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# Reinforced structural holes

Ronald S. Burt*

*University of Chicago Booth School of Business, Chicago, IL 60637, United States*

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ABSTRACT

Holes in social structure are variably reinforced by the social organization around the hole. The more reinforced the hole, the greater the difficulty in bridging it, but the more likely a successful bridge will carry information novel, and so potentially valuable, to people on the other side. To study how reinforcement varies with access to structural holes, and the achievement associated with access, I propose a measure of access to reinforced structural holes (RSH), and present results predicting achievement in an integrated banker organization and a balkanized supply-chain organization. In both study populations, the people who have access to structural holes also have access to reinforced structural holes, and all measures of access have a statistically significant association with achievement. However, there is no consistent prediction advantage from incorporating reinforcement in measures of access to structural holes. The reinforced-holes measure predicts compensation better or as well as network constraint and betweenness, but is weaker or no better than a count of nonredundant contacts. I do not infer from the results a rank-order of alternative measures so much as substitutability. I expect achievement to be associated with access to structural holes, but I expect the association to vary across alternative measures depending on how achievement is achieved in a specific population.



You are at a cocktail party. The hostess smiles, grabs you by the arm, and introduces you to someone, highlighting an interest she believes you two have in common. The hostess veers off to link up other people, leaving you and your new acquaintance to delight in hostess-highlighted mutual interest. You just experienced network brokerage. You have your social circle. Your new acquaintance has his. The hostess has facilitated connection across the structural hole between yours and his.

This paper is about situations one step more complicated. Suppose the other person is engaged in animated conversation with two colleagues. The hostess interrupts their conversation to introduce you. The polite thing to do—in deference to the hostess—would be for your new acquaintance to disengage from his colleagues to strike up conversation with you. But suppose the pull of their conversation is such that he does not break away. You are now the odd man out; their conversation continues with you the peripheral observer. This second situation is an example of what can be termed brokerage across a "reinforced" structural hole; the disconnection between you and your new acquaintance is reinforced by connections among he and his colleagues, and their mutual disconnect from you. The hole would be more reinforced if you had your own colleagues with you, to whom you returned after being slighted by the new acquaintance, and still more reinforced if there was a history of such slights between your and his colleagues. The structural hole between groups is reinforced by coordination within each group to the exclusion of the other. At some point, each group becomes a reference point for the other, with stereotypes about the other group made concrete in stories about those people.

Network models of bridging structural holes typically ignore reinforcement, despite the fact that the social dynamic of the odd man out is familiar in everyday life, and in academic discussion such as Durkheim (1933 [1893], p. 102) on group solidarity enhanced through shared distain of an outsider, or Caplow (1968) on "two against one." Popular network predictors measure access to structural holes without regard to reinforcement. For example, given the network around a person, ego, Freeman's (1977) betweenness measure is a count of the structural holes to which ego has exclusive access. Burt's (1980, 1992) network constraint and effective size variables measure the concentration of connections in redundant contacts, thus measuring ego's lack of access to structural holes. Reinforcement around the structural holes to which ego has access is defined by the network around each of ego's contacts (e.g., those colleagues of the new acquaintance to whom the hostess introduced you), but those networks around contacts are not essential to Freeman's betweenness measure, and typically ignored in Burt's constraint and effective size measures.

There are at least three reasons to continue ignoring reinforcement. First, current measures of access to structural holes ignore

* Tel.: +1 312 953 4089.
*E-mail address:* ron.burt@chicagobooth.edu

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reinforcement yet do well in predicting achievement. The gist of the network story is that information becomes homogeneous, tacit, and therefore sticky within clusters of densely connected people such that clusters disconnect, buffered from one another by structural holes between them, which gives information breadth, timing, and arbitrage advantages to people whose networks span the structural holes. Two people who have no connection with one another are more likely than connected people to work with different ideas and practices. The more disconnected the contacts in a network, the more likely the network spans structural holes. People who connect across the holes (call those people network brokers, connectors, hubs, or entrepreneurs) are exposed to the diversity of surrounding opinion and behavior so they are more likely to detect productive new combinations of previously segregated information, and more likely to see alternative sets of people whose interests would be served if the new combination were brought to fruition. Thus, a structural hole is a potentially valuable context for action, brokerage is the action of coordinating across the hole with bridge connections between people on opposite sides of the hole, and network entrepreneurs, or more simply, brokers, are the people who build the bridges. Network brokers are rewarded socially and materially for their work decoding and encoding information. Numerous research projects show that people with access to structural holes are paid more than peers, receive more positive evaluations and recognition, and get promoted more quickly to senior positions (see Burt, 2005; Burt et al., 2013, for review and contingencies; Aral and Van Alstyne, 2011, for an analysis of network structure as a proxy for information in predicting achievement; Aral and David, 2012, for replication; Rodan and Galunic, 2004, for a similar hypothesis tested with survey data; and Vilhena et al., 2014, for an innovative approach to measuring Pachucki and Breiger's, 2010, image of "cultural holes" as information boundaries coincident with structural holes).

There are second and third reasons to continue ignoring reinforcement. A second reason is that structural holes are reinforced in large part by coordination in the networks around each of ego's contacts, and research in diverse organizations shows no effect from those neighbor networks on the achievement associated with direct access to structural holes (Burt, 2010). Third, the competitive advantage of brokerage does not depend on collaboration between people on opposite sides of a structural hole. Advantage can involve collaboration, but in general—and I suspect usually—need not depend on collaboration. The broker learns something here, and sells it to his advantage over there. Here and there need never connect directly. Indeed, there are situations in which brokerage is valuable precisely because here and there do not connect directly (Kellogg, 2014).

On the other hand, argument can be made for bringing reinforcement into the analysis. As a concept grounded in the advantage-implications of cohesion around ego's contacts, reinforcement is related to the concept of secondary structural holes (Burt, 1992, pp. 38–42, 56). Primary structural holes are between ego's contacts. Secondary structural holes are between each contact and the people to whom ego could turn to replace the contact. Secondary structural holes have seen little application in empirical research on individual managers because analysis requires knowledge of the categories that define substitutes for ego's current contacts (e.g., I go to a doctor, for whom there are three alternative doctors to whom I could go). The concept of secondary structural holes has been applied for many years in organization research, where Department of Commerce industry categories define substitutable organizations. Evidence accumulated since 1975 shows that secondary structural holes in organization networks have their hypothesized effect of weakening network constraint such that performance increases (Burt, 1992, Chap. 3, 2010, Chap. 5). However, reinforcement is not about weakening constraint so much as hardening it. It is not about the ease with which difficult contacts in a cohesive group can be replaced by substitutes. It is about the difficulty, the improbability, of brokerage across cohesive groups.

Similarly, Krackhardt's (1992) concept of Simmelian ties is related to, but distinct from, reinforced structural holes. Simmelian ties are relations reinforced by mutual contacts. Simmelian ties become noteworthy for brokerage when they are bridges in an adjacent structure. For example, Tortoriello and Krackhardt (2010) study Simmelian ties between organization units to draw inferences about information flow between units. Managers A and B, respectively in units A and B, are more strongly connected when they have mutual contacts (versus managers in separate units who have no mutual contacts). Tortoriello and Krackhardt show that the innovation associated with bridging structural holes is more likely for managers whose bridging ties are reinforced by mutual contacts (for similar results, see Hansen, 1999 and Reagans and McEvily, 2003, on information transfer; Cross and Cummings, 2004, on brokerage and performance; Centola et al., 2005, on innovation diffusion more generally). Tortoriello and Krackhardt's analysis is in two ways distinct from the analysis here: (1) Their primary point is that reinforced relationships can facilitate information flow across structural holes, while the analysis here is about reinforced relations on either side of the hole inhibiting flow. (2) Tortoriello and Krackhardt rely on formal structure to define the structural holes, the boundries, between organization units (as in the early studies of boundary-spanning ties, Tushman, 1977). Here, to avoid the problem of defining which boundaries between organization units are structural holes and which are not, both bridges and holes are defined by the structure within one network (which could be defined by informal relations, or jointly defined by formal and informal). The deepest structural holes between organization units will be the ones most reinforced by strong internal cohesion within the respective units.

In contrast, Vedres and Stark's (2010) concept of a structural fold is very relevant to reinforcement. A structural fold exists where membership overlaps between two largely separate, cohesive groups. A person, ego, located in the fold between two groups bridges numerous structural holes between the groups. The concept of structural fold is closely related to the concept of structural hole, as illustrated by the network metrics to be presented—but there is also something new. The structural holes around the structural fold are reinforced by cohesion within each group and there is management evidence that peer pressure created in closed networks spills into adjacent networks (Burt, 2010, Chap. 6).

If brought into a network analysis, it is not obvious whether reinforcement would increase or decrease the achievement association with bridging structural holes. Reinforcement could be expected to increase the association with achievement. Cohesion within groups, and separation between groups, increases the probability that the groups operate with different points of view, which decreases the probability of people in either group seeing brokerage opportunities across the groups, while increasing the probability that productive knowledge in either group will likely be novel in the other group. More, ego's affiliation with both groups is an incentive for her to find synthetic understanding compatible across the groups. This positive effect of reinforcement is related to what has been discussed as the "depth" of a structural hole (Burt, 1992, pp. 42–44). Cohesion on either side of a structural hole increases its depth, making it easier for ego to play either side against the other, increasing ego's control over the situation. Ego is better positioned to synthesize understandings across the groups than are individuals within either group. Although consistent with the positive implication of reinforcement, there is no empirical evidence on the achievement implications of more or less deep structural holes.

