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CHAPTER 18

Social Networks, Cognition, and Culture

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Networks

Network studies are an important adjunct to further development of cognitive anthropology and theory. When reliable means of identifying relational properties of behavior, cognition, and cultural structures or systems are available they help overcome limitations of other types of descriptive studies, descriptive statistics, or ad hoc inferences about how mind, culture, and social behavior interact.

Roles

Roles form into key network and institutional structures which can be understood in relation to social processes. Network ethnography can also operate in this way to further understanding (White and Johansen 2006:ch. 1). Network studies enhance our understandings of cause and effects of emergent roles and their dynamical patterns of shifting stability, including hierarchy. Finding hierarchy and its network embeddings, for example, often depends on global as well as local information on how local patterns fit within global ones. Both the understanding of global network structure and analysis of micro–macro linkages are additional advantages. If we wanted to find the leaders in a large urban community (see Freeman et al. 1960), for example, we could start from a sample of potential leaders, ask *them* who the leaders are, and iteratively construct a snowball sample of higher order leaders until finally a leader sub-network or evidence of a single leader emerges.

Cohesive groups

Cohesive groups have patterned interactions that are self-reinforcing and self-stabilizing in certain spatio-temporal frames. Study of these interactions can also account for individual choices, the emergence of cohesive units as socially and cognitively recognizable

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entities and the consequences of these units and their changes through time for coordinated group behaviors. This kind of information may differ significantly from interview or observational accounts of individuals acting independently. The network concept of *structurally cohesive* sub-networks of varying intensity, as defined by *the least number of disjoint redundant links* between each pair of their nodes, provides ways to study to what extent social groups, affected by their patterns of cohesion, come to be self-reinforcing and consequential in their effects.

Cognition

Formally defined core concepts from network science help capture how cultural consensus forms and changes around emergent roles and cohesive groups, given that humans are cognizant of role and group structure. Such concepts provide the bases needed for explanatory theory about sharing and differentiation in societies and cultures. Both cognitive and brain networks include various types of hierarchical organization. The human eye and visual perception per se do not allow us to truly "see" reality but rather to extract patterns of perception at successively higher levels.[1] There are no inherently "true objects" or "natural attributes" of objects corresponding to our perceptual world(s), but rather complex patterns of relations that identify objects cognitively with varying coherence and descriptive categories involving variable salience. As with other species, our views of the world have evolved adaptively as per our Gibsonian affordances – that is, the means by which we relate to our environment. The organism–environment system is a relevant network for study.

Deeper Problems: Mind, Logics, and World

The frequent disconnect between social behavior and cognition is a useful problem for study in the context of social networks, cognition, and culture. D'Andrade's (1974) "behaviorscope" experiment showed that the categories subjects list in conveying their immediate judgments of others' behaviors differ greatly from those they later report from long-term memory of the same events. The experiment also showed that the similarity structure of categories used in memory-based judgments is closer to those of the linguistic categories involved in expressing recovered memory and uncorrelated with those used in immediate judgments of these events. No wonder, then, that the studies of Bernard, Killworth, and Sailer (Bernard and Killworth 1977; Bernard et al. 1980, 1982; and with Kronenfeld in Bernard et al. 1984) showed that there is roughly only 50 percent agreement between the network links that people form and their mental recall of these links. Freeman et al. (1987) showed that the "best" informants on behaviors in groups, according to consensus, "can be used to reveal long-range stable patterns of events," while average non-consensual judgments of the worst informants can be more useful "to reveal the details of a particular event of special interest" (the accident bystander phenomenon, for averaging perceptions of completely independent observers). These findings connect with the theories proposed by Gibsonian psychological studies reviewed herein: namely, that experience and memory are stored in continuous perceptions, feelings, and "narrative-like" constructions about ongoing interactions, that is, in episodes, rather than in bits of time or cognitive categorization.

Network science is not simply a "method" of data collection and analysis but theory-driven in ways that begin from decisions about coding or structuring data so as to focus the analysis on theoretical questions. Results are heavily dependent on mathematical theorems about graphs, networks, and relational algebra that capture "necessary connections" (see White 1974; White and Reitz 1983; White and Harary 2001) for results that are not prima facie visible to the observer, as either ethnographer, preceptor of a network graphic, or network participant. Local choices and subsequent behavior in networks, for example, have necessary implications for global features of networks, and vice versa. Some of these properties are best examined through formal definitions and theorems. Through proper tuning and validation of how to code networks (e.g., "experientially"), network modeling can contribute to ethnography and to cognitive anthropology, and vice versa.[2]

The three-world problem

Popper and Eccles (1977) debated aspects of what they call the three-world problem, which also confronts cognitive anthropology:

World 1: The physical world (and human brain and behavior in that world).
World 2: Mental activity and human consciousness.
World 3: Objective culture, "which is the creation of World 2 but takes on its own distinct and permanent existence."[3]

The topics of the present essay, and those of Read (2008) and Leaf (2007, 2008) on formal empirical models, confront the question of how these three worlds are related. How is it possible for "objective" culture to take on a distinct and durable existence? Figure 18.1 brackets the three-world problem at two levels: that of the sciences (networks, cognition, and culture) and how these play out at the individual level of brain, mind, and behavior or organism–environment linkage. Arguments between scientists such as neurophysiologist Damasio (2007) and philosophers like Gluck (2007), seemingly irreconcilable, fail to resolve these problems. Anthropology currently wrestles with apparently incommensurate dualities in the interfaces between brain as a physical organ and the mind as a non-material dynamical organized response pattern mediating the organism–environment, ego–alter, and other interfaces.

The sciences today are undergoing major transformations, rethinking, and resynthesis. They in turn are affected by transformations in physics, biology, and ecological psychology in dealing with complex systems and, in particular, the dynamics of complex systems. I address here how these new syntheses affect anthropology and those social sciences concerned with human cognition, culture, and networks. Cognitive anthropology is caught in a position of having to reconcile individual cognition in the human brain with the existence of cultural patterns in terms of shared and meaningful symbols.

