2

Recent Developments in Network Measurement

Peter V. Marsden
Harvard University

This chapter considers study design and data collection methods for social network studies, emphasizing methodological research and applications that have appeared since an earlier review (Marsden 1990). It concentrates on methods and instruments for measuring social relationships linking actors or objects. Many analytical techniques discussed in other chapters identify patterns and regularities that measure structural properties of networks (such as centralization or global density), and/or relational properties of particular objects/actors within them (such as centrality or local density). The focus here is on acquiring the elementary data elements themselves.

Beginning with common designs for studying social networks, the chapter then covers methods for setting network boundaries. A discussion of data collection techniques follows. Survey and questionnaire methods receive primary attention: they are widely used, and much methodological research has focused on them. More recent work emphasizes methods for measuring egocentric networks and variations in network perceptions; questions of informant accuracy or competence in reporting on networks remain highly salient. The chapter closes with a brief discussion of network data from informants, archives, and observations, and issues in obtaining them.

2.1 Network Study Designs

The broad majority of social network studies use either "whole-network" or "egocentric" designs. Whole-network studies examine sets of interrelated objects or actors that are regarded for analytical purposes as bounded social collectives, although in practice network boundaries are often permeable and/or ambiguous. Egocentric studies focus on a focal actor or object and the relationships in its locality.

Freeman (1989) formally defined forms of whole-network data in set-theoretic, graph-theoretic, and matrix terms. The minimal network database consists of one set of objects (also known as *actors* or *nodes*) linked by one set of relationships observed at one occasion; the cross-sectional study of women's friendships in voluntary associations given by Valente (Figure 6.1.1, Chapter 6, this volume) is one example. The matrix representation of this common form of network data is known as a "who to whom" matrix or a "sociomatrix." Wasserman and Faust (1994) termed this form a *one-mode* data set because of its single set of objects.

Elaborations of the minimal design consider more than one set of relationships, measure relationships at multiple occasions, and/or allow multiple sets of objects (which

may change over occasions). Data sets with two sets of objects – termed *two-mode* by Wasserman and Faust (1994) – are common; Table 7.4.1 of Chapter 7 in this volume gives an example, a network of national memberships in trade and treaty organizations. Many studies also measure multiple relations, as in Lazega's (1999) study of collaboration, advising, and friendships among attorneys. As Snijders (Chapter 11, this volume) indicates, interest in longitudinal questions about social networks is rising; most extant data sets remain single occasion, however. In addition to relationships, almost all network data sets measure attributes (either time constant or time varying) of objects, but this chapter does not consider issues of measurement for these.

A further variation known as a *cognitive social structure* (CSS) design (Krackhardt 1987) obtains measurements of the relationship(s) under study from multiple sources or observers. Chapter 9 in this volume presents models for such data. The CSS design is widely used to study informant variations in the social perception of networks. In applications to date, observers have been actors in the networks under study, but in principle the sets of actors and observers could be disjoint.

Egocentric network designs assemble data on relationships involving a focal object (*ego*) and the objects (*alters*) to which it is linked. Focal objects are often sampled from a larger population. The egocentric network data in the 1985 General Social Survey (GSS; see Marsden 1987), for example, include information on up to five alters with whom each survey respondent "discusses important matters."

Egocentric and whole-network designs are usually distinguished sharply from one another, but they are interrelated. A whole network contains an egocentric network for each object within it (Marsden 2002). Conversely, if egos are sampled "densely," whole networks may be constructed using egocentric network data. Kirke (1996), for instance, elicited egocentric networks for almost all youth in a particular district, and later used them in a whole-network analysis identifying within-district clusters. Egocentric designs in which respondents report on the relationships among alters in their egocentric networks may be seen as restricted CSS designs – in which informants report on clusters of proximate relationships, rather than on all linkages.

Aside from egocentric designs and one-mode (single-relation or multirelational), two-mode, and CSS designs for whole networks, some studies sample portions of networks. Frank discusses network sampling in depth in Chapter 3 (this volume). One sampling design observes relationships for a random sample of nodes (Granovetter 1976). Another, known as the "random walk" design (Klovdahl et al. 1977; McGrady et al. 1995), samples chains of nodes, yielding insight into indirect connectedness in large, open populations.

2.2 Setting Network Boundaries

Deciding on the set(s) of objects that lie within a network is a difficult problem for whole-network studies. Laumann, Marsden, and Prensky (1989) outlined three generic boundary specification strategies: a positional approach based on characteristics of objects or formal membership criteria, an event-based approach resting on participation in some class of activities, and a relational approach based on social connectedness.

Employment by an organization (e.g., Krackhardt 1990) is one positional criterion. The "regulars" at a beach depicted by Freeman (Figure 12.2.3, Chapter 12, this volume; see also Freeman and Webster 1994) were identified via an event-based approach; regulars were defined as persons observed 3 or more days during the study period.

Doreian and Woodard (1992) outlined a specific version of the relational approach called *expanding selection*. Beginning with a provisional "fixed" list of objects deemed to be in a network, it then adds objects linked to those on the initial list. This approach is closely related to the snowball sampling design discussed by Frank in Chapter 3, this volume; Doreian and Woodard, however, added a new object only after finding that it had several links (not just one) to elements on the fixed list. They review logistical issues in implementing expanding selection, and compare it with the fixed-list approach in a study of social services networks. More than one-half of the agencies located via expanding selection were not on the fixed list. Added agencies were closely linked to one another, although the fixed-list agencies were relatively central within the expanded network. The fixed-list approach presumes substantial prior investigator knowledge of network boundaries, whereas expanding selection draws on participant knowledge about them.

Elsewhere, Doreian and Woodard (1994) suggested methods for identifying a "reasonably complete" network within a larger network data set. They used expanding selection to identify a large set of candidate objects, and then selected a dense segment of this for study. They adopted Seidman's (1983) "k-core" concept (a subset of objects, each linked to at least k others within the subset) as a criterion for setting network boundaries. By varying k, investigators can set more and less restrictive criteria for including objects.

Egocentric network studies typically set boundaries during data collection. The "name generator" questions discussed in this chapter accomplish this.

2.3 Survey and Questionnaire Methods

Network studies draw extensively on survey and questionnaire data. Surveys allow investigators to decide on relationships to measure and on actors/objects to be approached for data. In the absence of archival records, surveys are often the most practical alternative: they make much more modest demands on participants than do diary methods or observation, for example. Surveys do introduce artificiality, however, and findings rest heavily on the presumed validity of self-reports.

