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A Test of Structural Features of Granovetter's Strength of Weak Ties Theory*

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Granovetter's 'strength of weak ties' theory offers a satisfying approach to the study of integration in networks of face-to-face interaction consisting of multiple subgroups. The present paper tests five hypotheses of this theory in the setting of a multidisciplinary social network of biological scientists. Considerable support for the theory is indicated: the local bridges and intergroup ties in the network are disproportionately weak ties.

Granovetter (1973) proposes a basis of integration of a type of social structure whose integration previously has appeared problematical. The theory has received widespread attention[1]. However, the propositions forwarded by the theory still await systematic tests. Killworth and Bernard (1974:346) suggest that their evidence does not support the theory. Since Granovetter himself supports his propositions on the basis of *ex post facto* interpretations of previously published results, the present empirical status of the theory is uncertain, even as it has become increasingly entrenched in the sociological imagination.

The theory most directly pertains to networks of face-to-face interaction. These networks often manifest a pattern of ties consisting of tight-knit clusters which are loosely coupled to each other; it is a pattern suggestive of local (intragroup) integration in combination with an anomy of the whole. Figure 1 illustrates the pattern.

Granovetter's theory rests on the idea that bridges (or local bridges) between cohesive clusters are important channels of information flow and bases of intergroup cohesion. In the graph analytic perspective, a bridge is a tie between two persons that is the sole path by means of which the two persons (and their direct contacts) are joined in a network (the definition of a local bridge is somewhat different and will be taken up later in the text). The importance of bridges, of course, is that they represent the only possibility of a flow of information between two sets of persons. Granovetter

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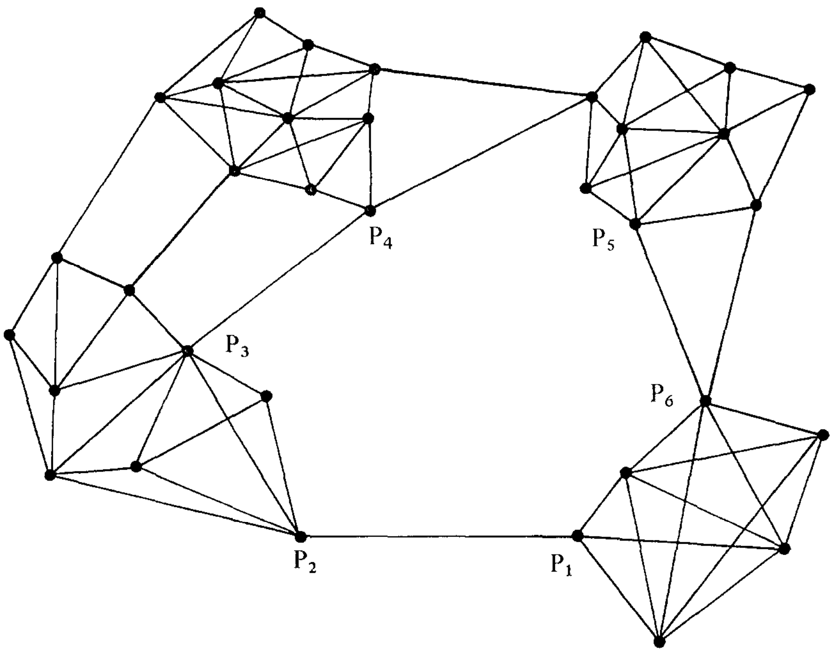
[1] By my count, the paper has been cited over fifty times during the six years since its publication.

Figure 1. *Hypothetical network of face-to-face interactions.*



goes beyond this, however, and argues that information does flow across the cleavages of a differentiated population by means of such bridges. He asserts that bridges tend to be weak ties, as opposed to the stronger ties which tend to be found within clusters. Hence, the importance of weak ties.

The results of a test of Granovetter's 'strength of weak ties' theory are reported in this paper. These results suggest considerable support for the idea that the structural coherence of differentiated populations depends disproportionately on weak ties.