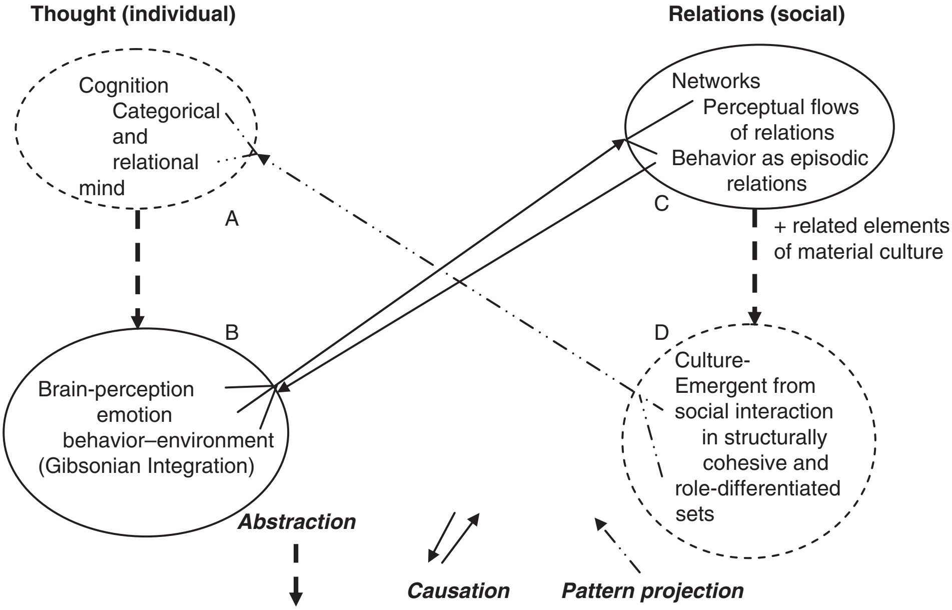

Figure 18.1 The three-world problem at two levels: individual and social, thought and relations. Arrows suggest directed cycles. Placement of Cognition and Culture avoids the implication that culture is superorganic or reified as "distributed cognition." Rather, from a not always consistent distillation of practices, culture emerges in roles and cohesively organized groups that can be cognized, and a reflexive cognitive D–A link for thinking about culture but no directed A–D link because "culture" does not "think." There are network and environmental physical B–C brain–behavior loops and an A–B–C–D cycle with non-material elements including mind and culture. The network oval C evokes the idea that episodic behaviors are internally (experientially) and externally perceptual and can be represented as network flows with an episodically temporal ordering in behavior that draws on restructured and weakly encoded memory of episodic experience. Solid and dashed ovals encircle material and immaterial elements, with causality between material items, pattern projections between thought and culture, and abstractions between material and immaterial counterparts: "mind studies brain, behavior models culture."

Figure 18.1 expresses a view which helps us to understand the relations between networks of behavior and cognition, mind and culture.[4] The upper ovals involve what individuals "do" in terms of thinking (internally) and behaving (externally). The lower ovals involve brain and the Gibsonian organism–environment interaction (left oval) and the non-material elements of culture (right). The left downward arrow (abstraction) refers to our cognitive ability to think about and study our brain, while the right abstraction arrow refers to our ability, through behavior, to project or reinvent culture. Culture, in turn, expresses our ability through learning to project culture into thought, including relational thinking. Rather than a positivist reduction to causal relations between acts → perceptions → thoughts (with incommensurate physical actions and immaterial thoughts), Figure 18.1 expresses how the three worlds may be related by material, abstract, and projective connections. It is also able to incorporate an A–C link that would support a network-based A–C–D cognitive modeling of cultural phenomena.

Relational thought

For humans, the assumption that mind operates largely through categories fails to be convincing because humans also think relationally, as has been demonstrated experimentally (Hummel and Holyoak 2005; Penn et al. 2008). One problem with 1960s cognitive anthropology was that meaning was seen as defined by categories, an element in the upper left oval of Figure 18.1, without the element of relational cognition.

An experimentally supported solution to the mind–body conundrum is that organism and environment constitute a single system (Turvey and Shaw 1979, 1995; Gibson 1966, 1979; West and King 1987; Swenson and Turvey 1991; Turvey 1991, 2009; Oyama 2000; Wagman and Miller 2003). Events are bounded in perception by changes in action that have networks of connected parts within events and recurrence across events. These views accord with those of Hutchins (1991, 1994) on the human–cognitive environment connection and the use of environmental material anchors in studies of human cognition, where part of cognition is "outside" but does not constitute "distributed cognition," which connotes direct immaterial mind–mind connection.

Time series of episodic events as experiences thus lend themselves *perceptually* to network coding and analysis. Such studies may be done at many different time scales. In our studies of kinship networks, for example (see White and Johansen 2006 for an ethnographic example) there are intergenerational events such as marriage, childbirth, death, migration, and proximal interactions within the culturally recognized and individually perceived event boundaries and time scales of event sequences. The network links between events and actors exhibit structural and dynamical patterns, including recurrences for which tools exist for studying complex dynamics (see Carollo and Moreno 2005 for methods), fractalities (White and Johansen 2006:136–137), and *structural cohesion* as a predictive network variable relating to shared-culture formation.

Cohesive groups in networks

Cohesive blocks (*maximum sub-networks in which each pair of nodes are connected by a certain minimum number k of disjoint paths*) are found operationally in a manner that fits the basic conceptual form for the idea of the cohesion of groups, the way cohesion is perceived for groups, and the way that cohesion ties a group together both internally and by resistance to being dismembered. It also shows the way that networks provide a particular set of the degrees of freedom in how cohesive groups may relate to one another through overlap (e.g., membership in multiple communities) and through core–periphery sub-group hierarchies for levels of cohesion. This opens the way to the following hypothesis.

The Cohesion and Consensus Hypothesis

Levels and variations of cohesion within social networks for society as a whole and within its varying segments, measured within networks for cohesive blocks (sub-networks) with a minimum level *k* of disjoint paths between every pair of their nodes, tend to predict levels and variations in cultural consensus, provided that the connections that define the network have some positive perceptual relation to the subject or contents of cultural consensus.[5]

This hypothesis was suggested by Schweizer (1996:116) but without an analytic measure of cohesion. It was reiterated by Ross (2004:124), who took density as a measure of cohesion, which it is not. White and Harary (2001) were the first to both formulate a formal measure of network cohesion that drew from the theory of graphs, and to test the predictiveness of the concept with a simple empirical example. They predicted how a karate club studied for two years by Zachary (1977) divided its membership between the club owner and the instructor, and the order of secession of members as the teacher formed a new club. This has a cognitive dimension because to decide with whom to disconnect individuals had to assess (1) their relation to others relative to the themselves, and owner and instructor, and (2) who their closer or more distant friends in the network were and how those allies stood in relation to the two leaders. Defectors moved to the teacher's side by breaking with those on the owner's side but did not follow a simple individual-level decision rule; rather, their behavior entailed a perception of group cohesion by breaking ties that were less cohesive with the owner's side than the ties they kept, and, for ties of the same level of cohesion, breaking the more distant tie from the owner. Attributes of the leaders with respect to those of students were not predictive.

Atran et al. (2002) tested friendship and social interaction as predictors of cultural agreement for environmental cognitions for populations but found no correlation (Ross 2004:122). Boster (1986) found kinship as a source of agreement among Peruvian manioc cultivators but, again, had no measure of cohesion and no findings for a cohesion consensus hypothesis. Interaction alone and network density alone, in these studies, were not predictive of cultural consensus. Atran et al.'s (2002) expertise networks, however, did predict cultural agreements, and might have been more cohesive.

Moody and White (2003) tested the predictiveness of White and Harary's structural cohesion measure, and showed that: (1) students' level of structural cohesion in friendship group "blocks" strongly predicted their reports of attachment to high school; and (2) cohesive strengths of co-memberships in the cohesive blocks of business alliances predicted similarities in the choices of firms in their political party alliances. In both cases, none of the other network or attribute variables – including density, centralities, and dyadic tie measures as well as student attributes – outperformed the predictiveness of the cohesion measure.