Both whole-network and egocentric network studies use survey methods, but the designs typically differ in how they obtain network data and in what they ask of respondents. A whole-network study usually compiles a roster of actors before data collection begins. Survey and questionnaire instruments incorporate the roster, allowing respondents to recognize rather than recall their relationships. Egocentric studies, however, are often conducted in large, open populations. The alters in a respondent's network are not known beforehand, so setting network boundaries must rely on respondent recall.

Whole-network studies ordinarily seek interviews with all actors in the population, and ask respondents to report only on their direct relationships. (The CSS studies

discussed later are an exception; they ask for much more data.) In egocentric studies, however, practical and resource considerations usually preclude interviewing a respondent's alters. Such studies ask respondents for data on their own relationships to alters, and also often ask for information on linkages between alters; moreover, they commonly request proxy reports about alters.

Surveys and questionnaires in whole-network studies use several response formats to obtain network data: binary judgments (often termed *sociometric choices*) about whether respondents have a specified relationship with each actor on the roster, ordinal ratings of tie strength, or rankings. Binary judgments are least difficult for respondents; ranking tasks are most demanding. Eudey, Johnson, and Schade (1994) found that a large majority of respondents preferred rating over ranking tasks. Ferligoj and Hlebec (1999) reported the reliability of ratings to be somewhat higher than that of binary judgments.

Batchelder (1989) considered network data of different scale types (dichotomous, ordinal, interval, ratio, absolute) and the inferences about network-level properties (e.g., reciprocation, presence of cliques) that can be drawn meaningfully from them. Among other things, Batchelder showed that findings may be affected if respondents have differing thresholds for claiming a given type of tie when making dichotomous judgments; Feld and Carter (2002) referred to this as *expansiveness bias* (see also Kashy and Kenny 1990). Likewise, implicit respondent-specific scale and location constants for rating relationship strength can complicate inferences. Eudey et al. (1994), however, used both ratings and rankings in studying a small group, and found quite high correlations between measures based on the two response formats.

Surveys sometimes include "global" items asking respondents about the size, density, or composition of their egocentric networks. Such questions pose extensive cognitive demands. To answer a global network density question, for instance, respondents must decide who their alters are, ascertain relationships among alters, and aggregate (Burt 1987). Sudman (1985) measured network size using both a global item and a recognition instrument; the measures had similar means, but the global item had a far greater variance. Instead of global items, contemporary studies usually measure egocentric networks using multiple-item instruments that ask respondents for only one datum at a time.

(A) *Name Generator Instruments for Egocentric Networks*

Surveys have long collected data on a respondent's social contacts and relationships (Coleman 1958). Such egocentric network instruments typically include two types of questions (Burt 1984): *name generators* that identify the respondent's alters, and *name interpreters* that obtain information on the alters and their relationships. Name generators are free-recall questions that delineate network boundaries. Name interpreters elicit data about alters and both ego–alter and alter–alter relationships. Many indices of network form and composition are based on such data.

Instruments for egocentric networks use both single and multiple name generators. A single-generator instrument focusing on alters with whom respondents "discuss important matters" first appeared in the 1985 GSS, and later in several other studies (Bailey

and Marsden 1999). It tends to elicit small networks of "core" ties; Marsden (1987) reported a mean network size of 3.0 for U.S. adults in 1985, whereas Ruan et al. (1997) reported a mean of 3.4 for adults in a Chinese city in 1993. Hirsch's (1980) Social Network List (SNL) for social support networks is another one-generator instrument. Respondents list up to twenty persons they regard as "significant" and have seen during the prior 4 to 6 weeks.

Any given name-generating relationship elicits only a fraction of a respondent's social contacts. Moreover, many conceptual understandings of networks extend beyond "core" ties to include more mundane forms of social support. Fischer (1982a), for example, used name generators for instrumental aid and socializing, as well as confiding. Fischer and Shavit's (1995) U.S.–Israel support network comparison used a multiple-generator instrument. Another example is the Social Support Questionnaire (SSQ; Sarason et al. 1983), a twenty-seven-generator instrument eliciting persons to whom respondents can turn and on whom they can rely in differing circumstances.

The first consideration in choosing between single and multiple name generator instruments must be a study's conceptualization of a network. Single-generator methods may be sufficient for core networks, but more broadly defined support networks almost certainly require multiple name generators. A practical issue is the availability of interview time. Multiple-generator instruments that elicit many alters can be quite long, and measuring egocentric networks must be a central focus of studies including them.

More extensive definitions of "a network" include alters and relationships that do not provide even minor social support. McCarty et al. (1997) sought to measure features of "total personal networks," including all alters "known" by a respondent, those who "would recognize the respondent by sight or by name" (p. 305). Networks thus defined are too large to enumerate fully. McCarty et al. sampled total network alters by selecting a series of first names and asking if respondents know anyone by those names; they posed name interpreter questions about the sampled alters. The authors acknowledge that age, gender, and race/ethnic differences in naming practices may limit the representativeness of their samples. Nonetheless, their sampled total networks are less dense and less kin centered than are core or support networks, as one would anticipate. Further investigation of this technique as a means of measuring extensively defined egocentric networks seems warranted.

Because name generator instruments are complex by comparison with conventional survey items (Van Tilburg 1998), they often are administered in person so interviewers can assist respondents who need help completing them. Such instruments have, however, appeared in both paper-and-pencil (Burt 1997) and computerized questionnaires (Bernard et al. 1990; Podolny and Baron 1997). Little research has examined differences in data quality by data collection mode.

Methodological research on name generator instruments rarely addresses questions of validity because criterion data from other sources are unavailable. Some test–retest studies of instrument reliability are reviewed subsequently. Most research, however, examines the in-practice performance of instruments: how name generators differ, how respondents handle sometimes challenging tasks that instruments pose, and how key terms are understood. Much of this research reflects attention to cognitive and

communicative processes involved in answering survey questions (Sudman, Bradburn, and Schwarz 1996).

Comparing Name Generators

Several studies systematically compare properties of name generators. Campbell and Lee (1991), Milardo (1992), and Van der Poel (1993) highlighted conceptual differences between generators in criteria for including alters. Some refer to specific social exchanges, such as discussing important matters or borrowing household items; others use affective criteria ("closeness"); others specify particular role relations such as kinship or neighboring; and still others measure frequent interaction. Also, some generators specify temporal (e.g., contact within the prior 6 months) or spatial/organizational restrictions on eligible alters (Campbell and Lee 1991).