On the other hand, reinforcement could weaken the brokerage association with achievement: Cohesive groups are more likely to insist on the priority of their point of view, which increases the pressure on ego to conform to each, and increases the difficulty of coordinating across the groups. Simultaneously affiliated with both groups, ego can expect to be rip-sawed by conflicting pressures, in response to which ego can keep a low profile in either group, or try to segregate in time or space his affiliation with the groups (Merton, 1957, on role strain; Podolny and Baron, 1997, on difficulty bridging structural holes in formal organization; Burt, 2005, pp. 235–240, on active versus passive structural holes; Reagans and Zuckerman, 2008, on brokerage difficulties created by dense networks around a broker's contacts).

We do not know how or whether reinforcement matters, but there is reason to suspect it could matter. Vedres and Stark (2010) present evidence of achievement associated with structural folds. However, the concept of structural folds is confounded with the concept of structural holes, so it is impossible to determine, without measuring both, how much of achievement is due to the reinforcement provided by structural folds versus the familiar achievement association with access to structural holes.

The purpose of this paper is twofold: (1) to propose a measure of the extent to which the structural holes in a network are reinforced to show how reinforcement duplicates, and differs from, currently popular measures of access to structural holes, and (2) to estimate the extent to which reinforcement affects the achievement association with access to structural holes. The next section introduces the proposed network measure as an extension to familiar measures of access to structural holes. Data are then introduced on two populations of senior business leaders, followed by results.

## Access to structural holes

Ego's access to structural holes is typically measured in terms of three characteristics: network size (many contacts increase the likelihood of brokerage opportunities), network density (strong connections between contacts lower the likelihood of brokerage opportunities), and network centralization or hierarchy (one or a few contacts connected to the other contacts mean that brokerage opportunities might not be available or have to be shared). Often-used summary measures are illustrated in Fig. 1 for a selection of small networks. Ego's contacts are indicated in Fig. 1 by gray circles. Lines indicate connections between contacts. Ego is of course connected with each contact, but to keep the sociograms simple, ego's relations are not presented.

*Network density and hierarchy are low around brokers*

A network contains few structural holes to the extent it is small and the contacts in it are interconnected. Size increases down the networks in Fig. 1, from networks of three contacts at the top, to networks of five, to networks of ten at the bottom. Connectivity increases from left to right, from networks at the left in which none of ego's contacts are connected (labeled "broker networks"), to the networks on the right in which all of ego's contacts are connected (labeled "clique networks"). Network density is the average strength of connection between ego's contacts, which in Fig. 1 is the number of connections divided by the number possible (multiplied by 100 to be a percentage). Density is zero for networks in the left column; no contact is connected with others. Density is one hundred percent for networks in the far-right column; every contact is connected with every other.

A second way contacts can be connected, closing the network around ego, is by mutual connection with a central person other than ego. This is illustrated by the "partner networks" in the middle column of Fig. 1. Partners provide a substantively significant kind of network closure useful in detecting diversity and coordination problems in a population (Burt, 1998, 2010, Chap 7). The middle-column networks in Fig. 1 are characterized by no connections between contacts except for all being connected with contact A. The networks are centralized around A, making A ego's "partner" in the network. This kind of network is detected with an inequality measure, such as the Coleman-Theil disorder measure in the third row of each panel in Fig. 1 (explained below). Hierarchy varies with the extent to which connections among ego's contacts are all with one contact. There is zero hierarchy when contacts are all

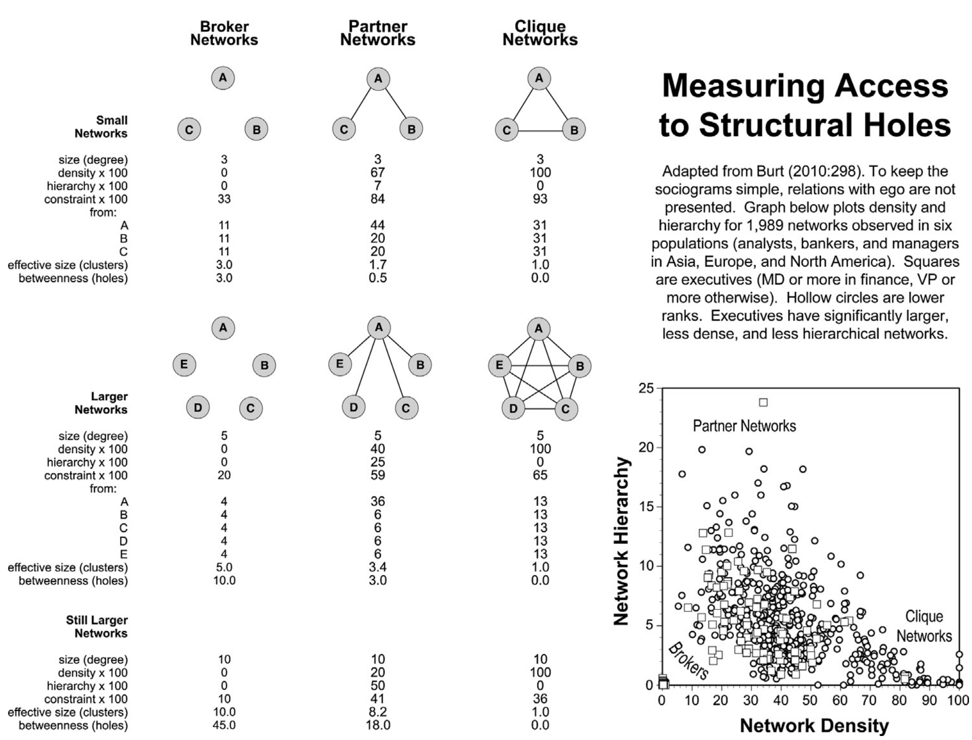



**Fig. 1.** Measuring access to structural holes.

disconnected from one another (first column in Fig. 1) or all connected with each other (third column). Hierarchy scores are only non-zero in the middle column. As ego's network gets larger, the partner's central role in the network becomes more obvious and hierarchy scores increase (from 7 for the three-person network, to 25 for the five-person network, and 50 for the ten-person network).

The graph in Fig. 1 provides a sense of the population distributions from which manager networks are sampled. The graph plots hierarchy scores by density scores for two thousand manager networks in six management populations. The populations, analyzed in detail elsewhere (Burt, 2010), include stock analysts, investment bankers, and managers across functions in Asia, Europe, and North America. The large, open networks of brokers are in the lower left of the graph, low in density and low in hierarchy. Closure can involve simultaneous hierarchy and density, but the extremes of each exclude the other. To the lower right are clique networks, in which there is no hierarchy because all contacts are strongly connected with each other. To the upper left are partner networks, in which density is low because there are no connections between contacts other than their mutual strong connections with ego's partner.

*Network constraint: brokers have large, sparse, flat networks*

The three characteristics—size, density, and hierarchy—are brought together in summary measures such as network constraint, which measures ego's lack of access to structural holes (Burt, 1980, 1992, pp. 54–56). Constraint decreases with the extent to which ego has many contacts (size), increases with the extent to which ego's network is closed by strong connections among ego's contacts (density), and increases with the extent to which ego's network is closed by a partner strongly connected with all of ego's contacts (hierarchy). A constraint score of 100 indicates no access to structural holes (ego had no friends, or all of ego's friends were friends with one another). Across the networks in Fig. 1, network constraint increases from left to right with closure by hierarchy or density (e.g., 20 points for the five-person disconnected network versus 65 points for the five-person clique network), and decreases from top to bottom with increasing network size (e.g., 93 points for the three-person clique network versus 10 points for the ten-person clique network).

Constraint begins with each of ego's relations, measuring the extent to which ego, $e$, would have a difficult time avoiding contact $k$, either because ego's relation with k is large or because everyone ego knows is connected to $k$: $c_{ek} = (p_{ek} + \Sigma_j\, p_{ej}p_{jk})^2$, where summation is across ego contacts $j$ other than $k$ ($j \neq k$), $p_{ek}$ is the proportion of ego's network spent directly with contact $k$, $p_{ek} = [z_{ek} + z_{ke}]/(\Sigma_j\, [z_{ej} + z_{je}])$, where summation is across ego's contacts $j$, and variable $z_{ej}$ measures the strength of connection from ego to contact $j$. The contact-specific constraint term $c_{ek}$ varies from zero to one with the extent to which ego cannot avoid contact $k$, either directly ($p_{ek}$) or indirectly ($\Sigma_j\, p_{ej}p_{jk}$). The term is squared to capture concentration in a single contact. Network constraint on ego is the sum of the squared terms across ego's contacts: Network Constraint $(C) = \Sigma_k\, c_{ek}$. Network constraint varies from zero to one—for all but very small networks—with the extent to which ego's network time and energy is concentrated in a single source, indicating that ego has no access to structural holes.[1] Scores are multiplied by 100 in Fig. 1 to indicate points of constraint.

Contact-specific constraint scores, $c_{ek}$, are listed in Fig. 1 for the networks composed of three and five contacts. Note the equal levels of constraint posed by each contact for ego in the broker networks to the left and the clique networks to the right. Unequal levels appear when one contact is better connected than the others, illustrated by the partner networks in the middle column. The more unequal the contact-specific constraints on ego, the more ego's network is co-owned with a partner. The network hierarchy scores in Fig. 1 are Coleman-Theil index scores measuring the extent to which contacts pose very different levels of constraint on ego (Burt, 1992, pp. 70–71): Network Hierarchy = $[\Sigma_k\, r_{ek}\,(\ln r_{ek})]/[N_e\,(\ln N_e)]$, where summation is across ego contacts $k$, $r_{ek}$ is the constraint posed by contact k relative to the average constraint posed by ego's contacts ($r_{ek} = c_{ek}/(C/N_e)$, and $N_e$ is the number of ego's contacts. Again, scores in Fig. 1 are multiplied by 100.