Powell et al. (2005), using the Moody–White measurement of structural (block) cohesion, analyzed time-lagged effects from year to year of multiple variables in the choice of partners for strategic collaborations in the biotech industry. They found that diversity of level of cohesion in the cohesive blocks to which potential partners belonged the year before were strong predictors of partner choice. Here, none of the other network or attribute variables outperformed the predictions of cohesion and diversity measures.

Multi-connectivity for networks of organizations, especially those with structurally cohesive block circuitry, is like a series of stacking blocks as shown in Figure 18.2: a child's stacking blocks game. Each successively smaller block may be stacked on a peg, here representing successively more *k*-cohesive groups, each with (by definition) a

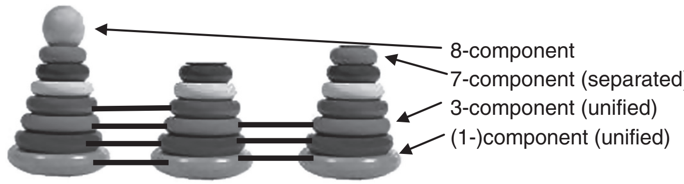

Figure 18.2 Stacking blocks, analogous to three cohesive hierarchies with overlaps of nodes in common.

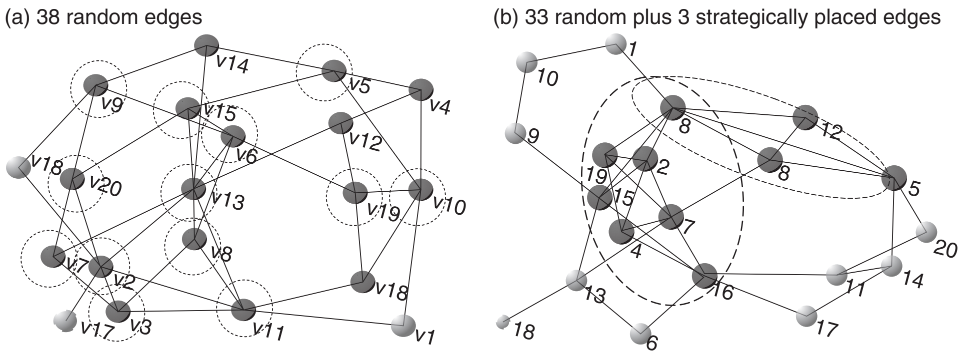

Figure 18.3 Cohesive blocking in graphs with 20 nodes and differing numbers of nodes and random edges, with additional edges added in (b). Shades of *k*-cores are $k = 3$ in black, $k = 2$ in gray, and $k = 1$ in white. This differs from sorting by *degree* (number of links per node), as shown by circled nodes in (a) for nodes with degree ≥ 4. (a) has a single cohesive hierarchy. (b) has two *k*-components that are not differentiated by the *k*-core concept but belong to the same 3-core. If the two 3-blocks in (b) were social groups, the cohesion and consensus hypothesis would predict greater consensus in each of the two 3-components than in their combined *k*-core (black nodes). For social interaction networks, greater consensus might be expected by the cohesion consensus hypothesis the greater the cohesion of a *k*-component.

non-increasing number of group members. The top block in each stack represents its most cohesive sub-graph for that stack of nodes in a network. What differs from the children's game is that blocks on different stacks may be part of a shared platform for their upper blocks, a platform representing overlap for their lower blocks.

The complexity of this example is difficult to envision because each *k*-component contains all blocks above a certain level and overlaps apply downwards to the blocks below. It is best stated abstractly as a mathematical definition for precisely bounded maximal sub-graphs of a larger graph whose sub-groups for levels *k* are found by blocking algorithm. The resultant blocks are most easily perceived by humans when the stacks and blocks are few and when viewed in a suitable format such as the spring embeddings of Pajek (Batagelj and Mrvar 1998).[6]

Figure 18.3 shows, with two different network structures, how cohesive blocks are defined and stacked by internal level of network-tie cohesiveness. The differences between (a) and (b) illustrate two slightly different model networks: (a) an "integrated" single stack of cohesive blocks and (b) a network with multiple cohesive blocks that are segregated but overlapping. In (a) the ties are fully randomized. Random edges always tend to create embedded levels of "socially integrated" *k*-cohesion, like a nest of Russian dolls, that is, forming a single hierarchy of cohesion. The biotech networks studied by Powell et al. (2005), for example, have single stack cohesion with maximum cohesiveness varying from 4 to 6 from year to year.

Each of the two graphs in Figure 18.3 has 20 nodes, but while (a) has 38 all-random edges, (b) has 33 random edges plus three strategic ties placed to create the greater complexity of two cohesive but overlapping sub-groups. The random graph in Figure 18.3(a), with its 20 nodes and 40 links (each link adding one degree to each of the two nodes linked) has an average degree per node of 4 edges (some with more and some with less). Those that have degree four or more are circled but no set of the 14 nodes with degree 4 forms a 4-component. Instead, there are 17 nodes that form a 3-component (black nodes). Here the 3-component is a sub-graph of the 2-component, which has additional (gray) nodes and nests in the largest (1-)component of all the connected nodes. In Figure 18.3(b), however, the black nodes differentiate into two 3-components.

The shades of nodes in Fig. 18.3 illustrate *k*-cores. A *k*-core (for $k = 1, 2, 3, \ldots$) is a unique largest sub-graph of a graph in which each node has degree *k* or more. Every *k*-component is a *k*-core but not every *k*-core is a *k*-component or *k*-block. In any network these are uniquely defined for the integers $k = 1, 2, 3, \ldots$, allowing for higher *k*-cores that are empty. In graph 18.3(a) but not 18.3(b) the *k*-cores and *k*-components are identical for each *k*. The *k*-cores of a graph are easily computed, for example, by Pajek (Batagelj and Mrvar 1998: menu/net/partitions/core), which deletes all nodes with less than the highest degree *k* and then recomputes degree, retaining those with *k* or more links, iteratively. Like the measure of sub-graph density, the use of *k*-cores (defined by Seidman and Foster 1978; Foster and Seidman 1989) is often taken in network analysis as a measure of group cohesion, even though this usage is invalid. A *k*-core for any value of *k* with more than $2k$ nodes may be completely disconnected. Even a sub-graph of two cliques (each completely connected) may have 50 percent density and yet be disconnected. Densities, like *k*-cores, are not measures of cohesion. For small graphs, the combination of spring embedding and *k*-core coloring usually allows visual identification of *k*-components, just as people with mature skills in relational cognition can often identify the unique *k*-components in their friendship groups. For a more sophisticated use of *k*-cores as fingerprints of network structure, recognizing that cores may be disconnected, see Alvarez-Hamelin et al. (2006).