Methods

A mailed questionnaire was used to gather information about the research network among faculty members in seven biological science departments of a single university – anatomy, biochemistry, biology, biophysics/theoretical biology, microbiology, pharmacology/physiology, and pathology. Each questionnaire contained a list of those faculty members in residence with a primary appointment in one of the departments.

For each faculty member listed on the questionnaire, the respondent indicated whether the following types of relationships existed between them:

1. I know something of person's work;
2. I have read or heard person present his/her work;

3. I have talked with person about his/her work;
4. I know something of person's current work;
5. I have read or heard person present his/her current work;
6. I have talked with person about his/her current work.

The instructions to respondents make it clear that the first three of these items refer to any research a person has done, while the remaining three items refer only to research a person is engaged in at the time of the survey. The response to the survey was 71.3% of 136 faculty members.

Construction of the network

The analysis focuses on unordered respondent pairs of which there are 4656: the analysis follows Granovetter who dealt with networks of undirected ties (*i.e.*, graphs). The structure of the faculty's research network is based on their responses to the item "I have talked with person about his/her current work", where 'work' is understood to refer to research.

Tie strength

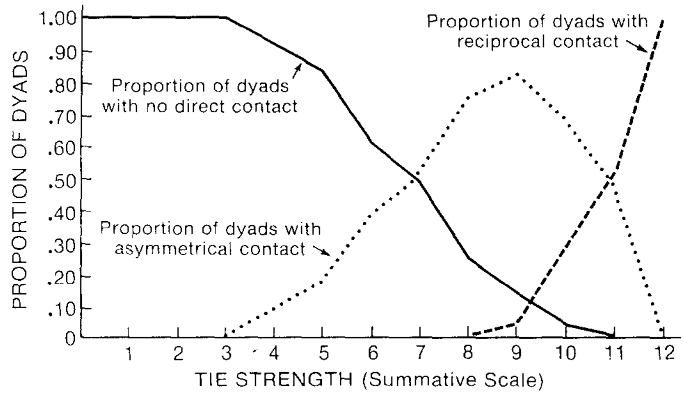
Describing the concept of tie strength, Granovetter writes, "The strength of a tie is a (probably linear) combination of the amount of time, the emotional intensity, and intimacy (mutual confiding), and the reciprocal services which characterize the tie" (1973:1361).

All the information a respondent provides about his or her relationships with another faculty member may be drawn upon to construct a measure of tie strength. A summative scale, the measure, is constructed by adding together the number of different relationships each member of a dyad reports having with the other member. Since there are six possible relationships, the measure has a range of 0 to 12: a dyad receives a score of zero if both members are unrelated on all six relationships and a score of twelve if they are reciprocally related on all six relationships. In dyads with a score of zero, there is no contact about or awareness of each member's past or present research; in dyads with a score of twelve, there is a reciprocated awareness of each member's current research based on reading or meeting attendance, as well as a reciprocated discussion of each member's current research.

For purposes of analysis it is convenient to use one component of the scale, rather than the scale itself, as the measure of tie strength: whether or not a discussion about current research is reciprocated or not reciprocated. Strong ties are defined as those in which both faculty members' current research activity has been discussed, and weak ties as those in which only one of the faculty members' current research has been discussed. The measure is consistent with Granovetter (1973:1364) who treats asymmetrical contact as a weak tie and reciprocal contact as a strong tie.

Figure 2 shows how the dyads in which there has been no contact, asymmetrical contact and reciprocal contact are distributed among the dyads that receive different scores on the summative scale of tie strength: the two measures are highly related (gamma = 0.975).

Figure 2. *Within groups of dyads with different tie strengths, the proportion of dyads without direct contact, with asymmetrical contact, and with reciprocal contact.*



Results

Local bridges and strength of ties

Granovetter develops the concept of 'local bridge'. Unlike a bridge, when a local bridge is removed from a network the members of the local bridge (and their contacts) remain joined in the network. The 'degree' of a local bridge is the length of the shortest path which joins the members of a local bridge, were the local bridge removed from the network. Granovetter points out that as the degree of a local bridge increases, bridges and local bridges may tend to become equivalent in terms of their roles in networks; for example, information will not tend to flow over very long paths, so that a local bridge of high degree or a bridge may be the only effective channel of information flow between two persons and their direct contacts. Local bridges have a minimum degree, which is three: directly joined dyads with one or more common contacts are not local bridges. Figure 1 contains several local bridges: for example, P_1-P_2 is a local bridge of degree eight and P_3-P_4 is a local bridge of degree four.