Varying name generator content influences egocentric network size, among other features. Campbell and Lee (1991) and Milardo (1992) showed that intimate name generators – whether affective or exchange based – elicit smaller networks than those specifying less intense thresholds for naming alters. Mean network sizes reported in seven intimate generator studies (all in North American settings) range between three and seven. Multiple-generator exchange-based instruments produce appreciably larger networks; across seven studies using such instruments, mean network size ranged between ten and twenty-two. Studies using exchange-based name generators tended to produce networks having smaller fractions of family members than did those using intimate generators.

Bernard et al. (1990) administered the GSS name generator and an eleven-generator social support instrument within a single study. The GSS instrument elicited smaller networks than did the social support instrument. These were core contacts: about 90% of GSS alters were also named for the social support instrument.

Instruments with many name generators impose appreciable respondent burden. Three studies suggest small sets of name generators for measuring support networks. Van der Poel (1993) identified subsets of name generators that best predict the size and composition of networks elicited using a ten-generator instrument. A three-generator subset consists of items on discussing a major life change, aid with household tasks, and monthly visiting; a five-generator version adds borrowing household items and going out socially. Bernard et al. (1990) isolated questions about social activities, hobbies, personal problems, advice about important decisions, and closeness as a "natural group" of name generators. Burt (1997) used a construct validity criterion – the association between network constraint and achievement – in an organizational setting. He concluded that a minimal module of name generators should measure both intimacy and activity; it might consist of the GSS "important matters" item, socializing, and discussion of a job change.

Recall, Recognition, and Forgetting

Brewer (2000) reviewed nine studies that asked respondents first to freely recall lists of persons, and then to supplement their lists after consulting an inventory listing all eligible persons. For instance, Brewer and Webster (1999) asked dormitory residents to recall their best friends, close friends, and other friends; the respondents then reviewed

a dormitory roster and could add to each list of friends. Friends recognized on the roster were deemed to have been "forgotten" in the recall task.

Across studies, Brewer reported an appreciable level of forgetting, although it varied substantially across groups and relationships. In the dormitory study, one-fifth of all friends were not named in the recall task. As in several other studies Brewer reviewed, the likelihood of forgetting alters varied inversely with tie strength: students forgot only 3% of best friends and 9% of close friends, but added 26% of other friends after inspecting the dormitory listing.

Brewer's review makes it clear that name generators elicit only a fraction of those persons having a criterion relationship to a respondent, and that intimate name generators enumerate a larger fraction of eligible alters than do weaker ones. Implications of these findings depend on the purposes for which network data are used. If one seeks to describe a network precisely or to contact alters (e.g., partner notification concerning an infectious disease; Brewer, Garrett, and Kulasingam 1999), then any shortfall in the enumeration of alters is an obvious drawback. If instead a study seeks indices contrasting the structure and composition of networks, then forgetting is more serious to the extent that indices based on the recalled and recalled/forgotten sets of alters diverge. Brewer and Webster (1999), for example, reported relatively high correlations between measures of centrality, egocentric network size, and local density based on recalled alters only, and the same measures based on recalled and recognized alters. They found appreciable differences in some network-level properties, however.

Brewer (2000) suggested several steps toward reducing the level of forgetting. These include the use of recognition rather than recall when possible and, if using recall methods, nonspecific probes for additional alters. Using multiple name generators may limit forgetting because persons forgotten for one generator are often named in response to others.

Test–Retest Studies

Brewer (2000) also reviewed eight test–retest studies. These used a variety of affective, support, and exchange name generators. Most test–retest intervals were 1 month or less. In all but one study, more than 75% of first-occasion alters were also cited at the second occasion. Brewer suggested that respondents may have forgotten the uncited alters.

Two studies examine over time stability in network size for social support instruments. Rapkin and Stein (1989) measured networks over a 2-month interval using both closeness and "importance" criteria. Between-occasion correlations of network size were 0.72 and 0.56, respectively. Size declined over time for both criteria, however, suggesting that respondents were unenthusiastic about repeating the task on the second occasion. Bass and Stein (1997) found higher 4-week stability in network size for the support-based SSQ (Sarason et al. 1983) than for the affective SNL (Hirsch 1980).

Morgan, Neal, and Carder (1997) conducted a seven-wave panel study of widows, using an importance criterion to elicit networks every 2 months. Core networks were very stable – 22% of alters were named on all seven occasions. These were often family members. There was also much flux at the periphery because 24% of alters were named only once. Morgan et al. found network properties to be more stable across

occasions than were alters. They suggest that between-occasion differences in alters mix unreliability (or forgetting) and genuine turnover.

Patterns in the Free Recall of Persons

Several studies of social cognition have examined the free recall of persons under different conditions. Their findings suggest strongly that social relationships organize memories for persons. Understanding these principles of memory organization can improve instruments such as name generators that seek to tap into such memories.

Bond, Jones, and Weintraub (1985) asked subjects to name acquaintances ("people you know") and recorded the order in which acquaintances were named. Successive nominations tended to be clustered by affiliations with social groups, rather than by similarity in physical or personality characteristics. Moreover, the time intervals separating names within a given group tended to be short; subjects paused for longer periods between names of persons in different groups. Social relations thus appear to be an important basis for remembering persons: Bond et al. concluded that "the person cognizer is more a sociologist than an intuitive psychologist" (p. 336). Fiske (1995) reported results for two similar studies; clusters of persons named by his subjects were grouped much more strongly by relationships than by similarity of individual features such as gender, race, or age.

Brewer (1995) conducted three studies asking subjects to name all persons within a graduate program, a religious fellowship, and a small division of a university. He too found that memory for persons reflects social relational structures: names of graduate students, for example, tended to be clustered by entering cohort, and shorter time intervals intervened between the naming of persons within a cohort than those in different cohorts. More generally, perceived social proximity appears to govern recall of persons. Brewer also found that subjects tended to name persons in order of salience. Those in groups proximate to the subject tended to be named first, as were persons of high social status and those frequently present in a setting.

These studies suggest that respondents recall alters in social clusters when answering name generators. The basis for clustering likely varies across situations, but it is plausible that foci of activity such as families, neighborhoods, workplaces, or associations (Feld 1981) offer a framework for remembering others. Aiding respondent recall with reminders of such foci might encourage more complete delineation of alters. Brewer's studies also indicate that respondents tend to order their nominations of alters by tie strength (see Burt 1986).