Figure 18.4 shows the results of cohesive blocking applied to Figure 18.3(b) using the algorithm of Moody and White (2003, in a version implemented by McMahan 2007). Nodes in both 3-components (3-connected) are black but, as also shown in the splitting diagram to the right, there are two overlapping 3-connected components. The output vector computed by the McMahan (2007) algorithm tells exactly which nodes are in each of the 3-components, as shown by dotted ovals in (b):

> [[3]] [1] "v2" "v3" "v4" "v7" "v15" "v16" "v19"
> [[4]] [1] "v3" "v5" "v8" "v12" (NB node "v3" is shared with 3-cohesive block [[3]].)

Note that "v3" occurs in both 3-components in the separate but overlapping dashed ovals.

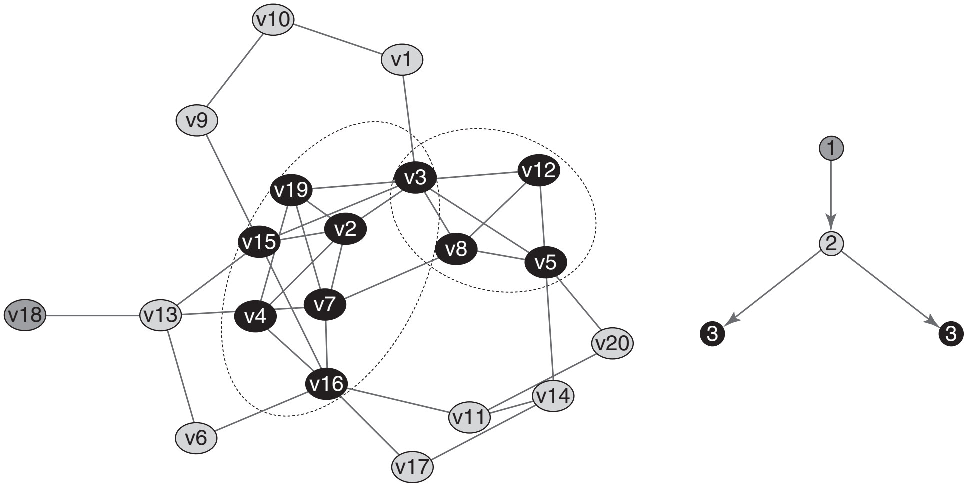

Figure 18.4 Cohesive blocking of the graph in Figure 18.3(b). The graph to the left is the network in Figure 18.3(b), also spring-embedded, but now with *k*-connectivity calculated by the cohesive blocks algorithm programmed in R freeware by Peter McMahan from the Moody and White (2003) algorithm. An appendix (White 2010a) gives cut-and-paste execution instructions in R.

Armed with this way of measuring the *distribution of cohesive groups at different levels of cohesion*, it is easy to see how a cohesion and consensus hypothesis could be tested by direct correlation with a pair-wise cultural consensus matrix (Romney et al. 1986). A single-consensus model would perfect match a network of type (a) – integrated cohesive groups, but a divergent-consensus model might match one of type (b) – separate even if overlapping cohesive groups, or one with more, or more discrete, components of cohesion. Areas in the graph of higher and lower correlation between consensus and cohesion could be mapped and compared.

Test of Structural Cohesion and Cultural Consensus

San Juan Sur (SJS) is a peasant community in the Turialba Canton of Costa Rica studied by Loomis and Powell (1949) in contrast to a nearby hacienda community (Atirro). Their network study is one of the few with data available to directly address issues of networks, cognition, and culture, for which the hypothesis linking structural cohesion to cultural consensus can be tested.

Costa Rica was then seen as the most democratic country in Latin America, "the land of peasant proprietors," where many of the rising hacendado class arose from peasant communities. The focus of their study was the transition to more stratified society, as

> peasant holdings are being gradually throttled by the large *fincas* and corporations thus reducing the status of the people from that of peasantry to peonage. Increasingly larger numbers of people are becoming *journaleros* and working for a subsistence wage as peons

> of the large land owners. What, then, might be expected if the country continues in the present trend toward a peon–patron type of system? For example, is there really a larger lower class on the hacienda than in the peasant community? How do the classes in these two situations compare with those in society at large? [Loomis and Powell 1949:448]

One focus of this study was on the impact of formal and informal social systems – social networks – on social change. Loomis investigated visiting relations between peasant proprietor families living in the SJS neighborhood and in the nearby hacienda of Atirro. The visiting network data they collected were published as simple directed graphs, without giving the number of visits but with arcs showing "frequent" visits from one family to another. For SJS 92 percent of visiting ties were within the community, and kinship ties were most often to the wife and/or husband's parents.[7] Line values classified the visiting relations: value one for ordinary visits, two for visits to kin, and three for those of ritual kin: god-parents, god-children and *compadres*. Judges and members of each community were asked to rate one another on a scale of social class from 1 to 10 (1–100 for the sum of ten judges). These data allow comparison of structural cohesion with consensual social class ratings in the two communities.

SJS and Atirro differ organizationally. The 60 Atirro residents interviewed were *finca* employees who worked for a small daily wage, lived in a tightly nucleated cluster, were much more mobile than the SJS residents (16 had lived there for less than a year) but enjoyed a rent-free *casa* during their employment. An administrator directed the work of the *finca* and a *mandador* directed the workers and was answerable to the *finca* owner. Here, structural cohesion would be expected to be fragmented but with some fragments indicating organizational specialization, as for example, in the *finca* hierarchy. The results of testing the cohesion–consensus hypothesis are positive for SJS but not for Atirro, where social cohesion in visiting is disrupted by turnover and *finca* organization.

SJS judges agreed on four classes for Atirro and SJS: upper and lower middle (18 percent of SLS) and upper and lower in a lower class (59 percent and 24 percent). The SJS peasant community is described ethnographically as egalitarian with no upper middle class. Nine of the ten judges in SJS rated themselves identically to how others rated them (Loomis and Powell 1949:149), and an SJS leader rated himself one rank lower than others rated him. Seven of the ten rated each other mutually as middle class. Figure 18.5, showing the SJS network, contains three types of directed ties: kinship visits were the most frequent, visits to ritual kin less frequent, and ordinary visiting infrequent. Reciprocal arcs are symmetric ties, as opposed to asymmetric directed arcs.[8]

For the cohesion–consensus hypothesis, SJS cohesive blocking shows black nodes for the large structurally integrated 3-component of the network, gray nodes that add to the 2-component, and a single white node that adds to the 1-component. SJS has the community integration structure associated with a single cohesive hierarchy, as in Figure 18.3(a). The correlation between upper middle-class families and levels of structural *k*-cohesion in ties for visiting kin in SJS is highly significant ($p < 0.003$) and somewhat less so ($p < 0.04$) are the ratings by judges of middle and upper low class (76 percent of the network) vs. lower low class (24 percent) with cohesive 3-component vs. lower cohesion correlation.[9] The correlation between *k*-cohesion and leadership status is equally significant.