*Effective size: brokers have many nonredundant contacts*

Two other summary measures are given in Fig. 1. Both are attractively intuitive metrics proven in empirical research. Both avoid the small-network issues of the constraint index (footnote 2). Effective size is a count of ego's contacts discounted for clustering—in essence, it is a count of the clusters to which ego is connected, or the number of nonredundant contacts in ego's network (Burt, 1992, pp. 51–54). Begin with a measure of contact $k$'s nonredundancy with ego's other contacts: $1 - \Sigma_j\, p_{ej}m_{kj}$, where summation is across ego contacts j other than $k$, $p_{ej}$ is the proportional strength of ego's connection with $j$ (defined above), and $m_{kj}$ is $k$'s marginal strength of connection with $j$ (connection between $k$ and $j$ divided by $k$'s maximum connection in ego's network). Sum the nonredundancy scores for ego's contacts to define ego's number of nonredundant contacts ($\Sigma_k$ nonredundance $k$). For networks of disconnected contacts, the first column in Fig. 1, network size equals effective size. Every contact is disconnected from the others, so each is nonredundant with the others. For the clique networks in the third column of Fig. 1, ego has only one nonredundant contact regardless of increasing network size, because each contact is redundant with the others.

*Betweenness: brokers have exclusive access to many structural holes*

The third summary measure in Fig. 1 is Freeman's betweenness index (Freeman, 1977, 1979). Betweenness is a count of the structural holes to which ego has exclusive access. Two disconnected contacts can provide one opportunity to broker a connection. Four contacts disconnected from one another can provide ego six opportunities to broker connections. Betweenness was proposed as a small-group centrality metric measuring ego's control over communication within a group. Freeman (1977) argued for the construct validity of the proposed measure by showing that betweenness predicted better than closeness centrality personal satisfaction in the Bavelas–Smith–Leavitt experiments on centrality and performance in small groups (Leavitt, 1951). Beginning with the symmetric, binary connections in the experiment, Freeman computed the proportion of shortest connections between j and k that go through ego (cf., Everett and Borgatti, 2005, pp. 33–34): $b_{jke}$ = (number $j$–$k$ geodesics through ego)/(number $j$–$k$ geodesics), where a geodesic between $j$ and $k$ is the shortest chain of connections that link $j$ with $k$. If $j$ and $k$ are connected directly, there are no geodesics through others. The shortest chain is the direct connection between $j$ and $k$. If $j$ and $k$ are disconnected people with three

[1] The index is ill-behaved for social isolates and dense networks of less than four contacts. The index can exceed one in such small networks. Since such networks provide no access to structural holes, I round their constraint scores to one. Constraint is undefined for social isolates because proportional ties have no meaning (zero divided by zero). Some software outputs constraint scores of zero for isolates. That would mean that isolates have unlimited access to structural holes when in fact they have no access, as is apparent from the low performance scores observed for managers who are social isolates. Network constraint should be set to its maximum for social isolates.

mutual friends, there are three two-step geodesics between $j$ and $k$; one through each mutual friend. The $b_{jke}$ ratio assigns to each of the three mutual friends equal one-third control over communication across the structural hole between $j$ and $k$. Summing across all $j$–$k$ pairs of contacts measures the number of disconnected pairs between whom ego is positioned to broker communication ($j < k$): Ego-Network Betweenness = $\Sigma_j\ \Sigma_k\ b_{jke}$.

For the networks of disconnected contacts to the left in Fig. 1, betweenness equals the number of possible connections between contacts. For example, betweenness is 10.0 for the broker network of five contacts because none of the 10 possible connections between ego's five contacts exist. For the clique networks to the right in the figure, betweenness is zero because there are no structural holes between ego's contacts. In the middle of Fig. 1, ego shares access to structural holes. Ego has access to the disconnect between contacts B and C in the three-person network, but so does contact A, so ego's betweenness score is .5, half of one structural hole. Ego has access to six holes between contacts in the five-person partner network, but access is shared with the partner, so ego's betweenness score is 3.0, half the number of holes to which ego has access.

Two asides: betweenness scores are usually higher in larger networks—an increasing number of contacts allows for an increasing number of structural holes. This is not a problem for measuring network advantage because there is neither theory nor empirical result to support a conclusion that broker success depends on brokering communication between every pair of contacts.[2] Also, the above betweenness index based on geodesics was proposed for binary network data, such as the data in Fig. 1 or the data in the Leavitt experiment, but the index is easily adapted to continuous measures of connection.[3]

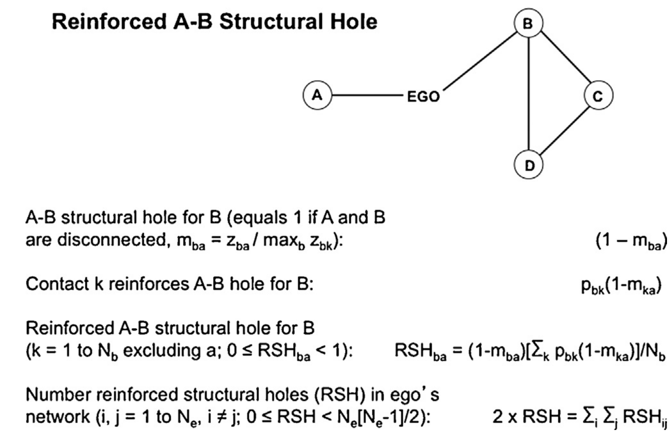



**Fig. 2.** Reinforced A-B structural hole.

The summary measures of access to structural holes—network constraint, effective size, and network betweenness—have in common four characteristics: larger networks provide more access, dense networks provide less access, and centralized, hierarchical networks provide less access. The shared fourth characteristic is that all three measures are computed in Fig. 1 from ego's direct contacts. Reinforcement from the networks around ego's contacts is ignored.[4]

*Access to reinforced structural holes*

The reinforced structural hole described at the beginning of this paper is illustrated in Fig. 2. The hostess is ego. She introduces you, A, to a person you do not know, B, who is engaged in conversation with colleagues C and D. The structural hole between you and B, as seen by B, can be measured by $(1 - m_{ba})$, where $m_{ba}$ is the marginal strength of B's connection with you (introduced earlier as the connection between A and B divided by B's maximum connection in B's network). If your connection with B were as strong as B's strongest other connections, then the term would be zero, indicating no A-B structural hole in B's network. Person A in Fig. 2 has no direct connection with B, so the term is one – indicating an A-B structural hole in B's network.

*Reinforcement*

One of B's contacts, $k$, reinforces an A-B structural hole for B to the extent that k is strongly connected to B and disconnected from A: $p_{bk}(1 - m_{ka})$. The first element in the product measures the proportional strength for B of his connection with $k$ ($p_{bk}$, introduced earlier as the connection between A and B divided by the sum of B's other connections). The second element in the product measures the marginal strength of $k$'s disconnect from A (corresponding to the $1 - m_{ba}$ above measuring B's disconnection from A). Sum the $p_{bk}(1 - m_{ka})$ product across B's contacts k to measure

[2] However, if betweenness is used as a measure of ego's tendency to be involved in bridge relations, it would be reasonable to normalize the index by its maximum value so that people can be compared for the extent to which they are positioned to broker communication between contacts. Since $b_{jke}$ is a proportion that varies between zero and one for each pair of contacts, the sum across pairs has a maximum equal to the number of pairs, which is $N(N-1)/2$, where $N$ is the number of direct contacts in ego's network. The ratio of betweenness to its maximum, 2 (ego-network betweenness)/($N[N-1]$), is a normalized betweenness index that varies from zero to one with the extent to which ego is positioned to broker communication between all of his contacts (Freeman, 1977, p. 38).

[3] Freeman et al. (1991) propose a betweenness measure in which information flow is inferred from strength and number of connections between people. Their focus on flow generalizes betweenness to continuous-strength network data and beyond shortest paths, the geodesics. But the geodesic through ego used in the initial definition of betweenness says two things: (1) ego is close to j and k, and (2) there is negligible direct connection between j and k. Generalizing the first quality to relative closeness is attractive, but preserving the second quality is essential to the idea of ego brokering communication (Burt, 1992, p. 57; and a point emphasized by Cook et al.'s (1983), experiments showing that people with exclusive access to a structural hole achieve more than people with high closeness centrality [position $E$ versus position $D$ in the network experiments]). For symmetric, continuous-strength network data, here is a betweenness index close in meaning to the original measure of exclusive access to structural holes. Begin with a measure (corresponding to $b_{jke}$ defined by geodesics in the text) of the extent to which communication between $j$ and $k$ through ego is strong and exclusive: $b_{jke} = (1 - z_{jk})\ (z_{je}z_{ek})/(z_{jk} + \Sigma_q\ z_{qj}z_{qk})$, where $z_{je}$ is a fraction measuring symmetric connection strength between ego and contact j ($0 \le z_{je} \le 1$), and summation is across ego contacts $q$ excluding $j$ and $k$ ($j \ne q \ne k$). The numerator in $b_{jke}$ is the strength of the $j$–$k$ connection dependent on ego (first parenthetical term measures the extent to which j and k do not communicate directly, which means there is a $j$–$k$ structural hole to be bridged, and the second term measures the strength of indirect $j$–$k$ connection through ego). The denominator in $b_{jke}$ is the total direct and indirect connection strength between $j$–$k$. To the extent that all $j$–$k$ connection is indirect through ego, $b_{jke}$ equals 1. Every contact is connected at some strength to ego within ego's network, so the denominator is always greater than zero. As with the geodesic definition, ego-network betweenness is the sum of the above $b_{jke}$ across all pairs of ego contacts $j$ and $k$ ($j < k$): $\Sigma_j\ \Sigma_k\ b_{jke}$. The sum is the number of structural holes between ego's contacts to which ego has exclusive access. Scores can be normalized, if desired, to their maximum score of $N(N-1)/2$. All betweenness scores in this paper are generated by the continuous-strength definition of $b_{jke}$. For the symmetric, binary network data in Fig. 1 and below in Fig. 3, the continuous-strength definition of $b_{jke}$ generates the same betweenness scores that would have been generated by the geodesic definition of $b_{jke}$. I also checked the above betweenness scores against NetDraw betweenness output for ego networks (Borgatti, 2002). With connections converted to symmetric, binary data for a random selection of bankers (Fig. 4) and managers (Fig. 5) with networks size 5, 10, 15, 20, and 25, betweenness scores defined by the above continuous-strength measure are identical to NetDraw betweenness scores.