The Meaning and Interpretation of Name Generators

Name generators always refer to a specific type of social tie, and researchers assume that respondents share their understanding of this criterion. Fischer (1982b) questioned this assumption for "friends" (see Kirke 1996, however). He and others suggested that meanings are more apt to be shared for specific exchanges than for role labels or affective criteria. This calls for studies of the meanings attributed to exchange name generators.

Because it has been widely used, several studies have examined the GSS "important matters" name generator. Respondents decide what matters are "important" while

answering, so the content of the specific exchanges it measures may vary. Ruan (1998) investigated the intersection between the sets of alters named for the GSS name generator and those for several subsequently administered exchange name generators. In her Chinese urban sample, the GSS name generator elicited social companions and persons with whom private issues are discussed, but not alters providing instrumental aid.

Bailey and Marsden (1999) used concurrent think-aloud probes to investigate how respondents interpret the GSS name generator. Their convenience sample of U.S. adults offered a variety of interpretations: some respondents referred to specific matters, but others translated the question into one about intimacy, frequent contact, or role labels. When probed about the matters regarded as "important," most respondents referred to personal relationships; health, work, and politics were other often-mentioned categories. Differences in interpretive framework or definitions of important matters were not strongly associated with the types of relationships elicited, however.

Straits (2000) conducted an experiment: one-half of his student sample answered the GSS name generator, whereas the other half answered a generator about "people especially significant in your life." The two question wordings produced virtually identical numbers of alters. Only modest compositional differences were observed: women named a somewhat greater number of male alters for the "significant people" question than for the "important matters" question. Overall, however, Straits concluded that the "important matters" criterion also elicits "significant people."

McCarty (1995) investigated respondent judgments of how well they "know" others. Indicators of tie strength – closeness, duration, friendship, kinship – were associated with knowing alters well. Frequent contact was linked to knowing others moderately well. Low levels of knowing were distinguished by awareness of factual (but not personal) information and acquaintanceship.

Interview Context Effects

When name generators contain terms requiring interpretation, respondents may look to the preceding substantive content of an interview for cues about their meaning. A context experiment was embedded in the Bailey and Marsden (1999) study. One-half of the respondents answered a series of questions about politics before the "important matters" name generator; the other half began with questions about family. When subsequently debriefed about what types of matters were "important," family-context respondents were considerably more likely to mention family matters than were political-context respondents. Because this study is based on a small sample, these findings only suggest the prospect that context influences the interpretation of a name generator.

Interviewer Effects

Three nonexperimental studies document sizable interviewer differences in the size of egocentric networks elicited by name generator methods. Van Tilburg (1998) studied a seven-generator instrument with an elderly Dutch sample, reporting a within-interviewer correlation of network size of more than 0.2. This fell only modestly after controls for respondent and interviewer characteristics. Marsden (2003) studied a single-generator instrument eliciting "good friends" administered in the 1998 GSS,

finding a somewhat smaller (0.15) intraclass correlation than Van Tilburg's. Straits (2000) reported a similar figure (0.17) for the GSS "important matters" name generator administered by his student interviewers.

These interviewer differences are much larger than typical for survey items (Groves and Magilavy 1986). Large interviewer effects are, however, common for questions like name generators that ask respondents to list a number of entities. One conjecture is that interviewer differences reflect variations in the extent of probing. The findings highlight the need for careful interviewer training to ensure standardized administration of name generators. They also suggest the potential value of computer-assisted methods for obtaining network data, which operate without interviewers.

Name Interpreters

Although name generators have attracted much methodological interest, name interpreter items provide much of the data on which measures of egocentric network form and composition rest. Once alters are enumerated, most instruments follow up with questions about each alter and about pairs of alters.

The survey research literature on proxy reporting (e.g., Moore 1988) includes many studies comparing self-reports with proxy reports. In most of these, proxy respondents report on others in their households, so findings may not apply directly to reports about alters in an egocentric network. Sudman et al. (1994) observed that memories about others (especially distant others) are less elaborate, less experientially based, and less concerned with self-presentation than are memories of the self. This implies that self- and proxy reporters use different tactics to answer questions. Proxy respondents are prone, for example, to anchor answers on their own behavior, rather than retrieving answers directly from memory (Blair, Menon, and Bickart 1991). Sudman et al. (1994) hypothesized that the quality of proxy reports rises with respondent–alter interaction, and offered supportive data from a study of spouses.

Studies in the network literature establish that survey respondents can report on many characteristics of their alters with reasonable accuracy (Marsden 1990). White and Watkins (2000) found that Kenyan village women could report observable data on their alters – such as number of children or household possessions – relatively well. Ego–alter agreement was much lower for use of contraception, something often kept secret. Respondents often projected their own contraceptive behavior onto alters.

Shelley et al. (1995) studied networks of HIV^+ informants. Most sought to limit knowledge of their HIV status to certain alters; only one-half of the relatives in these networks were said to know the informant's HIV status. Nonetheless, informants reported that this was a better-known datum than several others, including political party affiliation and blood type. Such findings call for caution in formulating name interpreters because respondents may often lack certain information about their alters.

In addition to proxy reports, important name interpreters refer to ego–alter and alter–alter ties. Studies of network perception discussed subsequently are relevant to understanding answers to such questions.

Providing name interpreter data about a series of alters can be a repetitive, tedious task. White and Watkins (2000) noted that their respondents quickly became bored when answering such questions, and they therefore asked about no more than four alters. A

useful step toward limiting respondent burden is to ask some or all name interpreter items only about a subset of alters (or dyads), as in Fischer (1982a) and McCarty et al. (1997). Acceptably reliable measures of network density and composition are often available from data on only three to five alters (Marsden 1993).

(B) *Additional Instruments for Egocentric Networks*

Many name generator instruments do not elicit weak ties that are crucial in extending network range. In addition, even single-generator instruments require substantial interview time and pose notable respondent burdens. This section reviews alternative instruments developed to address such limitations.

Instruments for Measuring Extensive Network Size

Estimating the size of extensive egocentric networks, including all alters someone "knows," is difficult in large, open populations. Several survey instruments have been developed for network size. The "summation" method (McCarty et al. 2001) uses global network questions to estimate the numbers of persons with whom respondents have sixteen relationships (e.g., family, friendship, neighboring), taking the sum of a respondent's answers as total network size. Two U.S. surveys using this method estimate that mean network size lies between 280 and 290.