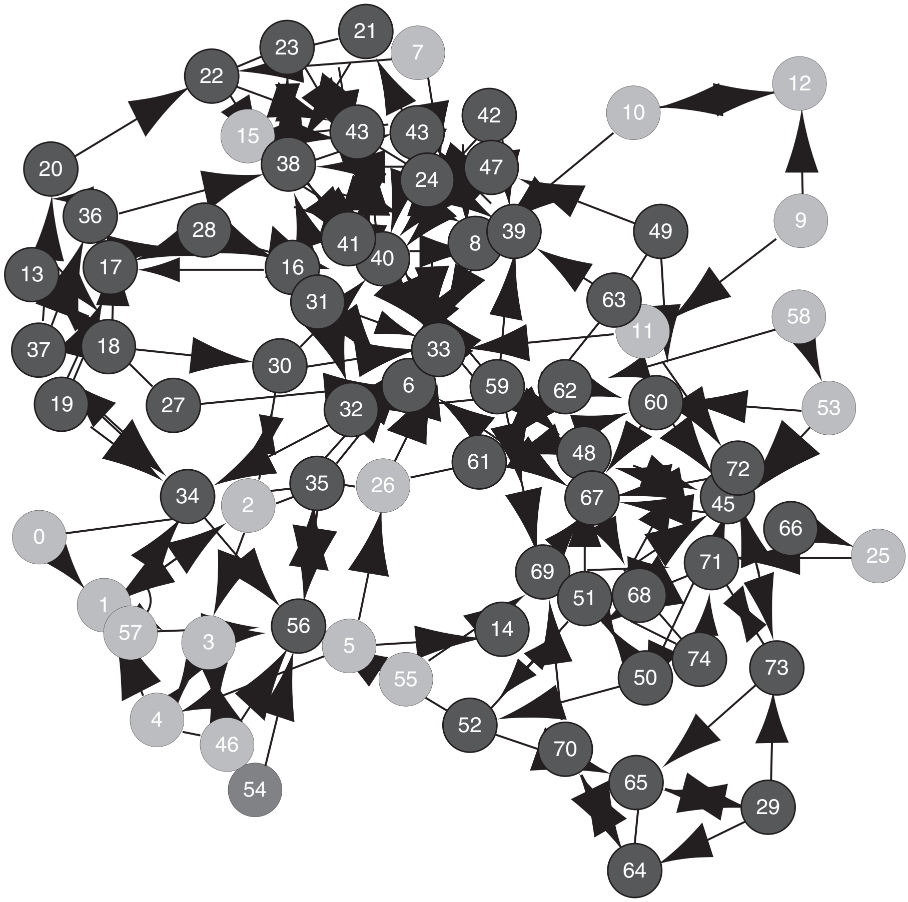

Figure 18.5 SJS network, with major contrasts between the structurally cohesive 3-component (dark nodes) of the network and the larger 2-component which also contains the lightest nodes. The one gray node adds to the 1-component, which includes the entire network. Kinship links are common within the 3-component, supplemented by a clustering of fewer non-kinship ties in the dense upper part of the graph, and very few scattered ritual kinship ties. These contrasts show up better at http://intersci.ss.uci.edu/wiki/pdf/Social_Nets_Cog-May2010_29pp_a.pdf. Edges without arrows are symmetric, arcs with arrows asymmetric.

In the Atirro *finca* there are no correlates of cohesion with class rank or leadership. "In Atirro the two upper classes have associations directed largely outside the community and little interaction orientated to other people in the village" (Loomis and Powell 1949:157). "The top prestige leaders … were not chosen from these two upper groups and there exists a barrier of significant proportion between the two lower groups and the two upper groups" (low and upper middle class). "The lack of informal communication between leaders [of the two lower classes] and the *finca* and commissary directors in the classes above is noteworthy." Mutual agreement on class levels does occurs for eight of ten judges but the community was split equally in their ratings of one resident and, for a leader, three judges agreed with his rating while six judged him higher.

Loomis and Powell (1949:157) conclude their article, in light of their concern with community disaffection in the hacienda regions of Central America, where Costa Rica was a bastion of the independent farmer. "The middle class philosophy of thrift, hard work, and higher regard for property is not as prevalent in the hacienda community as in the peasant proprietor community." In Atirro what little cohesion there is is highly fragmented and the largest set of extended family visiting ties are hierarchically connected to the hacienda employment hierarchy.

Tests of consequences of cohesion in P-graph structure of kinship networks

P-graphs illustrate how a network representation can be as complex or as simple as you want to make it. It may be intended to represent known sequences of selected or observed events, or to represent a narrative or story (as in the kinship network of the biblical Canaanites in White and Jorion 1992), a series of linked conversations, or a cultural model. Typically a network representation is a network model, similar to a cultural model in that a selection has been made of elements, connections, and processes through time that have some systematicity or coherence, or that exemplify complex interactions such as cycles, differential stability, or instability of elements and interactions, that is, complex dynamics. Network models of interactions may be simulated, and, conversely, most simulations will have elements and interactions that map out in time and could be represented as an evolving network, or as multiple co-evolving networks. Networks are not just made up of behaviors that instantiate cognition (Read 2008) but constitutive of the felt environment by which humans think, individually, and socialize their collaborative cognition.

For kinship networks of an Austrian farming community studied by Brudner and White (1997), more cohesively integrated members predict those who inherit productive property as opposed to those who do not and who tend to leave their natal community. For a Turkish nomad clan, more cohesively integrated members tended to predict those who would stay with the clan rather than emigrating to cities, inheriting in this case the productive property of pastoralism. Predictions of this sort are reviewed in White (2010b). To better study the structure of kinship networks the network units were converted from individuals to couples (P-graphs, as defined by White and Jorion 1992) so that cycles of marriage as well as marriage between consanguineal kin could be detected. These cycles are a special case of structure cohesion or k-connective where $k = 2$ (bi-components) are the maximal level of cohesion (two is the maximum number of parents in a P-graph and standard genealogy). This type of biconnectivity excludes cohesion within families and captures kinship units of *structural endogamy* (White 1997) within communities.

Perception and action based on cohesive structure

Case study findings such as those of Moody and White (2003) on school friendship networks and of business alliances in relation to political affiliation, and of Powell et al. (2005) on human biotech collaborations, each imply an ability to *act upon perceptions of* cohesive network structure even without any linguistic labeling of the cohesive groups or levels of cohesion, and that these perceptions proved to be largely correct.