In the network among the biological scientists, there are eleven local bridges.[2]

Hypothesis 1. All local bridges are weak ties (Granovetter 1973:1364). This assertion is supported: all eleven of the local bridges are weak (asymmetrical) ties. The majority of direct ties among the respondents are weak (0.69); however, the null hypothesis that these eleven weak bridges occurred

[2] Since all the persons are joined in a single network and have at least two direct contacts, the local bridges are simply those dyads that are not involved in a two-step joining path. All the local bridges found in the network are of degree three.

by chance is rejected ($p = 0.02$).[3] We shall see that there are additional bases of support for the idea that local bridges tend to be weak ties.

> *Hypothesis 2.* Consider, now, any two arbitrarily selected individuals – call them P and O – and the set, $S = X_1, X_2, X_3 \ldots$, of all persons with ties to either or both of them. The hypothesis which enables us to relate dyadic ties to larger structures is: the stronger the tie between P and O, the larger the proportion of individuals in S to whom they will both be tied, that is, connected by a weak or strong tie. The overlap in their contact circles is predicted to be least when their tie is absent, most when it is strong, and intermediate when it is weak (Granovetter 1973:1362).

Table 1 indicates support for the hypothesis: the contact circles of two scientists tend to overlap more as the strength of the tie between the two scientists increases. The figures in the tables are the average proportion of S that are the common contacts of two scientists, controlling for the size of S, and the absolute difference in the sizes of the two scientists' research circles.[4]

The purest test of Granovetter's hypothesis is found in the condition where the size discrepancy between two contact circles is small (the size of the smaller of two contact circles places a constraint on the possible degree of overlap that may occur). Where this discrepancy is relatively small (*i.e.*, 0 - 6), the data are entirely consistent with the hypothesis: for example, when S is in the range of 16 - 20 persons, on average 0.06 of S are the common contacts of untied dyads, on average 0.23 of S are the common contacts of weakly tied dyads, and on average 0.33 of S are the common contacts of strongly tied dyads. Throughout the entire table, there are three instances of non-support for the hypothesis.

A complementary perspective is also helpful in accounting for the result that bridges tend to be weak ties. A common contact of two untied persons may create opportunities for the two persons to meet and become tied on some criterion. Here the focus is on the nature of the contact's relations to members of a dyad, rather than, as above, on the dyad's relation.

> *Hypothesis 3.* Among dyads, $P–O$, with one common contact, X, the probability of a $P–O$ tie (weak or strong) is greatest when X has strong ties to P and O, $P–X–O$ Strong; it is lowest when X has weak ties to P and O, $P–X–O$ Weak; and it is intermediate when X has one weak and one strong tie to P and O, $P–X–O$ Mixed (*cf.* Granovetter 1973: 1363).

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[3] The binomial test:

$$P(X) = \left(\frac{N!}{X!(N-X)!}\right) P^X Q^{N-X}$$

where $N = X = 11$, $P = 0.69$, and $Q = 0.31$.

[4] Let C_1 be the set of P's contacts and C_2 the set of O's contacts, then $C_1 \cap C_2 / C_1 \cup C_2$ equals the measure of overlap: this ratio is computed for each $P–O$ dyad that falls in a particular condition of the two control variables; it is the averages of these ratios that are reported in Table 1. A test of significance is not appropriate here, since the assumption of independence is violated. Consequently, the decision about whether or not the hypothesis is supported is determined by the extent of consistency of the results reported in the table.