Killworth et al. (1998b) developed "scale-up" methods that estimate extensive network size using data on the known size of subpopulations, such as people named "Michael" or people who are postal workers. These methods rest on the proposition that egocentric network composition resembles population composition, that is,

$$\frac{m}{c} = \frac{e}{t},$$

where m is the number of alters from some subpopulation in an egocentric network, c is network size, e is subpopulation size, and t is population size. Survey data on m, together with data on e and t from official statistics or other archives, lead to scale-up estimates of network size c.

The previous proposition will not, of course, hold precisely for all persons and subpopulations. Implementations of the scale-up approach estimate c using data on m and e for several subpopulations. Studies using the approach yield a range of values for mean network size. Killworth et al. (1990) obtained a mean of around 1,700 for U.S. informants, and one of about 570 for Mexico City informants; these estimates assume a broad definition of "knowing" ("ever known during one's lifetime"). Killworth et al. (1998a) reported the mean size of "active networks" (involving mutual recognition and contact within the prior 2 years) to be about 108 for Floridians; Killworth et al. (1998a) obtained a mean active network size of 286 from a U.S. survey. The authors note that scale-up methods depend heavily on a respondent's abilities to report accurately on the numbers of persons known within subpopulations.

The *reverse small world* (RSW) method (see, e.g., Killworth et al. 1990) is still another approach to measuring extensive networks. It presents respondents with many (often 500) "target" persons described by occupation and location, asking for an alter more likely than the respondent to know each target. RSW identifies alters who could

be instrumentally useful; it omits those who are known, but not judged to be useful. Bernard et al. (1990) reported mean RSW network sizes of 129 for Jacksonville, Florida, informants, and 77 for Mexico City informants.

Position Generators

Rather than identifying particular alters and later ascertaining their social locations using name interpreters, the "position generator" measures linkages to specific locations directly. It asks respondents whether they have relationships with persons in each of a set of social positions. For example, Lin, Fu, and Hsung (2001) asked respondents if they have any relatives, friends, or acquaintances who hold fifteen different occupations. Follow-up questions may ascertain the strength of links to locations. Position generator data allow construction of indices of network range (e.g., number of occupations contacted) and composition (e.g., most prestigious occupation contacted).

Several empirical studies (e.g., Erickson 1996) use the position generator effectively. It identifies weak and strong contacts, if the threshold for contact with locations is of low intimacy; Erickson, for example, asked respondents to "count anyone you know well enough to talk to even if you are not close to them" (1996: p. 227). Because position generators do not ask about individual alters, they require less interview time than do many name generator instruments. However, position generators measure network range and composition only with respect to the social positions presented. Most applications focus on class or occupational positions; thus, the resulting data do not reflect racial or ethnoreligious network diversity, for example.

Smith (2002) experimentally compared measures of interracial friendship based on a one-item position generator, a name generator instrument, and a global approach in the 1998 GSS. His global items asked for a respondent's number of "good friends" and the number who are of a different race. Percentages of respondents claiming interracial good friends were highest for the position generator (whites, 42%; blacks, 62%), intermediate for the global approach (whites, 24%; blacks, 45%), and lowest for the name generator instrument (whites, 6%; blacks, 15%). Smith suggested that the name generator approach provides the most valid figures because it enumerates friends first, and later determines their race. The other approaches focus attention on the particular social location (race) of interest, encouraging respondents to inventory their memories for anyone who might meet the "good friend" criterion. Respondents seeking to present themselves favorably might alter their definition of "good friend" so they can report an interracial friend. Smith's findings may or may not apply to position generators measuring contact with occupational positions. Further instrument comparisons like this are needed.

The Resource Generator

Very recently, Van der Gaag and Snijders (2004) proposed the "resource generator" as an instrument for measuring individual-level social capital, which they defined as "resources owned by the members of an individual's personal social network, which may become available to the individual" (p. 200). Their instrument focuses on whether a survey respondent is in personal contact with anyone having specific possessions or capacities, such as the ability to repair vehicles, knowledge of literature, or high income. The resource generator does not enumerate specific social ties: in its most elementary

version it measures only whether a respondent "knows" anyone having each resource. Follow-up questions may ask about the number of ties to each resource, or qualities of the strongest tie to each resource. Using data from a Dutch survey, Van der Gaag and Snijders identify four social capital subscales, which they label prestige, information, skills, and support.

(C) *CSS Data*

As defined by Krackhardt (1987), CSS data consist of judgments by each of several perceivers about each dyadic relationship in a whole network. Such data offer many potential measurements of a network. Krackhardt called attention to three: a single observer's "slice" of judgments, a "locally aggregated structure" of judgments by the two actors directly involved in each dyad, and a "consensus structure" based on all judgments about a given dyad.

CSS data have been collected via several survey/questionnaire methods. Krackhardt (1987) used a checklist of dichotomous items about the outgoing ties of each actor in the network. Casciaro (1998) presented informants with a labeled matrix, asking that they mark pairs linked by directed ties. Batchelder (2002) used a questionnaire about outgoing ties, asking for dichotomous judgments at two thresholds of tie strength. A third response task asked informants to rank the three closest contacts of each network actor; some informants did not or could not complete the rankings, however. Johnson and Orbach (2002) asked informants for the three most frequent ties of each actor, but did not request a ranking.

These designs entail a considerable respondent burden that rises with network size, as Krackhardt (1987) noted. For example, Krackhardt asked twenty-one workplace informants for 400 dichotomous judgments about each of two types of tie (friendship and advice). Batchelder's ranking task or Johnson and Orbach's "pick three" task make fewer demands: each would require 126 judgments per informant for Krackhardt's group. Freeman and Webster's (1994) pile sort – which first asks that informants identify groups of closely related actors, and later permits them to combine groups linked at lower-intensity thresholds – is another less burdensome approach. Freeman (1994) suggested a graphic interface: informants position actors with respect to one another within a two-dimensional space. This requires only as many judgments as there are actors, albeit much more complex ones than those of other CSS tasks.

Batchelder (2002) found strong similarities among consensus structures based on dichotomous ratings, trichotomous ratings, and her ranking task. She concluded that dichotomous ratings may be sufficient for CSS data, given the volume of data in the design. The high between-task similarity found in her study, however, may result in part because informants could consult their responses on the rating tasks when providing rankings.

