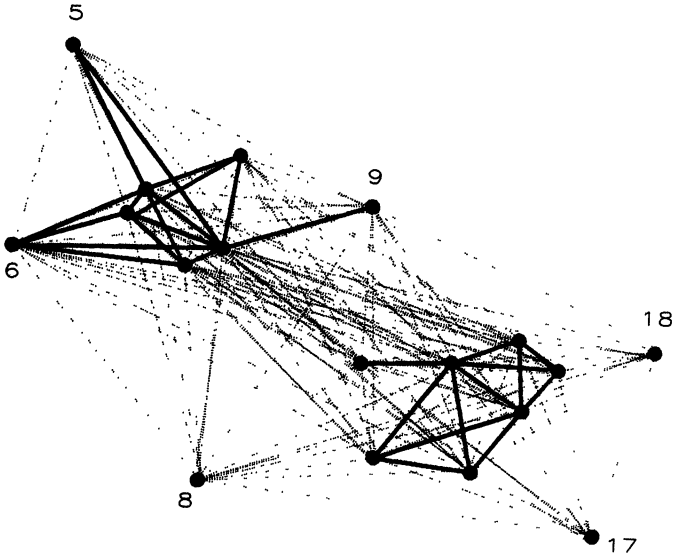


FIG. 4.—Strong and weak ties in the Old South data set

Since we can count the total number of acceptable triples for each of our data sets at all levels, we can evaluate the magnitudes of the numbers in table 1. For any particular data set, we can calculate the probability that a randomly selected triple is acceptable. Then, by multiplying these probabilities, we can calculate the probability of encountering a series of acceptable triples as long as the one observed, by chance alone. As the table shows, these probabilities are dramatically small for the Old South, Frat, Lunch, and Beach data sets. But the Office, Tech, and Karate data

TABLE 1
NUMBER OF ACCEPTABLE TRIPLES TABULATED
BEFORE ENCOUNTERING A G-TRANSITIVE TRIPLE

Data Set	No. of Triples
Old South	62**
Office.....	4
Frat.....	108**
Tech.....	0
Lunch.....	51**
Beach.....	104**
Karate.....	0

** $P \leq .01$.

sets all yield probabilities too large to be significant. Thus, the model based on Granovetter's conception of weak and strong ties reveals groups in some, but not all, cases.

V. CONCLUSIONS

The results of confronting the Winship model of group structure with data on human interaction are unambiguous. Interaction is simply not patterned in the neat way suggested by that model. But the results of confronting the Granovetter-based model with data show that the model reveals groups in at least some of the data sets.

Marsden and Campbell (1984) have provided a clue that may help to explain this result. They have proposed that the kinds of records of interaction frequencies used here provide poor measures of social affiliation. They argue that interaction frequencies are inadequate because they tend to reflect the effects of external constraints. People who are neighbors or co-workers, they suggest, may interact frequently, but their interaction need not embody the sort of intimacy envisioned in the group concept.

Whether this is a problem or not probably depends on the context in which interaction frequencies are observed. When the context permits observation of interaction that is voluntary and informal and ranges over a broad spectrum of activities, there is no reason to suspect that the individuals involved are interacting in terms of external constraints.

Indeed, if we assume that interaction frequencies provide a reasonable index of social affiliation only in settings where interaction is relatively unconstrained, the present results make sense. The Old South, Frat, Lunch, and Beach data all exhibit a clear group structure. And they are all based on records of interaction in informal, voluntary settings. In contrast, the Office and Tech data sets do not exhibit group structure. Both sets are based on observations of interaction in the workplace, where we would expect a good deal of interpersonal interaction to be determined by the formal tasks of the organization.

The fact that groups are not present in the Karate data is more difficult to interpret. On one hand, the data consist of records of the number of different nonclub contexts in which the members of the karate club were observed together. This would suggest that the data should embody patterns of informal voluntary interaction. But, on the other hand, the ethnographic report stresses the fact that, during the time the data were collected, the club members were involved in a major conflict that ultimately led to its breakup. The poor fit observed here might be a consequence of the fact that outside contacts among the club members were made in an instrumental effort to further organizational interests.

In any case, the model based on Granovetter's ideas does reveal groups in more than half of the data sets. And the cases in which it does are exactly those in which there are no evident constraints on interaction. These results suggest that Homans (1950) was probably wrong when he proposed that sentimental ties *necessarily* emerge from sustained interaction. Indeed, the amount of correlation between interaction frequency and strength of sentimental links between persons might be expected to vary with setting. In settings that are entirely free from constraints, the correlation is likely to be high; in those where constraints loom large, the correlation should be low.

Moreover, the patterning of interaction appears to be more complex than that envisioned by Homans (1950, p. 84) when he argued that *all* group members interact with other group members more than they do with *any* outsider. But here we have shown that nonoverlapping groups can be specified in such a way that individual group members may interact as much or more with outsiders than they do with some of their fellow group members. The important feature of the groups specified by the Granovetter model is that any group member interacts more *with at least one* fellow group member than with any outsider.

Finally, the formal model introduced here reveals an important implication of Granovetter's original statement. In his own treatment, the discussion of tie strength seemed to be somewhat vague. He distinguished between "strong" and "weak" ties, but did not suggest how we might determine which was which in any given situation. The model developed here, however, shows that a systematic way to distinguish between weak and strong ties was already implicit in his original formulation.

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