Table 1. *Relationship between the strength of a dyadic tie (absent, weak, strong) and the degree of overlap in their contact circles (average proportion of common contacts), controlling for the size of the union of the contact circles and the absolute difference in the sizes of the circles**

Size of the union of the contact circles	Absolute difference in the size of the contact circles: 0 - 3			4 - 6			7 - 9			10 - 12			13 - Hi		
	Tie strength														
S	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S
0 - 5	–	–	–	–	–	–	–	–	–	–		–	–	–	–
6 - 10	0.22	–	–	0.06	–	–	–	–	–	–	–	–	–	–	–
11 - 15	0.07	0.32	–	0.10	–	–	0.05	–	–	0.05	–	–	–		–
16 - 20	0.06	0.23	0.33	0.07	0.22	0.33	0.09	0.26	–	0.06	0.19	–	0.02	–	–
21 - 25	0.06	0.24	0.38	0.06	0.18	0.19	0.06	0.20	0.25	0.05	0.21	0.21	0.07	0.16	0.18
26 - 30	0.06	0.14	0.27	0.06	0.14	–	0.06	0.14	–	0.06	0.15	0.25	0.06	0.18	0.20
31 - 35	0.06	0.17	0.18	0.07	0.26	–	0.05	0.22	0.30	0.08	0.22	–	0.07	0.17	0.16
36 - 40	0.06	0.15	–	0.06	0.23	–	0.11	0.25	–	0.08	0.20	0.20	0.06	0.15	0.23
41 - 45	0.11	0.25	–	0.11	–	0.31	0.06	0.16	–	0.07	0.22	0.24	0.07	0.14	0.23
46 - Hi	0.12	0.25	0.32	0.10	0.20	0.26	0.13	0.23	0.31	0.08	0.19	0.33	0.07	0.15	0.23

*The average proportion was not computed where the number of cases upon which it is based was less than three.

Supportive of the hypothesis are the findings that the proportion of dyads that are directly tied rises from 0.01 among those without any common contacts, to 0.02 among those with one *P–X–O* Weak contact, to 0.04 among those with one *P–X–O* Mixed contact, and to 0.07 among those with one *P–X–O* Strong contact. These results are from Table 2, where it is also seen that the likelihood of a direct connection between two persons generally rises with increase in the number of common contacts: close inspection of the table indicates that the average marginal product of *P–X–O* Weak and *P–X–O* Mixed ties is comparable (approximately 0.06), while that of *P–X–O* Strong ties is substantially higher (0.14); that is to say, controlling for the number of other types of ties that the common contacts of a dyad have with the dyad, an additional *P–X–O* Strong tie contributes on the average over twice as much to the probability of a direct tie existing in the dyad relative to *P–X–O* Mixed and Weak ties.[5]

This evidence suggests that local bridges tend to be weak ties because strong ties encourage triadic closure, which eliminates local bridges. Other things being equal, weak local bridges will tend to be maintained over time, while strong local bridges will tend to be eliminated.

Structural significance of local bridges and weak ties

Bridges have a clearcut structural significance in that they are the only path between two sets of persons. On the other hand, the structural significance of local bridges is variable: the higher the degree of a local bridge, the greater is its structural significance. In general, however, Granovetter asserts:

> *Hypothesis 4.* The significance of weak ties ... (is) that those which are local bridges create more, and shorter, paths. Any given tie may, hypothetically, be removed from a network; the number of paths broken and the changes in average path length resulting between arbitrary pairs of points (with some limitation on length of path considered) can then be computed. The contention here is that removal of the average weak tie would do more 'damage' to transmission probabilities than would that of the average strong one (Granovetter 1973:1365–6).

Table 3 shows the results of an analysis in which the consequences for the network structure of deleting local bridges, nonbridging weak ties, and strong ties are assessed. To permit comparison, repeated random samples of eleven nonbridging weak ties and strong ties were removed; it is the average effect over these samples that is entered in the table. Thus, the consequences of removing the local bridges are compared to the average consequences of removing eleven arbitrarily selected strong ties and nonbridging weak ties.[6]

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[5] As in the consideration of the previous hypothesis, a test of significance is not appropriate since independence is violated. With fewer internal replications to support the hypothesis, it remains on somewhat less firm ground than does the previous hypothesis.