(D) *Informant Biases in Network Perception*

Several patterns recur in studies based on CSS data. These findings hold both substantive and methodological interest. They advance substantive understanding of social

perception by revealing schemas or models on which informants draw when describing their social environments, and indicate tendencies to anticipate when informants report on their own social ties and those of others.

Studying informants in an organizational department, Kumbasar, Romney, and Batchelder (1994) compared individual CSS slices to a consensus structure. Informants occupied more central locations in their slices than in the consensus structure; more than one-half placed themselves first or second in degree centrality, for example. Johnson and Orbach (2002) replicated this finding of "ego bias" in their study of a political network, finding it to be strongest among peripheral informants.

Kumbasar et al. (1994) also examined differences between reporting on relationships among adjacent alters and on ties involving actors not directly linked to informants. Reports about adjacent alters had higher density, reciprocity, and transitivity. The authors concluded that informants experience cognitive pressures toward reporting balanced local environments. This echoes Freeman's (1992) claim that informants simplify observations of interaction, imposing a "group" or "balance" schema by selectively creating or neglecting relationships among alters. His experimental evidence indicates that subjects had difficulty recalling relationships in unbalanced structures. Krackhardt and Kilduff (1999) too found that perceptions of relationships draw on a balance schema. Their studies of four CSS data sets, however, found higher levels of reciprocity and transitivity for both close *and* distant alters; perceived balance was lowest for alters at intermediate geodesic distances from the informant. Krackhardt and Kilduff reason that informants lacking detailed memories about distal relationships fill in details about them using the balance schema as a heuristic.

Johnson and Orbach (2002) suggested that, when information about social ties is limited, reports draw on a "status" schema giving positions of prominence to high-status actors. Webster (1995) too suggested that status considerations influence reports about relationships, and Brewer (1995) noted that high-status persons tend to be salient within informant memories.

Notwithstanding the various perceptual biases isolated, Kumbasar et al. (1994: p. 488) concluded that their informants were "fairly reliable" judges of the affiliation pattern in the group studied. Findings that informants employ a balance schema nonetheless suggest that relatively high local densities will be obtained using name interpreter items about relationships among alters because informants overstate the degree of closeness among alters they cite.

2.4 Informant Accuracy and Competence

Landmark studies by Bernard, Killworth, and Sailer (BKS; 1981) problematized the validity of respondent reports on social ties, documenting a far-from-complete correspondence between survey reports of interaction frequencies ("cognitive" data) and contemporaneous observations ("behavioral" data). BKS drew pessimistic conclusions about the utility of self-reported network data, stimulating many responses and much further research. Freeman, Romney, and Freeman (1987), for instance, showed that discrepancies between survey reports and time-specific observations of interaction

were not random, but instead biased toward longer-term regularities. They argued that informants can make largely accurate reports about enduring patterns of interaction (see also Freeman 1992).

Research on the cognitive-behavioral correspondence continued throughout the 1990s. Closely related work examines variations in cognition about networks as a phenomenon in and of itself, revealing variations in reporting "competence" that might offer aid in selecting informants.

(A) *Correspondence Between Reports and Observations*

In a reexamination of the BKS data, Kashy and Kenny (1990) showed that actors who received many cognitive citations had high observed interaction levels; moreover, behavioral data tended – although not inevitably – to corroborate pairwise reports of unusually high or low interaction. There was little correspondence, however, between an actor's number of outgoing citations and observed interaction levels. Thus, a major source of inaccuracy lies in the different response sets or thresholds that respondents use when making citations. Kashy and Kenny nonetheless concluded that cognitive network data contain useful information about interactions.

Freeman and Webster (1994) compared cognitive data from a pile sort task with observations of interaction. They too found substantial correspondence between the two measurements. Freeman and Webster noted, however, that the structure of their cognitive data was simpler than that of their observations; discernable clusters in the observations were much more marked in the sort. They contended that cognitive data are based on observed interactions, but reflect the use of a "group" schema storing information about categorical affiliations rather than dyadic ties. Freeman and Webster observed, moreover, that informants made more nuanced distinctions about proximate actors, smoothing over details about ties among distant ones.

Corman and Bradford (1993) recorded interactions among participants in a simulation game, and subsequently asked them to recall their interactions. Highly active participants tended to omit observed interactions from their self-reports, an outcome attributed to communication overload. Corman and Bradford theorized that participants who are highly identified with a group will tend to overreport, but their study did not measure identification directly.

These studies provide some confidence in self-reports as a valid source of network data, albeit with caution. They also suggest that observing social ties is itself difficult. Kashy and Kenny (1990), for instance, noted that time sampling introduces random elements into observed interaction records. A limited cognitive-behavioral correspondence, then, may reflect flaws both in observations and in self-reports.

(B) *Studies of Informant Competence*

In an early reexamination of the BKS data, Romney and Weller (1984) found that reliable informants (whose cognitive data resemble those of other informants) tend to be accurate (i.e., their cognitive data are close to aggregated observational data).

They posited that some informants may be better sources than others in reporting on interaction patterns. Romney, Weller, and Batchelder (1986) subsequently developed a general model for inferring shared cultural knowledge from informant reports, in which informants have differential "competence" to the extent that their reports correspond with those of others. This notion of competence parallels Romney and Weller's (1984) "reliability."

Several studies using CSS data investigate variations in informant competence in reporting on a whole network. These studies often refer to an informant's "accuracy." Their assessments of accuracy, however, do not compare cognitive data to an external referent, as in the BKS studies or Romney and Weller (1984). Instead, they usually examine the difference between an informant's slice of CSS data and some representation (e.g., a locally aggregated or a consensus structure) based on data from all informants. Such comparisons reflect what Romney et al. (1986) termed competence. To avoid ambiguity, the following remarks refer to "competence" rather than "accuracy."

These studies consistently find that centrally positioned informants tend to have higher competence (Krackhardt 1990; Bondonio 1998; Casciaro 1998; Johnson and Orbach 2002). Central informants have more opportunities to observe and to exchange information with others. Casciaro's (1998) finding that part-time workers are less competent reflects similar considerations.

Bondonio (1998) pointed to proximity as a source of competence: informants were more competent in reporting on the networks of close than of distal alters. Casciaro (1998) suggested that individual differences in motivation might lead informants to be differentially attentive to their social environments. High need for achievement was associated with greater competence in her CSS study.