[4] Network constraint and effective size are typically computed from ego's direct contacts, but network betweenness is often computed with respect to structural holes far removed from ego. When betweenness is computed across indirect contacts beyond ego's network, the index is better interpreted as a measure of prominence across the ego-networks in a study population (see Podolny, 1993 on status; Freeman, 1979; Brandes, 2008; Valente and Fujimoto, 2010, on global network betweenness).

contacts reinforcing an A-B hole for B. Multiply the sum by the extent to which there is an A-B structural hole for B to define a variable $RSH_{ba}$ that varies from zero to one with the extent to which the network around B reinforces an A-B structural hole:

$$RSH_{ba} = \sum_{k} (1 - m_{ba}) p_{bk} (1 - m_{ka}).$$

where summation is across all of B's contacts $k$, $k \neq a, b$. The expression $RSH_{ba}$ is zero when there is no A-B structural hole for B ($m_{ba}$ equals one) or all of B's other contacts are bridges to A (all $m_{ka}$ equal one). The index approaches one to the extent that B is disconnected from A, and B's closest contacts are also disconnected from A. $RSH_{ba}$ will never reach 1.0 because of integrative connection through ego (discussed below). Summing dyad scores across pairs of ego contacts yields a measure of reinforced structural holes in ego's network:

$$2RSH = \sum_{i} \sum_{j} RSH_{ij},$$

where summation is across all $N(N-1)$ ordered pairs of ego's contacts ($i \neq j$). The raw index RSH varies from zero up toward a maximum equal to the number of structural holes in ego's network.[5]

To measure the average extent to which ego's contacts are separated by reinforced structural holes, the raw RSH index can be divided by the number of dyads in ego's network: $RSH/(N[N-1]/2)$. This normalized index varies from zero to one with the extent to which ego's network is characterized by reinforced structural holes. I multiply the ratio by 100 to discuss percentage points of reinforcement (percent RSH). The percentage approaches its maximum as each of ego's contacts is connected into a large, cohesive group that excludes all of ego's other contacts.

*Modularity*

In addition to measuring the extent to which ego's access is to reinforced structural holes, it would be useful to have a control measure of the extent to which ego's contacts are clustered such that they could reinforce. Given a partition of ego's contacts into groups, an obvious measure of within-group clustering would be the proportion of connections between ego's contacts that occur within groups: $\sum_{ij} (z_{ij} w_{ij})/M$, where $z_{ij}$ is the strength of connection from $i$ to $j$, $w_{ij}$ is 1 if contacts $i$ and $j$ are in same group (else zero), M is the sum of all relations among ego's contacts, $M = \sum_{ij} z_{ij}$, and summation is across all ($N^2$) relations among ego's $N$ contacts, including self relations. Isolates drop out of the summation since $w_{ij}$ is zero for $i$ disconnected from ego's other contacts $j$.

The proportion is trivially 1.0 if everyone is assigned to one group, so Newman (2006, 2010, p. 224; Newman and Girvan, 2004) proposes that network clustering be guided by a "modularity" score that weights observed tie strength for the strength expected if tie strength were independent of each contact's centrality in the network (connections between two people with many contacts are more likely than between two people with few contacts). The difference between observed and expected defines element $b_{ij}$ in what Newman discusses as a "modularity" matrix, $b_{ij} = z_{ij} - E(z_{ij})$, and modularity, $Q$, measures the extent to which relations are stronger than expected within groups relative to relations between groups: $Q = \sum_{ij} b_{ij} w_{ij}/M$, where tie strength expected under independence, $E(z_{ij})$, is defined like an expected frequency under independence in a contingency table: the volume of relations in the network, $M$, times the random probability of connection from $i$, $\text{row}_i = \sum_j (z_{ij})/M$, times the random probability of connection to $j$, $\text{col}_j$, so $Q$ can be written as $\sum_{ij} (z_{ij} - [\text{row}_i \, \text{col}_j \, M]) w_{ij}/M$. I follow Newman (2006) in using an eigenvector extracted from the modularity matrix to identify groups among ego's contacts.[6] A modularity of zero indicates no clustering in ego's network (no connections between contacts or completely connected). Modularity varies from negative one to positive one with the extent to which relations stronger than expected are concentrated within groups among ego's contacts.

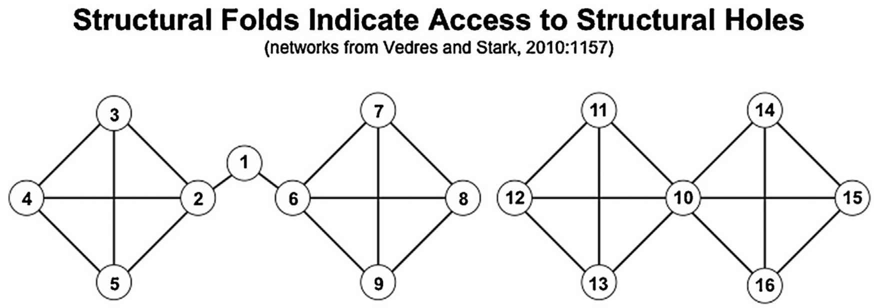
*Illustration*

Fig. 3 contains metrics for the two networks used by Vedres and Stark (2010, p. 1157) to illustrate their concept of a structural fold. Vedres and Stark distinguish a person in a structural fold (person 10) from the kind of people they believe have been studied as network brokers (person 1). In fact, there are three categories of network brokers in Fig. 2: Person 1 is unique in having the least access to structural holes. He has access to the hole between persons 2 and 6. He is a network broker, but just barely. Persons 2 and 6 have slightly more access, three structural holes each. Person 10 is unique in having the most access, nine structural holes and the lowest level of network constraint.

All of the structural holes in Fig. 3 are reinforced. The table in Fig. 3 shows that the one structural hole to which person 1 has access is strongly reinforced for both of his contacts 2 and 6 separated by the hole. Consider the structural hole from person 2's perspective. The hole exists ($1-m_{26}$ equals 1), and is reinforced by three colleagues: the strong connection to person 3 who is disconnected from person 6 ($p_{23}[1-m_{36}]$ equals .25), the strong connection to person 4 who is disconnected from 6 ($p_{24}[1-m_{46}]$ equals .25), and the strong connection to person 5 who is disconnected from 6 ($p_{26}[1-m_{56}]$ equals .25). The hole is not reinforced by 2's relation with person 1, who is ego in this calculation, since person 1 is strongly connected with person 6 ($p_{21}[1-m_{16}]$ equals 0). The four dyadic $RSB_{26}$ scores sum to .75. The corresponding $RSB_{62}$ measures from person 6's perspective similarly sum to .75, so the raw RSH index for person 1 is .75. When the raw score is divided by the one dyad in person 1's network, the normalized RSH index equals 75%. Person 1 faces the most difficult brokerage; he has access to only one structural hole, which is 75% reinforced.

[5] There is an assumption in the index that a structural hole can be reinforced by cohesion on either side of the hole. In Fig. 2, the A-B structural hole is reinforced for B but not for A. As a sum of dyadic $RSH_{ba}$ scores, RSH increases when holes are increased on either side. The most obvious alternative is that holes are only reinforced when both sides are reinforced. I tested for the alternative by computing RSH as an average of products $\Sigma_j \Sigma_k (RSH_{jk} RSH_{kj})^{.5}$, $j < k$. The multiplicative measure only registers reinforcement when there is cohesion on both sides of a $j$-$k$ structural hole. Where reinforcement is symmetric on both sides of a structural hole, the additive and multiplicative measures are identical (e.g., additive and multiplicative RSH both equal 6.0 for person 10 in Fig. 3). I computed multiplicative scores for the two study populations discussed in the next section. Marginal and proportional strengths of the symmetric connections can be asymmetric, but additive and multiplicative versions of the RSH index are virtually identical in the two populations. Average multiplicative scores are slightly lower than additive scores (37 versus 39 among the managers, 574 versus 578 among the bankers), but relative scores are closely correlated (.99 correlation in both populations). I therefore rely on the simple additive version in the text. More generally, the symmetric measurement presented in the text can be explored in finer detail, with data of sufficiently high quality, by distinguishing asymmetries in the flow of connection and reinforcement between broker and contacts (Gould and Fernandez, 1989; Fernandez and Gould, 1994; Gargiulo et al., 2009).