[6] The programs, written in Fortran, are available from the author upon request. The results are based on four random deletions of sets of eleven nonbridging weak ties and strong ties.

Table 2. *Relationship between the presence of a direct connection in a dyad (the proportion of dyads in which one member is directly tied to the other) and the number of dyadic contacts who have strong ties, weak ties, and mixed (strong and weak) ties to the members of the dyad.**

Number of contacts with strong ties to the dyad	Number of contacts with weak ties to the dyad: 0					1					2				
	Number of contacts with mixed ties to the dyad: 0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
0	0.01	0.04	0.04	0.17	0.23	0.02	0.06	0.14	0.18	0.42	0.03	0.10	0.13	0.20	0.50
1	0.07	0.09	0.13	0.15	0.14	0.13	0.26	0.16	0.43	0.14	0.30	0.30	0.41	0.39	0.46
2	–	0.33	0.20	0.33	0.25	0.20	0.40	0.43	0.38	0.40	–	0.67	0.44	0.33	0.80
3	–	–	0.75	–	–	–	1.00	0.25	0.50	0.67	–	–	0.83	1.00	–
4	–	–	1.00	–	–	–	–	1.00	–	–	–	–	–	–	–

Number of contacts with strong ties to the dyad	Number of contacts with weak ties to the dyad: 3					4					5				
	Number of contacts with mixed ties to the dyad: 0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
0	0.11	0.22	0.33	0.27	0.50	0.26	0.27	0.33	0.58	0.60	0.30	0.36	0.35	0.33	0.60
1	0.17	0.24	0.53	0.71	0.29	0.50	0.44	0.29	0.46	0.57	–	0.17	0.56	0.80	0.71
2	–	0.33	0.75	0.75	–	–	–	0.40	0.60	–	–	–	1.00	–	0.88
3	–	–	–	0.00	0.00	–	–	–	–	–	–	–	–	0.67	–
4	–	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–

*Proportions are not computed where the number of cases upon which they are based is less than three.

Table 3. *Consequences of deleting local bridges, nonbridging weak ties, and strong ties from the network**

a. Joining	Cumulative percent of dyads joined at different removes					Number of dyads joined at different removes					Average path length
	1	2	3	4	5	1	2	3	4	5	
Observed network	15	74	99	100	100	712	2725	1190	29	0	2
Eleven local bridges removed	15	71	99	100	100	701	2610	1304	41	0	2
Eleven nonbrid. weak ties removed**	15	73	99	100	100	701	2708	1217	30	0	2
Eleven strong ties removed**	15	74	99	100	100	701	2720	1204	30	0	2
b. Path redundancy	Average number of geodesics joining dyads at different removes***					Number of geodesics joining dyads at different removes					
	1	2	3	4	5	1	2	3	4	5	
Observed network	1	3	12	36	–	712	7824	14724	1048	–	
Eleven local bridges removed	1	3	11	37	–	701	7558	14899	1528	–	
Eleven nonbrid. weak ties removed**	1	3	12	36	–	701	7646	14680	1081	–	
Eleven strong ties removed**	1	3	12	35	–	701	7685	14531	1038	–	

*There are eleven local bridges in the observed network. To permit comparison, four random samples of eleven nonbridging weak ties and strong ties were removed: it is the average effect over these samples that is entered in the table.

**Averages.

***A geodesic is the shortest path which connects a dyad.

With respect to certain aggregate properties of the network, removal of the different types of ties makes very little difference. The average length of the geodesics (*i.e.*, shortest paths) remains unaffected as does the average number of geodesics which join the pairs that are 2-step, 3-step, and 4-step joined. However, the cumulative percent of dyads joined by paths of increasing length does indicate some support for the hypothesis: removal of the local bridges causes the most pronounced drop in the percent of dyads joined in 1 - 2 steps, followed by the nonbridging weak ties and, in turn, the strong ties; removal of eleven strong ties has, on average, no effect on the network.