(C) *Prospective Uses of Informants*

Network researchers implicitly take reports by actors involved in a dyad to be more valid than those by third-party informants. Apart from CSS data and name interpreters on alter–alter ties in egocentric instruments, little use has been made of informant reports about relationships of others. Torenvlied and Van Schuur (1994), however, suggested a procedure for eliciting CSS-like data from key informants. Burt and Ronchi (1994) measured egocentric networks for a subset of managers in an organization, some of whom offered data on the same relationships. Burt and Ronchi used this overlap in reports to develop imputations for unmeasured relationships in the full managerial network.

Competence studies also suggest intriguing prospects for using informants. For instance, a whole network might be measured by asking a small number of informants to complete CSS-like instruments, rather than seeking self-reports from all participants. This would be viable if CSS data reveal a strong correspondence between, for example, a consensus structure based on reports by all informants and one based on reports of some subset of highly competent informants. It would also require data – on likely centrality or need for achievement, for example – with which to screen prospective informants for competence.

2.5 Archival Network Data

Network studies use much information residing in archives that were not created expressly for social research. Such data provide unobtrusive measures of social ties. They sometimes trace relationships of actors who are reluctant to grant interviews. Archival data are often inexpensive, especially when in electronic form; if maintained over time, archives support longitudinal network studies. Archival materials are a mainstay source for studying networks in the past.

Some recent examples illustrate the range of applications for archival network data. Podolny (1993) measured the status of investment banks based on their relative positions in "tombstone" announcements of syndicated securities offerings. Using patent citations, Podolny and Stuart (1995) developed indicators of niche differentiation for innovations. Alexander and Danowski (1990) coded links between actors in Roman society recorded in Cicero's letters. Hargens (2000) depicted the structure of research areas via citations linking scientific papers. Adamic and Adar (2003) mined homepages on the World Wide Web for connections among university students. Two-mode data on membership relations (e.g., Table 7.4.1, Chapter 7, this volume) often are to be found in archives.

Relatively few explicitly methodological studies of archival data appear in the network literature. Although properties surely vary from source to source, a few generic issues and questions can be raised about such data.

The validity of archival data rests on the correspondence between measured connections and the conceptual ties of research interest. Sometimes this can be quite close; Podolny's interest in tombstone advertisements lies in the status signals (bank affiliations) they convey to third-party observers, and observers see exactly the information Podolny coded. In other cases, there may be slippage. Rice et al. (1989) observed that researchers often assume that academic citations track the flow of scientific information, but that in practice citations have many purposes, including paying homage to pioneers, correcting or disputing previous work, and identifying methods or equipment, among many others. Hargens (2000) conducted citation-context analyses revealing differences in citation practices – and the possible meanings of citations – across research areas.

Attention to the conditions under which archives are produced may be helpful in judging their likely validity with respect to any given conceptual definition of relationships. For example, Meyer (2000) reviewed the social processes underlying patent citations. Such citations acknowledge "prior art" related to a given invention, thereby distinguishing and narrowing an applicant's legal claims to originality. Interactions among applicants, patent examiners, and patent attorneys determine prior art citations. Examiners can add citations to an application before a patent is granted; applicants often claim to be unaware of the added works, although they do acknowledge other materials not included among the examiner's "front page" citations. Patent citations, then, are not simple traces of the process leading to an invention.

Likewise, the conditions under which objects come to be included in an archive merit attention. There are some reasons to anticipate that citation databases will be relatively comprehensive: authors have clear incentives to publish their works, much

as inventors have for guarding their claims. Rice et al. (1989), however, reminded us that editorial policies determine what journals are tracked by abstracting and indexing services, and thus what outgoing citations are recorded. In some instances, availability of archival materials may be quite selective. Adamic and Adar's (2003) homepage study, for example, notes that students decide whether to maintain a page. Moreover, some student pages exist, but reside in domains other than the one they examined.

Problems analogous to expansiveness bias in survey data (Feld and Carter 2002) arise by virtue of varying criteria for recording relationships in archives. Many affiliation data – such as corporate board memberships – may be relatively clear-cut. Patent citations should satisfy a common standard of "relevance" (Meyer 2000), although one might envision "examiner effects" on the number of outgoing citations. Academic citation practices, however, may differ appreciably across authors and fields. Authors of homepages have full discretion over page content, and pages almost certainly vary greatly in whether and why they include links. Adamic and Adar (2003) reported outgoing links for 14% and 33% of personal homepages in two universities.

Rice et al. (1989) also noted various mechanical problems that can introduce error into archival network measures. Journal-to-journal citation counts, for example, may be inaccurate if journal names change or if databases include "aberrant" journal abbreviations. Similar difficulties can affect author-to-author counts. Problems of this sort are easily overlooked, especially for electronically available archives.

Computer-mediated systems (Rice 1990) offer potentially rich data on human communication that network analysts have only begun to exploit. Such records are, however, medium specific: e-mail archives, for instance, exclude face-to-face communication that may be highly significant. The volume and detail of the data recorded in some such sources raises important issues of how to protect the privacy of monitored communication.

2.6 Observation

Observations made as part of extended fieldwork were important sources of data in some early network studies (Mitchell 1969). Relatively fewer recent network studies have drawn on such data, by comparison with survey and archival sources. Gibson's (2003) real-time observations of conversations in managerial meetings are one recent example.

The difficulty of obtaining observational data should not be understated. Corman and Bradford (1993) experienced problems in coding dyadic interactions from video- and audiotapes; it was not always possible for coders to discern who was addressing whom. Webster (1994) commented on problems in focal behavior sampling as an observational method, remarking that the relevant behaviors must be readily visible in the context studied and of sufficiently low frequency to allow an observer to record all relevant instances. Corman and Scott (1994) added that observation of large groups may require multiple observers positioned in all locations of group activity. They suggested that wireless microphones might be used in place of human observers; using a small set

of recordings, they illustrated a procedure for establishing dyadic communications by matching digitized signal patterns.

2.7 Conclusion

Notable advances in network measurement have occurred since 1990, especially for survey and questionnaire data. Instruments for measuring egocentric networks are now much better understood, and much has been learned about cognitive processes and biases involved in answering questions about social relationships.