[6] In preference to the iterative cluster analysis described in Newman and Girvan (2004) and Newman (2006), I base groups on the initial eigenvector extracted from the modularity matrix. I would not do this if groups were the focus of the analysis, but groups are being used here only as a control for the level of clustering within ego's network. Groups are distinguished as follows: Remove ego from his network. Put aside isolates (contacts who are disconnected from all of ego's other contacts). Compute the eigenvector for the modularity matrix among the remaining contacts. Contacts with equal scores on the eigenvector are assigned to the same group. See Fig. 3 for illustration.




| Kind of Network | Network Size (Contacts) | Effective Size (NonRedundant Contacts) | Network Constraint | Ego-Network Betweenness (Structural Holes) | Reinforced Holes (RSH) | | Ego-Network Modularity (Newman Q) |
|---|---|---|---|---|---|---|---|
| | | | | | Raw | Normalized | |
| Closed (3, 4, 5, 7, 8, 9, 11, 12, 13, 14, 15, 16) | 3 | 1.0 | 92.6 | .00 | .00 | 0% | .00 |
| Broker (1) | 2 | 2.0 | 50.0 | 1.00 | .75 | 75% | .00 |
| Broker (2, 6) | 4 | 2.5 | 58.3 | 3.00 | 1.75 | 29% | .00 |
| Fold Broker (10) | 6 | 4.0 | 46.3 | 9.00 | 6.00 | 40% | .50 |

**Fig. 3.** Structural folds indicate access to structural holes (networks from Vedres and Stark, 2010, p. 1157).

Persons 2 and 6 have an easier situation with access to more structural holes that are less reinforced. Each of person 2's three contacts in the group to the left in Fig. 3 reinforce structural holes between people in the group and 2's contact outside the group, person 1 ($RSH_{31}$, $RSH_{41}$, and $RSH_{51}$ all equal two thirds). The holes are less reinforced from person 1's perspective because he has only person 6 to reinforce him ($RSH_{63}$, $RSH_{64}$, and $RSH_{65}$ all equal .5). Summing the dyadic scores, and dividing by two yields a raw RSH score of 1.75. Normalizing by six dyads among person 2's four contacts, yields a normalized RSH score of 29.2%.

Consistent with Vedres and Stark's use of Fig. 3, the broker in a structural fold, person 10, has the most access to structural holes (betweenness equals 9.0) and the most access to reinforced structural holes (RSH equals 6.00). The structural holes to which he has access are reinforced (40%), but he has several alternative routes to brokerage given his exclusive access to nine holes between the two groups. Fig. 3 illustrates how structural folds are confounded with access to structural holes, and in Fig. 3 make the same predictions made by familiar measures, viz., person 10 has the most access, the other three brokers have less access, and the people in closed networks have no access. Thus the empirical question for this paper: How does the brokerage association with achievement vary with access to structural holes versus reinforcement around the holes?

*Clustering versus reinforcement*

The modularity scores in the last column of the table in Fig. 3 illustrate similarity and difference between clustering and reinforcement. As just described, reinforcement increases across networks in the four rows of the table. However, clustering does not. Modularity is zero in the first three rows, then substantial in the fourth row. There is no clustering in the completely connected networks, such as around person 3, so there are no structural holes and modularity is zero. When person 1 is removed from his network, two isolates remain (persons 2 and 6)—so modularity is zero. Persons 2 and 6 are more complicated. They have access to structural holes, and some reinforcement around the holes, but when they are removed from their networks, the result is an isolate and a completely closed network (e.g., person 1 is an isolate for person 6, and persons 7-8-9 are a closed network)—which results in zero modularity. The only network with nonzero modularity is the one around the fold broker, person 10. When person 10 is removed from his network there are two separate closed networks remaining, which generates a modularity score of .5 (and which would increase to .67 if there were a third separate cluster of three contacts in person 10's network). The general point is that reinforcement is about more than the presence of clustering in ego's network. It is about how ego is positioned in the clustering. It is useful to have modularity scores available to see how clustering alone is associated with achievement.

*Ego's presence counteracts reinforcement*

Ego can play a significant integrative role in these small networks. Relational scores $p_{be}$ and $m_{ea}$ are nonzero for ego, so each dyad score $RSH_{ba}$ is less than one, which means that the sum of dyadic scores, RSH, is consistently less than the number of dyads in ego's network. In short, RSH will never reach $N(N-1)/2$.[7] This was illustrated above in describing how the network around person 2 in Fig. 3 reinforces the structural hole in person 1's network between persons 2 and 6. The $RSH_{26}$ score is .75, with the last 25% of reinforcement missing because of 2's integrative connection to 6 through ego, person 1. Ego's integrative presence is less in larger networks. The larger the network, the smaller the proportional connections with ego, which means a smaller integrative effect from ego's affiliation with everyone in his network. For example, imagine the network around person 1 in Fig. 3 expanded from four-person groups on both sides to ten-person groups on both sides. Person 2's proportional connection with 1 would decrease from .25 to .10, so the structural hole between persons 2 and 6 would be 90% reinforced. Ego has a weaker integrative presence in the larger network. The substantive implication is that

[7] This has implications for normalizing RSH scores since raw scores normalized by the $N(N-1)/2$ dyads in ego's network will always be less than one. An alternative is to divide by the number of holes available to be reinforced. The ratio of RSH to maxRSH is an index that varies from zero to one with the extent to which ego's access to structural holes is limited to reinforced structural holes, where maxRSH is RSH computed from dyad scores assuming that every hole in the network is completely reinforced ($maxRSH_{ba} = 1 - m_{ba}$). When there are no structural holes in ego's network, there are none to be reinforced, so the value of the normalized RSH should be zero—but no structural holes in ego's network means that maxRSH is zero, so the ratio of RSH to maxRSH is undefined. Normalizing by maxRSH requires computations that specify RSH equals zero when divided by a maxRSH of zero.

whatever effect ego's integrative presence has on successful brokerage, it will be more pronounced in small groups. Conversely, ego trying to improve his odds of successful brokerage would do well to sequester a small number of representatives from the two groups between which he is attempting brokerage.

*Ersatz reinforcement*

Fig. 1 is a useful counterpoint to Fig. 3. None of the structural holes in Fig. 1 are reinforced. The RSH index is zero for all of them. The broker networks in Fig. 1 only contain holes, so there is no clustering to reinforce the holes. The partner networks contain closure provided by the partner, but the closure provided is identical to ego's, so the partner only serves to affect ego's access to the available structural holes. The clique networks are rich in clustering but they contain no holes to reinforce.

Comparing Figs. 1 and 3 highlights the kind of error created if reinforced structural holes are measured using only data on ego's network. The RSH index is computed using data on ego's network plus data on the network around each of ego's contacts. Let "ersatz RSH" be the index score when computation is limited to data within ego's network. The RSH and ersatz RSH indices will be correlated. Both will be zero for people who have no access to structural holes (the dozen Fig. 3 people in closed networks). The two indices will be identical for people whose ego network contains everyone connected to their contacts (person 10 in Fig. 3, RSH and ersatz RSH both equal 6.0). The two indices will differ to the extent that people outside ego's network reinforce the holes within ego's network. Persons 2 and 6 in Fig. 3 are an example. The ego network around person 2 for example, contains persons 1, 2, 3, 4, and 5. Person 6 is not included, but person 6 reinforces for person 1 his disconnects from person 3, 4, and 5. The result is that ersatz RSH is lower than the RSH index (1.00 versus 1.75 respectively for person 2).

Person 1 in Fig. 3 is a more extreme example. Person 1 has access to the structural hole between persons 2 and 6, which is strongly reinforced since person 2 has three contacts to the left that reinforce his disconnect from person 6, and person 6 has three contacts to the right that reinforce his disconnect from person 2. The RSH index equals .75 for person 1. If measurement were limited to person 1's ego network, however, the 2–6 hole would appear to be completely open since all of the reinforcing contacts lie outside ego's network (ersatz RSH equals 0.0 for person 1).

## Data

I look for implications of reinforced structural holes in two study populations that differ in the social clustering that reinforces structural holes. Fig. 4 contains 346 investment bankers in a large financial organization during four successive years in the mid-1990s. The bankers were employees of the organization during all four years. Relations come from annual 360 evaluations in which each banker was asked to indicate colleagues with whom the banker did frequent or substantial work during the year. Connection variable $z_{ij}$ is the number of years for which banker *i* or *j* cited the other, divided by the maximum of four. Banker performance is indicated by a banker's annual *z*-score total compensation averaged across the four years. The network and performance data are discussed in detail elsewhere (Burt, 2007, 2010), along with controls for whether the banker had senior job rank, his or her years with the company, mean colleague evaluation, minority race/gender, and whether the banker worked at the organization's headquarters.