The first is an example of friendships in relatively small networks within single organizations (high schools), while the second and third are medium- and large-sized networks of firms *and* other alliances of the firms (in the first, political parties, in the second, other organizations that serve functions for the biotech firms). A cognitive ability that would allow individuals or firms to act in such a way that their choice behavior for network ties is predicted by structural cohesion presumes recognition of cohesive structure even when names for *k*-components are lacking in ordinary discourse.[10]

The fallacy that thought depends on language

We know from experimental comparisons between human and other animals that relational reasoning (Hummel and Holyoak 2005) is critical to humans' ability to negotiate their extensive skills in social networks. The special relationship between human cognition and the complexity of human social networks includes those of "non-perceptual relational similarity based on logical, functional, and/or structural similarities between relations and systematic correspondences between the abstract roles that elements play in those relations" (Penn et al. 2008:111).[11]

Dominant anthropological views of the early 1960s, however, assumed that cognition and culture were largely constructed through language and linguistic categories, which in an extreme case can be problematized in a quote from Helen Keller: "Before I had words I had only sensations." Keller, however, was deafblind. It has been shown experimentally that with sight alone humans have enormous complexity in their understanding of social relations. Orang-utans and other higher primates also have understanding of complex relations acquired by watching and listening. This hints at where words and language fit in Figure 18.1 as opposed to non-linguistic, for example relational, cognition.

We can narrativize culture as a phenomenon taking on "its own distinct and [durable] existence," and as such stories are supported experientially by the duration of network groupings with a high degree of structural cohesion (Moody and White 2003) and where social networks form detectable communities (Estrada and Hatano 2008). The algorithmic science of finding unique "strong boundaries" of cohesive network sub-groups, as proven mathematically for cohesive blocking (overlap detection for hybrid communities) is barely in its infancy. Yet White and Harary's (2001) time-series predictions of karate club member decisions are replicated in Estrada and Hatano's model, and serve as an example of precisely matching predictive models for how ties dissolve as a club splits in two during a conflict between leaders. For every population in which there are data on the kinds of elements that constitute a culture or subculture, tests can now be constructed using cohesive blocking models and also Estrada's community detection algorithm to predict consensus or other patterns of behavior.

Co-descendant sidedness: South Asia

Humans can cognize complex role and structural patterns in social networks, only some of which are encoded in language. An illustration of complexity in pattern recognition is explicit in South Asian kinship cognition, expressed in discourse that is explicitly computational. When two people in a Dravidian language region are uncertain how they are related, for example, it is a computational discussion of whether they have a common close ancestor that allows them to decide whether they are "parallel kin" or marriageable "cross" relatives. This calculation expresses the existence of positions in the kinship network connecting same or opposite sides of two sets of intermarrying male lines (*viri*-sides) so if there is an *even number* of their female links – mothers of male or agnatic ascendants linking them to an ancestor – then they are cross and marriageable (Kris Lehman, personal communication), as with ♂ZD, ♂FZD, ♂MBD, or more remote cross-sided kin (♂MZS of course is not marriageable either). Otherwise they are same-sided, as with Z, FZ, MB. This shows cognizance of a balance principle of signed graphs that is proven as a theorem by Cartwright and Harary (1956): If we regard the male links as (+) same-side ties and female links as (–) opposite-side in a marriage network, the balance theorem partitions all and only the (+) links into one of two sides, assures that (–) links connect opposite sides, and that all cycles contain only even numbers of (–) links (but any number of (+) links). Descendants with overlapping ancestors need only marry properly sided consanguines (e.g., ZD, FZD, MBD) to form *viri*-sides (opposing sets of agnatic lines) that intermarry. The *viri*-sided balance principles implicit in Dravidian egocentric kinship terminology organize coherent sidedness for networks of consanguineal marriages. Caveats for consistency are that sidedness can incorporate totally foreign spouses but cannot apply to distant families related through marriage, for the practical reason that (1) there are too many paths to follow, unlike tracing near ancestors, and (2) these may not be among "your" kin who share a common network structure of sidedness. Thus, a network of consanguineal marriages will be sided if everyone follows the local co-descendant *viri*-sidedness rule (or, in a matrilineal society, a *uxori*-sided rule wherein an even number of *fathers* of *uterine* ascendants will create same-sidedness in a *uxori*-sided consanguineal marriage network).

The structure of kinship networks is often valuable in understanding how kinship works, even at the terminological level. Leach's (1961) *Pul Eliya* contains a complete genealogy of a Sri Lankan community with agnatic compounds and cross and parallel kinship terms with Dravidian sidedness rules. Named matrimonial moieties are absent. The restudy of these data, analyzed by Houseman and White (1998a) and White (1999), shows that among those kin linked by common ancestors, 100 percent of the male links in the kinship network can be divided into *viri*-sides such that women from one side marry men on the other (Houseman and White 1998b). We show that the Dravidian "practice" of sided marriage in a kinship network of this sort is sufficient to result in a sided "structure" of a network of consanguineal marriages, without recourse to sides as named social groups, or as defined by unilineal descent. Pul Eliyans lack a rule for membership in corporate male descent groups that is consistent with network male-based (*viri*-)sidedness. Thus, language categories themselves, such as Dravidian kinterms, do not inevitably tell us what we might wish to know about kinship reasoning.

Although Pul Eliyans have a concept for network sidedness that is rooted in kinship terminology, there is a minority of wrong-sided marriages between non-consanguines. The name for them is *dos*, "improper," marriages. They also have a reason *not* to practice *viri*-sidedness village-wide or with outsiders because irrigation rights and extended family residences in compounds are normally inherited by sons and allocated to a daughter when she lacks brothers. To inherit *and* avoid *dos* marriage, the heiress will marry a man from a distant village whose sidedness can be ignored (some brothers from distant villages are able to marry women on opposite sides). Thus, community members have an elaborate understanding of network sidedness expressed in their kinterms and they retain consistent sidedness among the majority of the village that are connected through common ancestors, while a minority of non-sided marriages occur for those who do not marry consanguines within the core community. Strategic marriages preserve cognatic inheritance relations without violating the integrity of a cognized but not fully articulated linguistic inscription of network sidedness. Sidedness and its strategic alterations are difficult to perceive in Leach's (1961: flyleaf) genealogy but rather easy to interpret in the *viri*-sided P-graph diagrams of Houseman and White (1998b:figs. 4.3, 4.4, 4.5).

Residential inheritance dependence: The Chuukese puzzle

Another example important for understanding kinship is how behavior choices are made as part of "shared culture" but in ways that are ascribed by fixed categories such as descent or residential groupings. Relational thinking about where to reside after marriage, for example, is analyzed in a network study by Skyhorse (1998) of the Romanum Chuukese (aka Trukese) genealogies. This is a question that spawned the Fischer–Goodenough residential rules controversy (Goodenough 1956; Fischer 1958): should residential choice be broken down into categories based on the lineage of the wife or husband, with the wife's father's maternal uncle, or husband's father, and so forth, and should the categories be "emic" (how people think about these choices) or "etic" (describing choices in the observer's language). Skyhorse, however, shifted the question to show cultural uniformity in terms of how the context of networks relationships predicted choice. Nearly 100 percent of the couples she studied with the aid of complete Romanum genealogies went to live with the holder of lineage land who was "closest" to the husband or the wife in terms of the rules for inheriting land. This is the kind of decision analysis (Fjellman, Geoghegan) reviewed in White (1974), but now contextualized by how people were embedded by meaningful links within the global kinship network of genealogical links.