Important questions of validity and reliability for survey/questionnaire data remain. The number and range of network studies that draw on archival materials has risen. Given the opportunities that archival sources present, it is important to scrutinize the quality of such data as closely as data from self-reports. Assessments of data quality, regardless of source, will be facilitated if researchers clearly articulate their concepts of the "true scores" they seek to capture with empirical indicators of network ties.

Acknowledgments

For helpful comments, I am grateful to Devon Brewer, Peter Carrington, Freda Lynn, and Joel Podolny. Thanks to Hilary Levey and Freda Lynn for research assistance.

References

Adamic, Lada A., and Eytan Adar (2003) "Friends and Neighbors on the Web." *Social Networks* 25: 211–230.

Alexander, Michael C., and James A. Danowski (1990) "Analysis of an Ancient Network: Personal Communication and the Study of Social Structure in a Past Society." *Social Networks* 12: 313–335.

Bailey, Stefanie, and Peter V. Marsden (1999) "Interpretation and Interview Context: Examining the General Social Survey Name Generator Using Cognitive Methods." *Social Networks* 21: 287–309.

Bass, Lee Ann, and Catherine H. Stein (1997) "Comparing the Structure and Stability of Network Ties Using the Social Support Questionnaire and the Social Network List." *Journal of Social and Personal Relationships* 14: 123–132.

Batchelder, Ece (2002) "Comparing Three Simultaneous Measurements of a Sociocognitive Network." *Social Networks* 24: 261–277.

Batchelder, William H. (1989) "Inferring Meaningful Global Network Properties from Individual Actor's Measurement Scales," pp. 89–134. In Linton C. Freeman, Douglas R. White, and A. Kimball Romney (eds.), *Research Methods in Social Network Analysis*. Fairfax, VA: George Mason University Press.

Bernard, H. Russell, Eugene C. Johnsen, Peter D. Killworth, Christopher McCarty, Gene A. Shelley, and Scott Robinson (1990) "Comparing Four Different Methods for Measuring Personal Social Networks." *Social Networks* 12: 179–215.

Bernard, H. Russell, Peter Killworth, and Lee Sailer (1981) "Summary of Research on Informant Accuracy in Network Data and on the Reverse Small World Problem." *Connections* 4(2): 11–25.

Blair, Johnny, Geeta Menon, and Barbara Bickart (1991) "Measurement Effects in Self vs. Proxy Responses to Survey Questions: An Information Processing Perspective," pp. 145–166. In Paul P.

Biemer, Robert M. Groves, Lars E. Lyberg, Nancy A. Mathiowetz, and Seymour Sudman (eds.), *Measurement Errors in Surveys*. New York: John Wiley & Sons.

Bond, Charles F., Jr., Rosalind L. Jones, and Daniel L. Weintraub (1985) "On the Unconstrained Recall of Acquaintances: A Sampling-Traversal Model." *Journal of Personality and Social Psychology* 49: 327–337.

Bondonio, Daniele (1998) "Predictors of Accuracy in Perceiving Informal Social Networks." *Social Networks* 20: 301–330.

Brewer, Devon D. (1995) "The Social Structural Basis of the Organization of Persons in Memory." *Human Nature* 6: 379–403.

Brewer, Devon D. (2000) "Forgetting in the Recall-Based Elicitation of Personal Networks." *Social Networks* 22: 29–43.

Brewer, Devon D., Sharon B. Garrett, and Shalini Kulasingam (1999) "Forgetting as a Cause of Incomplete Reporting of Sexual and Drug Injection Partners." *Sexually Transmitted Diseases* 26: 166–176.

Brewer, Devon D., and Cynthia M. Webster (1999) "Forgetting of Friends and Its Effects on Measuring Friendship Networks." *Social Networks* 21: 361–373.

Burt, Ronald S. (1984) "Network Items and the General Social Survey." *Social Networks* 6: 293–339.

Burt, Ronald S. (1986) "A Note on Sociometric Order in the General Social Survey Network Data." *Social Networks* 8: 149–174.

Burt, Ronald S. (1987) "A Note on the General Social Survey's Ersatz Network Density Item." *Social Networks* 9: 75–85.

Burt, Ronald S. (1997) "A Note on Social Capital and Network Content." *Social Networks* 19: 355–373.

Burt, Ronald S., and Don Ronchi (1994) "Measuring a Large Network Quickly." *Social Networks* 16: 91–135.

Campbell, Karen E., and Barrett A. Lee (1991) "Name Generators in Surveys of Personal Networks." *Social Networks* 13: 203–221.

Casciaro, Tiziana (1998) "Seeing Things Clearly: Social Structure, Personality, and Accuracy in Social Network Perception." *Social Networks* 20: 331–351.

Coleman, James S. (1958) "Relational Analysis: The Study of Social Organizations with Survey Methods." *Human Organization* 17: 28–36.

Corman, Steven R., and Lisa Bradford (1993) "Situational Effects on the Accuracy of Self-Reported Communication Behavior." *Communication Research* 20: 822–840.

Corman, Steven R., and Craig R. Scott (1994) "A Synchronous Digital Signal Processing Method for Detecting Face-to-Face Organizational Communication Behavior." *Social Networks* 16: 163–179.

Doriean, Patrick, and Katherine L. Woodard (1992) "Fixed List Versus Snowball Selection of Social Networks." *Social Science Research* 21: 216–233.

Doreian, Patrick, and Katherine L. Woodard (1994) "Defining and Locating Cores and Boundaries of Social Networks." *Social Networks* 16: 267–293.

Erickson, Bonnie H. (1996) "Culture, Class, and Connections." *American Journal of Sociology* 102: 217–251.

Eudey, Lynn, Jeffrey C. Johnson, and Edie Schade (1994) "Ranking Versus Ratings in Social Networks: Theory and Praxis." *Journal of Quantitative Anthropology* 4: 297–312.

Feld, Scott L. (1981) "The Focused Organization of Social Ties." *American Journal of Sociology* 86: 1015–1035.

Feld, Scott L., and William C. Carter (2002) "Detecting Measurement Bias in Respondent Reports of Personal Networks." *Social Networks* 24: 365–383.

Ferligoj, Anuška, and Valentina Hlebec (1999) "Evaluation of Social Network Measurement Instruments." *Social Networks* 21: 111–130.

Fischer, Claude S. (1982a) *To Dwell Among Friends: Personal Networks in Town and City*. Chicago: University of Chicago Press.

Fischer, Claude S. (1982b) "What Do We Mean by 'Friend': An Inductive Study." *Social Networks* 3: 287–306.