The bankers form a loosely connected, global network. Two bankers are connected by a line in Fig. 4 when one or both cited the other in one of the four annual evaluations. Every banker is connected directly or indirectly to every other banker. The average path distance from one banker to another is 2.33 links, a little more than one intermediary. Bankers are close together in Fig. 4 to the extent that they were repeatedly connected and had mutual contacts (spring-embedding algorithm in NetDraw, Borgatti, 2002). There are bankers loosely connected at the periphery of the sociogram, but these are not social isolates so much as they are bankers whose

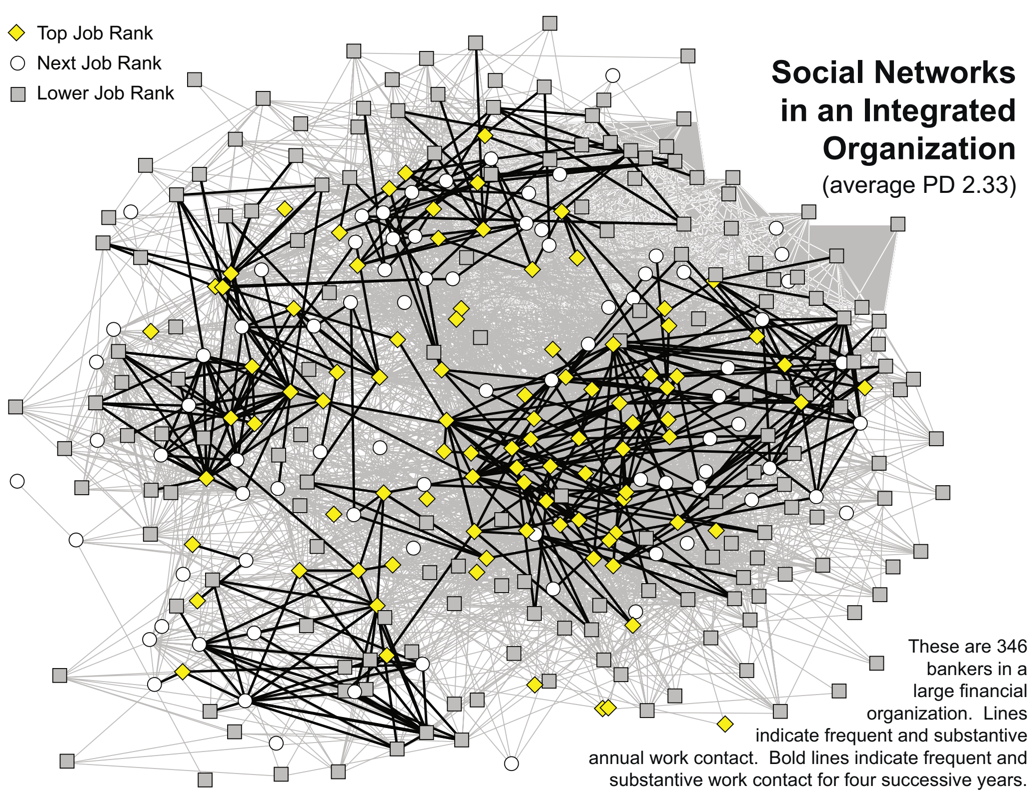



**Fig. 4.** Social networks in an integrated organization.

networks were concentrated in employees at lower job ranks in the organization. In fact, the lines in Fig. 4 are so dense, they merge into a solid at center of the sociogram. These senior bankers are participants in a mature capital market, quickly connected to colleague information across the globe.

Still, there is clustering. Bold lines connect bankers linked by citation every year. The bold lines show four clusters of recurring work relations. The four clusters correspond to global cities in which the organization had substantial operations. In other words, the most obvious reinforced structural holes here are geographic, between the global cities in which the organization has substantial operations. There were numerous work relations across cities, indicated by the light lines in Fig. 4, but the structural holes should not be underestimated. The bankers were at once intimates and strangers. Yes, they were connected; two thirds of the Fig. 4 pairs are connected through a mutual colleague. At the same time, most bankers had no direct contact with one another during the four years. The 346 bankers define 59,685 pairs. Of the pairs, most (53,654) never cited one another in any of the four annual evaluations. Connections through familiar contacts were indirect, and long. Suppose the bankers relied on information obtained through the bold-line, recurring ties in Fig. 5. The average bold-line connection is indirect, through five colleagues, and most of the banker pairs remain disconnected (5.03 average path distance for connected pairs, 42,634 pairs not connected). In sum, the bankers are disconnected from the majority of their colleagues at the same time that colleagues are familiar through stories shared by mutual friends: “Yes, that seems like something John would do; I worked with him three years ago.” The implication is that the effect of reinforced structural holes among the bankers is undermined by short-term working relations across the holes. Whatever the effect of reinforcement on brokerage in an average organization, the effect is likely to be lower among the bankers.

Reinforced structural holes are more obvious among the Fig. 5 supply-chain managers in a large American electronics company. Relations come from a network survey of 455 managers and their many contacts, of whom 598 hold job rank sufficient to be included in Fig. 5. Connection variable $z_{ij}$ equals 1 if manager $i$ or $j$ cited the other as their immediate supervisor, or as a colleague with whom “you most often discuss supply-chain issues,” or the colleague with whom they had discussed their best idea for improving the company supply chain. Connections are scaled to .65 for relations of less-close contact, 0 for disconnected managers (Burt, 2004, p. 361). Lines in Fig. 5 indicate frequent discussion; light lines less frequent discussion, and bold lines discussion embedded in more than three mutual contacts (median number of mutual contacts). Manager performance is indicated by annual salary (bonus compensation and stock options are a small portion of annual compensation at all but the highest job ranks in this organization). The network and performance data are discussed in detail elsewhere (Burt, 2004, 2007, 2010), along with controls for a manager’s job rank, age, education, minority race/gender, high-tech versus low-tech business, and whether the manager worked at company headquarters.[8]

Similar to the bankers, every manager in Fig. 5 is connected to every other manager directly or indirectly, but indirect connections between the managers are more common and longer; average path distance between the managers is 4.81 links, or about four intermediaries. The managers are balkanized into clusters of local business. Divisions making very different products fan out from corporate headquarters like spokes on a wheel. To the left are managers in the company’s Western division (triangles), which contains a substantial subgroup located in another state (shaded triangles to the upper-center of the sociogram). Bold lines are concentrated inside the Western clusters, with substantial connections into corporate headquarters (squares located in the center of the sociogram). The cluster of white circles to the northeast in the sociogram contains managers in the company’s Eastern division. Again strong connections are concentrated inside the division, with few connections out except to corporate headquarters. The fourth and final division contains the company’s Southern operations (shaded circles in the sociogram). Again, strong relations are concentrated inside the division and to corporate, with a clear subcluster to the east in the sociogram that corresponds to company operations in an area adjacent to the company’s main southern operations. The focus on local business was well-known within the company (which is why the network survey was commissioned). The managers worked in legacy organizations that had been acquired by the parent company, but retained substantial freedom to purchase supplies where they wished. In each product line, managers were familiar with their piece of the supply chain. There was little incentive to know the supply chain for products elsewhere. With the focus on local business, operations were based on tacit knowledge about how we do things here; local coordination was important, and coordination elsewhere relatively unimportant. The emphasis on local operations could reinforce the structural holes between locations.

## Correlations among the network measures

Descriptive statistics in Table 1 summarize differences between the study populations with respect to structural holes. The bankers have less constrained networks (17 points of constraint on average versus 42 for the managers), more nonredundant contacts (average effective size of 28 versus 7 for the managers), exclusive access to more structural holes (198 betweenness on average versus 39 for the managers). Clustering is more evident in the supply-chain organization (Fig. 5 versus Fig. 4), but the manager contacts are more concentrated within business divisions, so modularity is higher for the bankers (.17 on average versus .09 for the managers)—the larger banker networks more often span clusters in their organization so clusters appear more often within the average banker’s network. The bankers on average are connected to a larger number of structural holes reinforced by connected colleagues (578 average RSH for the bankers, versus 39 for the managers).

Correlations in the two populations are more similar than different. To begin, Table 1 shows similar correlation pattern among the network measures. Not surprisingly, the effective size and betweenness measures of access to structural holes are positively correlated with each other and negatively correlated with network constraint. Clustering is more likely in large, open networks (constraint and modularity are correlated −.53 and −.60 for the bankers and managers respectively). Access to reinforced structural holes is almost identical to betweenness in both populations (.99 correlation among the managers, .96 among the bankers).[9] Principal

[8] A *Social Networks* reviewer commented that innovation is an achievement more central than compensation to the structural holes argument that network brokers have information advantages of breadth, timing, and arbitrage. The reviewer suggested using an achievement measure similar to the “good ideas” measure in Burt (2004). Compensation is an often-used achievement indicator in analyses of structural holes, but the reviewer’s comment is correct. Fortunately, the supply-chain organization studied here is the study organization in Burt (2004), so I can show that the pattern of results obtained on compensation are also obtained when good ideas are the achievement indicator (see footnote 11). However, I only have idea data in the supply-chain organization, so I focus in the text on compensation, an achievement indicator available in both study populations.

[9] This similarity warrants closer inspection in future. I computed RSH scores in another balkanized population of managers (Burt, 2010, pp. 59–72), and again found a .99 correlation with ego-network betweenness. Ego-network betweenness is written to measure ego’s access to structural holes, but the exclusiveness of ego’s access