Sub-group versus individual centrality

In the two examples discussed above, and in my karate club example, network-based cognitions and decisions play out in the mutualities of how two people regard each other with respect to others: in the "sidedness" of mutual ancestral descent, the mutual considerations of alternative inheritances by spouses play a leading part in residential choice, and dyadic considerations about dropping friendships in factional disputes. In sociology these are known as Simmelian effects of the network embedding of dyads within triads, or how network structure and groups influence behavior. While the centrality of individuals has been shown to be an important influence on their behavior (Freeman 1979 distinguishes effects of betweenness versus closeness or simply number of connections, for example), Estrada and Hatano (2008) test a more Simmelian measure of *sub-group* centrality that characterizes the relative participation of each individual node in all sub-graphs in a network. This measure, over a large sample of empirical networks, is almost totally uncorrelated with betweenness centrality for individual nodes. Estrada and Rodriguez (2005) go a step further to exploit their group-oriented method to define uniquely determined network communities based on patterns of shared sub-group centrality and the clustering of "communicability" in networks. Measures based on group effects such as these (and structural cohesion) should predict degree of cultural sharing between members of a network, no matter how extended, and effects on individual agency and on the potential agency of groups.

Diversity and sharing

The integration of network approaches into cognitive anthropology reopens significant new problems of sharing and diversity; continuity and discontinuity in culture; and stability, metastability, and instability in complex systems (including culture). New approaches can help in new syntheses at the ethnographic level and theoretical level, including comparison and explanation. The concepts of structural cohesion are ones around which communication, social reinforcement, and agreement may shape cultural consensus. These group-oriented network measures also identify social boundaries that may overlap and that may change rapidly. Members of a cohesive group may also affiliate elsewhere to create complex network formations.

Continuity

Many anthropologists have felt obliged to explain how continuity in culture occurs. Sir Herbert Spencer coined the term "superorganic," as if society were an organism whose existence required shared culture. This pseudo-explanatory word game was continued by Durkheim who referred to collective consciousness. Alfred Kroeber and Leslie White continued the use of the superorganism concept as if it were an explanation, and we see the term "distributed cognition" in use today in cognitive anthropology. J. W. Powell in 1880 coined the term "enculturalation" to describe what we see today in evolutionary syntheses of developmental (ontogenetic) processes. For Oyama (2000:71) and many contemporary researchers, "What passes from one generation to the next is an entire developmental system" that is inheritance-dependent but, as the outcome of a dynamical process; this is a view that can benefit from further empirical research testing the modern synthesis in developmental and cognitive psychology supported by new experimental evidence of *direct perception* (Michaels and Carollo 1981:11–13), with network and organism–environment embeddings as part of unexpected solutions to the mind–body two-world problem.

Discontinuity

Dynamical processes, like episodic direct perception, have discontinuities, often cycling between different states. Leach's (1961) study of the Pul Eliya emphasizes that there is no corporate charter of norms linked to the permanency of descent groups that continue indefinitely, and all is not harmony: most of the many conflicts he described involved failures of delayed reciprocation in discretional transfers of property between matrimonial sides. Statistical changes as well as institutional ones (like policies introduced by British colonial authorities) may change frequencies of behavior that change the context in which new expectations and norms are formed around changed network formations of structurally cohesive groups.

Metastability and instability in complex systems, including culture

Re-examining the problems of continuity and discontinuity in culture, sharing and diversity, and stability, metastability, and instability in complex systems (including culture) can help in a new synthesis of cognitive and social anthropology. These include problems of theory and method and issues of dualist versus monist social theories as described by Leaf (1979).

White and Johansen (2006) provide a longitudinal network study that exemplifies metastability by documenting the ethnogenesis, growth, and decline of ten lineages linked through structurally endogamous marriages in a nomad clan and the formation of new groups as clan members emigrate or resettle in urban areas. It focuses on how the initial formation of a structurally endogamous group through strategic intermarriage provides the cohesion for a leader of a long-range migration to form a new clan and move to occupy new territory. It then focuses on how equalitarian rotating leadership creates a period of reciprocal interlineage alliances that holds the growing population together for many generations. Intense competition for resources favor large sibling sets with many siblings-in-law while population pressure shunts less competitive smaller families off to resettle in towns and cities. The growing numbers of interlinked nomads and ex-nomads eventually support the movement of wealthier lineage leaders and their families to the city, and ties between the lineages gradually thin out to the point where the clan ceases to be cohesive, as new occupational forms are taken up.

Conclusion

I have provided here the first true tests, using data from the San Juan Sur and Atirro studies in Costa Rica, of various hypotheses about how aspects of cultural consensus are predicted by measures of sub-group cohesion in social networks based on formal graph-theoretic concepts, aka structural cohesion or multiple (k-)connectivity.[12] These kinds of hypotheses provide explanations for how multiply reinforcing social interactions can serve as key mechanisms for the emergence of cultural sharing. This extends as well to sharing in social roles where the role occupants interact cohesively with the overlapping role alters. The latter hypothesis has been extensively tested in sociology using the formal measure of structural equivalence and by Reichardt and White 2007 in their overlapping role equivalence models of complex networks.[13] Cohesion in overlapping role equivalence and the cohesiveness of groups provide theoretical bases for the emergence of cohesion-based institutional structures as an aspect of cultural organization.[14] Models of cohesive groups and role overlap structures, as formal measurement concepts, also predict that cohesion-based aspects of culture will be cognized in patterned ways that are likely to be shared between individuals (i.e., because of the common group or role overlap in environmental perceptions). Studies that integrate networks, cognition, and cultural frameworks ought to be far more effective than studies that divorce these topics from one another in the study of culture.

This paper advanced the propositions that: (1) cognition is not exclusively based on language; (2) human cognition is well capacitated to perceive complex relational structures in networks of behavior without a necessary dependence on named concepts or categories; (3) behaviors can be organized on the basis of these perceptions; and (4) reliance on categories and typologies as the exclusive basis of individual or culturally shared cognition is ill advised. There is weighty scientific evidence for these propositions. This brings weight to the idea that network structure and dynamics are key components for understanding human behavior, adding to but semi-independent of symbols, language, narratives, and other needed components.

Another proposition is that the most useful codings of social networks are those that emerge from a narrative structure, regardless of whether these narratives are explicit in speech or text. This is supported by the Gibsonian propositions that (1) a relevant network for study beyond just individual organisms and their ties is the organism–environment behavioral system, including what is afforded in this interaction that become sources of adaptation; and (2) types of human experience as cognitively encoded in Gibsonian psychological formats (as in the studies reviewed here) can fit into the conceptualization of social networks. That is, if experience and memory are stored in continuous perceptions, feelings, and "narrative-like" constructions about ongoing interactions, that is, in episodes, rather than in bits and pieces of categories, modeling these interactions as networks may be more useful. These ideas may suggest useful ways for social networks data to be encoded. Multiple types of directed links may represent different modes of interaction between two or more individuals in episodes of joint experience.