The absolute numbers involved in these cumulative percentages show that removal of the eleven local bridges causes a loss of 2-step joined dyads in the network that is approximately seven times as great as the average loss produced by removing eleven nonbridging weak ties and 23 times as great as the average loss produced by removing eleven strong ties. In terms of absolute numbers, it also can be seen that removal of the local bridges causes a loss in the number of 2-step geodesics that is approximately 1.5 times as great as the average loss produced by removing nonbridging weak ties, and approximately 2 times as great as the average loss produced by removing strong ties.

Weak ties in general

Weak ties, because persons can maintain many more of them than strong ties, permit a level of structural cohesion to be attained in large networks that could not be attained on the basis of strong ties alone. Granovetter suggests that strong ties tend to fall within groups. Hence, it may be the weak ties that tend to integrate the different groups occurring in a network, whether or not these weak ties are bridges or local bridges. Blau (1977: 85) has emphasized this particular implication of Granovetter's argument: weak ties are significant, not only because local bridges tend to be weak ties, but because weak ties may be disproportionately involved in the structural integration (intergroup cohesion) of heterogeneous networks.

Hypothesis 5. Intergroup ties consist disproportionately of weak ties. The evidence of Table 4 supports this hypothesis: 0.77 of the interdepartmental ties are weak ties in comparison to 0.65 of the intradepartmental ties ($p = 0.002$).

Discussion

The local bridges and intergroup ties in a multidisciplinary population of biological scientists consist disproportionately of weak ties. The present evidence supports Granovetter's approach to the problem of integration in social structures that are differentiated into subgroups.

Table 4. *The strength of intergroup ties*

		Group composition of tie*		Totals
		Intragroup tie	Intergroup tie	
Strength of tie	Weak	65% 315	77% 176	491
	Strong	35% 168	23% 53	221
	Totals	100% 483	100% 229	712

Corrected χ^2 = 9.29 with 1 degree of freedom. Significance = 0.002, Yule's Q = 0.278

*Based on joint departmental affiliations and other affiliations such as with committees on Evolutionary Biology, Genetics, and Virology.

Of course, to point to local bridges and weak ties as a primary basis of intergroup cohesion is not to have solved the problem of integration. Granovetter's theory, to the extent that it is a powerful theory, rests on the assumption that local bridges and weak ties not only represent opportunities for the occurrence of cohesive phenomena (*e.g.*, information and influence flows, intergroup coordination and mobilization, *etc.*), but that they actually do promote the occurrence of these phenomena. A major empirical effort in the field of social network analysis will be required to support this aspect of Granovetter's theoretical approach.

We must be very careful in our interpretation of the significance of weak intergroup ties and, in particular, local bridges. It is one thing to argue that when information travels by means of these ties it is usually novel and, perhaps, important information to the groups concerned. It is another thing to argue that local bridges and weak ties promote the regular flow of novel and important information in differentiated structures. One may agree with the former and disagree with the latter.

If we accept the proposition that regular flows of information depend on the presence of multiple, short paths between persons, then a local bridge does not represent a likely path of information flow, though it represents a possible path of such flow. A local bridge may be a feeble contributor to the regular flow of information in social networks in general because the two members of a local bridge lack common contacts (*i.e.*, short alternative paths) by which information might be transmitted. Hence, if one accepts the idea that cohesive network structure promotes the regular flow of information, one cannot accept the idea that local bridges promote the regular flow of information.

One might argue that such information as does flow by means of local bridges is crucial to the social integration of differentiated populations, *i.e.*, that regular flows of information between differentiated groups are not crucial to their systemic integration. If so, one is asserting that there are different bases of macro and micro integration; for example, that macro integration can be based on weak ties which permit episodic transmissions of information among groups, while micro integration is based on a cohesive set of strong ties which permit regular transmissions within groups.

Granovetter has argued that his theory addresses the relation of micro level interactions and macro level patterns. I hope to have indicated that important issues and dilemmas which have yet to be resolved are raised by Granovetter's promising approach.

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