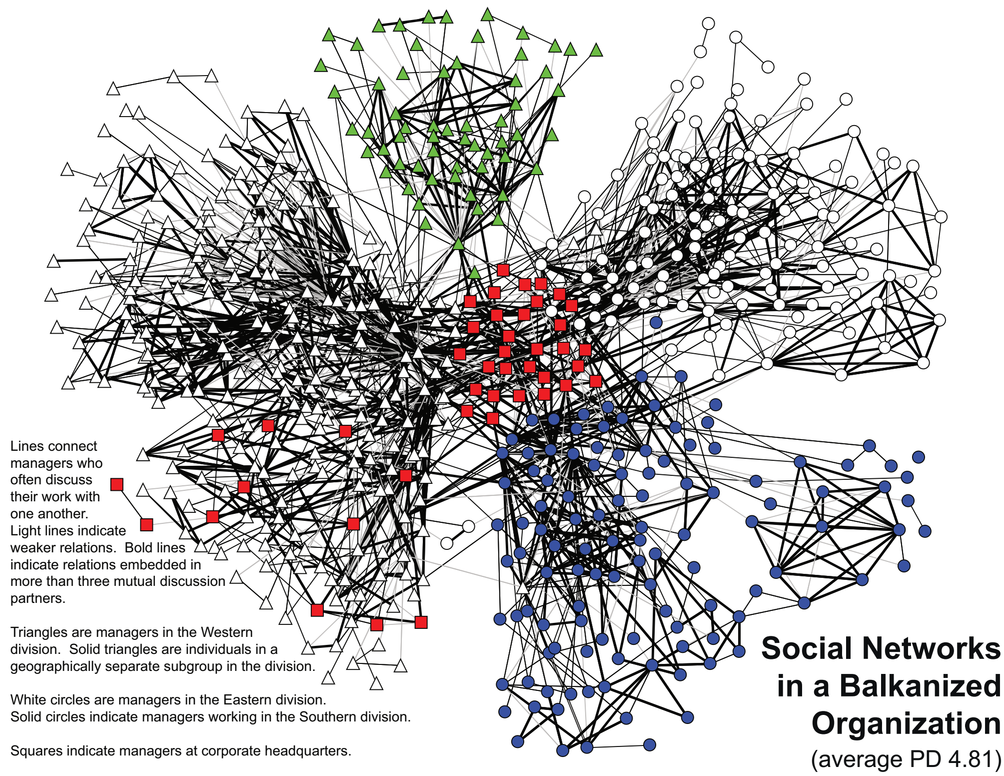



**Fig. 5.** Social networks in a balkanized organization.

**Table 1**
Network metrics.

| | | | Network constraint | Effective size | Ego-network betweenness | Reinforced structural holes Raw | Reinforced structural holes Percent | Ego network modularity | Salary |
|---|---|---|---|---|---|---|---|---|---|
| | Means | | 41.69 | 6.51 | 38.55 | 39.29 | 37.33 | 0.09 | 0 |
| | | SD | 20.67 | 6.83 | 137.39 | 142.92 | 19.74 | 0.18 | 1 |
| Network constraint | 17.17 | 12.39 | – | −0.65 | −0.35 | −0.35 | −0.78 | −0.6 | −0.54 |
| Effective size | 27.55 | 17.49 | −0.68 | – | 0.88 | 0.88 | 0.63 | 0.52 | 0.6 |
| Ego-network betweenness | 198.48 | 242.57 | −0.5 | 0.91 | – | 0.99 | 0.38 | 0.3 | 0.45 |
| Reinforced structural holes | | | | | | | | | |
| Raw | 578.59 | 736.52 | −0.5 | 0.94 | 0.96 | – | 0.38 | 0.3 | 0.47 |
| Percent | 68.08 | 11.98 | −0.67 | 0.62 | 0.52 | 0.47 | – | 0.55 | 0.5 |
| Ego-network modularity | 0.17 | 0.12 | −0.53 | 0.41 | 0.34 | 0.27 | 0.59 | – | 0.32 |
| Compensation | 0 | 1 | −0.57 | 0.66 | 0.55 | 0.64 | 0.32 | 0.19 | – |

*Note*: Results below diagonal are for the 346 investment bankers in Fig. 4 integrated organization. Above-diagonal results are for 455 supply-chain managers in Fig. 5 balkanized organization. Percent reinforced structural holes is 100 times the raw RSH score divided by the number of dyads in ego's network, $N(N-1)/2$. Banker compensation is annual z-score salary plus bonus, averaged over four years. Manager compensation is annual z-score salary. Compensation correlations with constraint are with log constraint.

component factor analysis of the six network measures shows a dominant factor describing access to structural holes that is negatively correlated with network constraint and positively correlated with the other five measures (principle component describes 87% of network variance among the bankers, 81% among the managers).

## Results predicting compensation

For the bankers and supply-chain managers, respectively, Tables 2 and 3 each contain five predictions, one for each of five measures of access to structural holes: network constraint (measuring the lack of access to holes), effective size (number of ego's nonredundant contacts), betweenness (number of holes to which ego has exclusive access), reinforced structural holes (RSH, measuring the number of reinforced holes to which ego has access), and percent reinforced structural holes (the extent to which the average pair of contacts in ego's network are separated by a reinforced structural hole).

I see four patterns in the Tables 2 and 3 results. First, test statistics in parentheses show that each of the hole measures has its expected association with compensation as an achievement indicator. Compensation is higher for people with less constrained networks (models A), a larger number of nonredundant contacts (models B), more exclusive access to a larger number of structural holes (models C), access to a larger number of reinforced structural holes (models D), and having contacts typically separated by reinforced structural holes (models E). Compensation associations with

picks up reinforcement around the holes to which ego has access. Given ego with two contacts affiliated with their own separate groups (e.g., person 1 in Fig. 3), adding connections between the two groups outside ego's network erodes ego's exclusive access to the hole between the groups, and erodes reinforcement on either side preserving the hole.

**Table 2**
Predicting banker compensation.

| | r | A | B | C | D | E |
|---|---|---|---|---|---|---|
| Network constraint (lack of holes) | −0.57 | −0.68 (−7.4) | | | | |
| Effective size (nonredundant contacts) | 0.66 | | 0.03 (−10.4) | | | |
| Ego-net betweenness (exclusive holes) | 0.55 | | | 0.01 (−8) | | |
| Reinforced structural holes | 0.64 | | | | 0.01 (−10.3) | |
| Percent reinforced holes | 0.32 | | | | | 0.02 (−3.9) |
| Modularity | 0.19 | −1.05 (−3) | −0.88 (−2.8) | −0.44 (−1.4) | −0.3 (−1) | −0.6 (−1.5) |
| Senior job rank | 0.6 | 0.8 (−9.1) | 0.74 (−9.1) | 0.88 (−10.5) | 0.8 (−10) | 0.98 (−11.2) |
| Z-score peer evaluation | 0.3 | 0.23 (−4.9) | 0.23 (−5.2) | 0.27 (−5.9) | 0.24 (−5.6) | 0.3 (−6.2) |
| Years with the firm | 0.44 | 0.03 (−3.6) | 0.02 (−2.5) | 0.02 (−3.1) | 0.01 (−2.5) | 0.04 (4.4) |
| Minority | −0.21 | −0.13 (−1.4) | −0.12 (−1.4) | −0.15 (−1.7) | −0.13 (−1.5) | −0.19 (−2) |
| Headquarters | 0.01 | −0.12 (−1.5) | −0.13 (−1.8) | −0.07 (−1) | −0.1 (−1.4) | −0.01 (−0.2) |
| Intercept | | 1.47 | −1.01 | −0.77 | −0.76 | −1.69 |
| $R^2$ | | 0.56 | 0.61 | 0.57 | 0.61 | 0.51 |

*Note*: First column is row-variable correlation with average annual z-score compensation for the 346 bankers in Fig. 4 over a period of four years. Other columns are ordinary least-squares estimates of regression coefficients predicting compensation. Network constraint is the log of constraint. Ego-network betweenness and RSH are divided by 10, so their coefficients are change in *z*-score compensation with access to another 10 structural holes. Percent reinforced structural holes is 100 times the raw RSH score divided by the number of dyads in ego's network, $N(N-1)/2$. Senior job rank is 1 if the banker is ever in the senior job rank during the four years. *Z*-score peer evaluation is average colleague evaluation of the banker during the four years (*z*-score coding of 1, 2, 3, 4 for poor, adequate, good, outstanding; my synonyms for company words). Minority is 1 if the banker is a woman or of a minority race. Absolute values of test statistics are given in parentheses.

**Table 3**
Predicting manager salary.

| | r | A | B | C | D | E |
|---|---|---|---|---|---|---|
| Network constraint (lack of holes) | −0.54 | −0.19 (−3.7) | | | | |
| Effective size (nonredundant contacts) | 0.6 | | 0.02 (−7.1) | | | |
| Ego-net betweenness (exclusive holes) | 0.45 | | | 0.01 (−6.7) | | |
| Reinforced structural holes | 0.47 | | | | 0.01 (−7) | |
| Percent reinforced holes | 0.5 | | | | | 0.003 (−2.3) |
| Modularity | 0.32 | −0.02 (−0.2) | −0.12 (−1.1) | 0.07 (−0.7) | 0.07 (−0.7) | 0.1 (−0.8) |
| Job rank | 0.9 | 0.56 (−33.5) | 0.53 (−33.7) | 0.56 (−36.3) | 0.55 (−36) | 0.57 (−34.4) |
| Age | 0.15 | 0.01 (−3.6) | 0.01 (−4) | 0.01 (−3.9) | 0.01 (−3.9) | 0.01 (−3.3) |
| Minority | −0.17 | −0.04 (−0.9) | −0.054 (−1.39) | −0.06 (−1.6) | −0.06 (−1.6) | −0.04 (−1.13) |
| High-tech business | 0.09 | 0.11 (−2.5) | 0.101 (−2.35) | 0.09 (−2.13) | 0.09 (−2.2) | 0.11 (−2.4) |
| Low-tech business | −0.13 | −0.21 (−2.9) | −0.23 (−3.2) | 0.22 (−3) | −0.22 (−3) | −0.21 (−2.9) |
| Regional headquarters | 0.18 | 0.18 (−3) | 0.18 (−3.1) | 0.17 (−3) | 0.17 (−2.9) | 0.19 (−3.1) |
| Corporate headquarters | 0.34 | 0.29 (−5.3) | 0.3 (−5.6) | 0.3 (−5.6) | 0.3 (−5.6) | 0.29 (−5.2) |
| Intercept | | −0.94 | −1.75 | −1.67 | −1.67 | −1.74 |
| $R^2$ | | 0.85 | 0.86 | 0.86 | 0.86 | 0.84 |

*Note*: First column is row-variable correlation with annual salary for 455 managers in Fig. 5. Other columns are ordinary least-squares estimates of regression coefficients predicting *z*-score salary. Network constraint is the log of constraint. Ego-network betweenness and RSH are divided by 10. Minority is 1 if the manager is a woman or of a minority race. High-tech businesses is 1 if the manager works in either of the two businesses at the cutting edge of company technology. Low-tech business is 1 if the manager works in the facility services business. Absolute values of test statistics are given in parentheses.

the control variables are the same as in earlier published analyses of these populations, and remain consistent across the alternative models.