Ways of coding networks may also be tied in with newer models and measures of cohesive groups wherein interactions are likely to develop that help to coordinate behavior, cognition, mutually understood use of language and communications, and where the development of cultural models is within bounded social units. Extension of cohesion-based models of roles can help to understand how role interactions in organizational settings can become institutional. Contemporary network studies (Powell et al. 2005; Vedres and Stark 2008) are uncovering the benefits of research on such topics as internal group cohesion versus extra-group structural holes in networks role structure (Burt 2001) that reflect a congruence between anthropological ideas about benefits to groups in shared culture and roles in broader organizational structure. An anthropological approach to networks and culture, then, through proper tuning and validation of how networks are coded in terms of these experiential encodings, provides network modeling that can contribute to cognitive anthropology, and vice versa.

Because groups and roles are given to instabilities or meta-stabilities in complex interactive structures it may be useful to succinctly code and analyze network interactions through time to understand interaction system dynamics. The synthesis of cognition and network embedding in joint study offers an enrichment of the fields of cognitive studies, network studies, and cultural studies.

General problems of culture and cognition are also complemented by the "memes" approach, for example, of Sperber and Wilson (1986). Cultural units of meaning or "memes" can be studied "epidemiologically" through diffusive percolation, through convective network routes or role transmissions, or through propagation by omnidirectional radiation, for example popular media. Memes do not simply diffuse, but are also carried by interactions that can be shaped in cohesive groups and spread in cohesion-based networks of roles. And, at the cognitive level, networks of relevance give interpersonal focus to attention and thus to shared understandings that are spread by various mechanisms.

Two of the most basic concepts relevant to social sciences have been those of group and role. In this paper I have tried to move the status of these concepts up from the descriptive level (or middle-range theoretical constructs) to a level of measurement in networks of interactions where more formal and thus measurable theoretical concepts can be tested at a causal level, exemplified by how cultural emergence can be explained and predicted as consensus at the level of cohesive group emergent out of interaction, and predictive consequences of levels of structural cohesion in groups and role structures.

My model of process, shown in Figure 18.1, is that perceptions of material and behavioral entities and relations (C) flow into behavior–environment systems with organism–brain sentience and emotion (B). These networks are abstractly parsed in mind–cognition (A) which can recognize abstracted patterns in other (B, C) networks, the compounds in these cases constituting joint entities. This parsing flows back recursively within the mentally constructed network of episodic memory (A), coupled to perception–emotion responses (B), to produce networks of self-generated and both self- and other-perceived behavior structured into network-codable episodes (C), the compounds in these cases constituting joint entities. The shared cohesive patterns of these networks (D) can be recognized in mind (A), abstracted by mind–cognition back from emergent patterns of shared culture (D). This model has room for network analyses at multiple levels. It is not as simple as a positivist reduction to causal relations between acts → perceptions → thoughts, which mixes levels of the material and the immaterial. In separating the elements and relations of actions, thoughts, and culture, and analyzing their network components and effects, we may come to better understand human behavior, cognition, and culture.

NOTES

1 Because these patterns are constructed in the mind by interactions of neural networks, our mind has a perception of durability and continuity in our experiences, chunks of which will persist in various aspects of memory and mental schemata even as our attention is intermittently shifting from one experience to another.

2 Biotech organizations (Powell et al. 2005), for example, self-report their new collaborative contracts annually in their trade journal *because* collaborations contribute value to reputation; Aydınlı nomads proudly report their marriages and ancestors to ethnographers (White and Johansen 2006); network surveys may constrain and limit responses but also ask respondents to report on personal experience as well as experiential observations. The dyadic self–other reporting may provide estimates of the reliability of such reports.

3 See, further, http://intersci.ss.uci.edu/wiki/index.php/Culture%2C_science_and_the_world - _note-1, accessed October 4, 2010.

4 See the concepts of schema, prototype, and instantiation summarized by D'Andrade (1995:122–124). The positivist "model of the mind," however, in contrast to Figure 18.1, attributes causality to relations between material and non-material ("reified") entities, conflates constructs of mind (thought, wish, intention) with materially causal agents, mediates feelings through thought, and conflates them with "mindless" action.

5 There are, of course, other network predictors of cultural consensus, such as parentage or ancestry, common history, common educational experience, or exposure to the same media sources such as specific TV and radio sources. These are "vertical" rather than "horizontal" influences as in structurally cohesive groups. There are also "oblique transmission" influences such as effects of common types of prestigious figures that inspire learned agreement.

6 The spring embedding or FDP (force-directed placement) visualization algorithm pulls nodes together if they are connected and pushes them apart according to the length of the singular chains that connect them but which are not embedded in cohesive blocks.

7 These ties show an extended family structure in SJS with a common – consensual role – pattern in the visiting behaviors for kin. Removing symmetric ties for visiting between kin gives 46 remaining asymmetric visiting ties that form a connected but partially ordered visiting hierarchy differing significantly from random rearrangements of ties ($p = 0.00000000000003$). This is evidence of the salience of a P-graph structure (see following section) for the kinship network (individual members of couples and their siblings linked to parental couples).

8 These contrasts can be seen in color at http://intersci.ss.uci.edu/wiki/pdf/Social_Nets_Cog-May2010_29pp_a.pdf, accessed September 24, 2010.

9 Figure 18.4 has 54 red nodes and 20 green–blue nodes (one node is obscured), and nine green–blue nodes with social class ratings below 46 on the scale 0–66 in figure 2 of Loomis and McKinney (1956:407).

10 The cohesive blocks in the biotech industry were unnamed, and it is doubtful that the friendship groups were named because they cut across grade levels and they partitioned groups within grade levels.

11 Cohen (1969; Cohen et al. 1968) had shown evidence of modes of reasoning using relational reasoning rather than analytical categories of non-verbal tests but such evidence has been largely ignored.

12 For SJS the direction of this radix prediction (one predictor, many dependent variables) for multiple aspects of consensus (among judges of middle-class position, for upper- to middle- vs. lower-middle and lower-class ranking of individuals, and for leadership roles, etc. is more likely prima facie than the multiple regression prediction (many predictors, one dependent variable). Atirro lacks all but very fragmented social cohesion or cultural consensus.

13 The concept of role models with overlaps of alters is that every occupant of a role X which interacts with role Y has some overlap with common alters and thus a partially shared perceptual environment. A dynamical model of overlapping roles computes this algorithm in successive time periods. Reichardt and White (2007) give an example of a role overlap model for the 2000 global economy.

14 It may make more sense for the study of culture to ground the notion of systemic cohesion not by "institutions" but by substituting a term for more concretely cohesive entities such as "organizations." This specifies more concrete linkages, objectives, and adaptive redesign (Leaf 2008). Then in the domain of adaptive cognition (Posner 1989) and language there are two concrete adaptive levels for conceptual networks with concrete linkages that are either tighter through logical construction or looser through Ashby's principle of adaptive variability, where collaborative cognition occurs through the natural and constructed environment, artifacts, and observables (Hutchins 1991).

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