Second, the strength of expected association is stronger among the bankers than among the managers. The test statistic for each network measure is stronger in Table 2 than it is in Table 3 (e.g., *t*-test of 8.0 in Table 2 for banker betweenness versus a lower 6.7 in Table 3 for betweenness). A strong bureaucracy underlies the balkanized business units in the supply-chain organization, which is evident from the stronger compensation association with job rank in the supply chain (e.g., *t*-test of 9.1 for banker job rank in Table 2, model A versus a higher 33.5 in Table 3 for manager job rank in the same model). The point is clear from the test statistics, but it will be helpful to have a more accessible evidence display. Fig. 6 shows contribution to $R^2$ from the structural-holes network predictor in each model (dark shading), the job-rank predictor in each model (white), and all other variables in each model (gray).[10] The height of a bar in Fig. 6 is the $R^2$ for a prediction in the tables (e.g., first bar in Fig. 6 goes up to .56, corresponding to the .56 $R^2$ for Model A in Table 2). The higher bars to the right in Fig. 6 illustrate that compensation is more accurately predicted in the supply-chain organization. However, the predominantly white area in each supply-chain bar shows that the bulk of the prediction is job rank. Salaries do increase with more access to structural holes, but job rank is the dominant predictor of manager salary. The weaker network association in the balkanized study population is not central to this article, but an implication is that comparative analysis of alternative network measures predicting achievement will be less productive in balkanized organizations if they provide less effect variance to study.

Regardless of how the two study populations differ, they are similar with respect to the third result pattern: The test statistics

[10] Given outcome *Y* and predictor *X*, contributions are computed by multiplying the *XY* correlation times the standardized regression coefficient for predictor *X*. For example, log network constraint has a −.57 correlation with banker compensation in Table 1, and the −.68 regression coefficient for log network constraint in Table 2 (model A) is −.37 when standardized, so the network-constraint contribution to predicting banker compensation in Fig. 6 is .21 (−.57 times −.37). The gray areas of the bars are computed by subtracting from $R^2$ the contributions from job rank and the structural holes predictor (e.g., for network constraint predicting banker compensation, the gray area is .12, which equals the $R^2$ for model A in Table 2, .56, minus the contribution from network constraint, .21, minus the contribution from job rank, which is .23). This evidence display can understate the effects of the control variables summarized by the gray areas, but the gray areas in Fig. 6 are relatively constant across predictions within each study population, and I am using Fig. 6 to communicate the relative contributions of job rank and each network predictor.

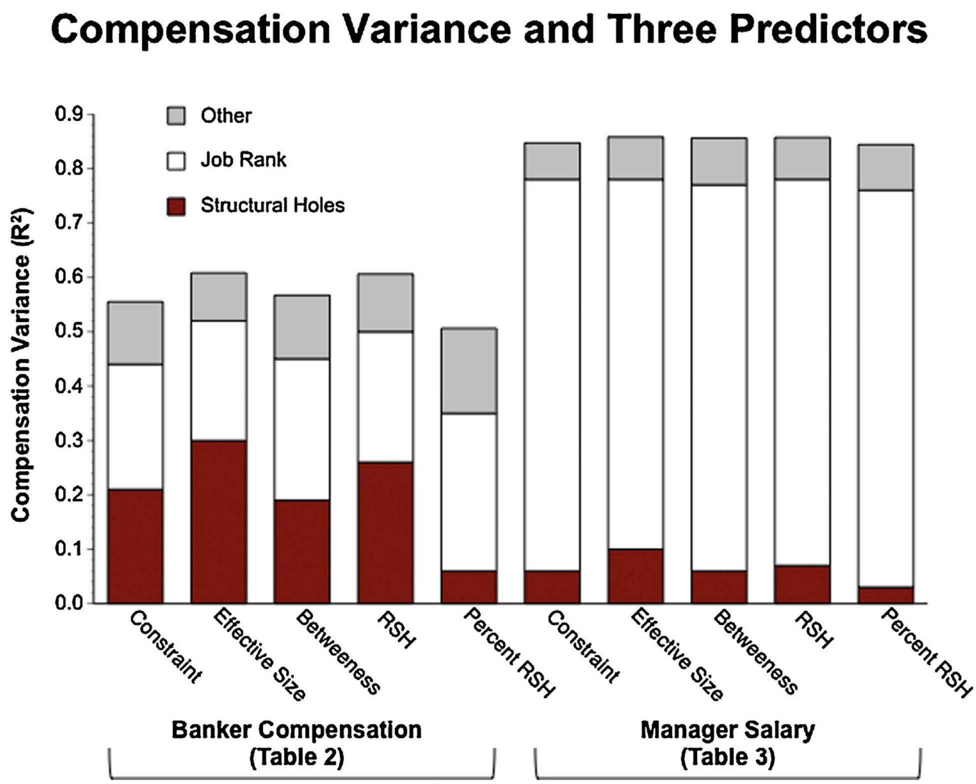



**Fig. 6.** Compensation variance and three predictors.

in Tables 2 and 3—illustrated by the relative height of the dark areas at the bottom of the bars in Fig. 6—show no consistent prediction advantage from incorporating reinforcement in measures of access to structural holes. The reinforced-holes measure RSH predicts compensation better or as well as network constraint and betweenness, but is weaker or no better than the count of nonredundant contacts (effective size). These results are based on only two study populations, however, the two differ considerably in their network structure and the third result pattern is consistent across the populations.[11]

The two study organizations are also similar with respect to the fourth, and final, pattern in the results: A high average level of reinforcement around the structural holes in ego's network is a poor predictor. Percent RSH varies from 0 to 100 with the extent to which each pair of a person's contacts is separated by a reinforced structural hole. The measure has a statistically significant association with compensation in both Tables 2 and 3, but the association is the weakest of the five hole measures—illustrated in Fig. 6, especially among the bankers, for whom the other four hole measures are strongly associated with compensation. The modularity variable offers related evidence. Modularity is a measure of clustering on average in a person's network, which is irrelevant to compensation in eight of the ten predictions in Tables 2 and 3.

## Conclusion

Holes in social structure are variably reinforced by the social organization around the hole. The more reinforced the hole, the greater the difficulty in bridging it, but the more likely a successful bridge will carry information novel, and so potentially valuable, to people on the other side.

To study how reinforcement varies with access to structural holes, and the achievement associated with access, I proposed a measure of access to reinforced structural holes (RSH), and presented results predicting achievement in an integrated banker organization and a balkanized supply-chain organization.

In both study populations, the people who have access to structural holes also have access to reinforced structural holes, and all measures of access have a statistically significant association with achievement. However, the alternative network measures differed in the strength of their association with achievement. The strongest network predictor was the number of nonredundant contacts in a person's network (effective size), followed closely by the number of reinforced structural holes to which the person had access (RSH), followed by network constraint and betweenness.

The results could be used to dismiss reinforcement. The usual measures of access to structural holes—network constraint, effective size, and ego-network betweenness—can be computed using only data on the network around an individual. Measuring access to reinforced structural holes requires considerably more data. The person's network has to be expanded to include the network around each of the person's contacts. If I can get as strong or stronger predictions with a count of the number of nonredundant contacts in a person's network (effective size), why should I incur the added cost of measuring reinforcement around the holes in the person's network?

[11] Introduced in footnote 8, the pattern is also replicated with a "good ideas" measure of achievement. I have a measure of each supply-chain manager's best idea for improving the value of the supply-chain organization. Measurement details are given elsewhere (Burt, 2004), but the point of the measure is to distinguish managers whose ideas are deemed by senior management to be worth pursuing versus managers whose ideas are dismissed as "vague, too whiny, or incomprehensible." When I re-estimate the models in Table 3, replacing salary achievement with the "good ideas" measure of achievement, I get a −3.86 *t*-test for log network constraint, a 3.46 *t*-test for effective size (nonredundant contacts), a 2.41 *t*-test for betweenness, and a 2.12 *t*-test for the reinforced-holes measure RSH. The RSH measure is the weakest predictor of "good ideas," but it is not much weaker than betweenness. Again, the point is that there is no consistent advantage from incorporating reinforcement in measures of access to structural holes.

I do not infer from the results a rank-order of alternative measures so much as a substitutability of measures. I expect achievement to be associated with access to structural holes, but I expect the association to vary across hole measures depending on how achievement is achieved in a specific population. In the two study populations considered here, effective size was the strongest predictor, indicating that advantage came from having contacts in many separate groups. If betweenness had been the strongest predictor, I would infer that advantage came from having exclusive access to contacts in many different groups. If reinforced structural holes had been the strongest predictor, which it nearly was, I would infer that advantage came from having contacts in many, separate, cohesive groups. More, the failure of average RSH next to strong results for RSH indicates that even when reinforcement on average is irrelevant to achievement, reinforcement could be an important consideration in selecting targets for brokerage. In short, there is wisdom in computing multiple indicators of access to structural holes as a clue to how achievement in a population depends on bridging structural holes. Fortunately, the RSH measure is readily available in UCINET, along with the usual measures of access to structural holes, so it is a simple matter to include multiple indicators in most analyses.

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