CHAPTER 4

Communication Networks: Measurement Techniques*

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The idea of structure is one of the fundamental issues that any science must address. In its broadest sense, structure refers to the arrangement of the parts of the system that the science studies. Structure is fundamental because it significantly determines the processes of the system, that is, the ways in which the system can function or behave,

The science of human communication studies the communication systems that people use as they live their daily lives. Like every. other scientific object, structure is a fundamental part of every communication system. Identification of this structure requires that we identify the people that comprise the various elements of the system and determine the arrangement of information exchange among these parts. In the science of human communication, the study of structure is usually undertaken under the rubric of network analysis.

The general idea of a network is one that is familiar to most people since we have all had frequent contact with concrete networks such as telephones, highways, and electrical power lines. But networks of social structure, of which communication is one type, are harder. to identify. The difficulty stems from the fact that communication networks are comprised of abstract human behavior over time, rather than concrete physical material such as wires, pipes, and macadam.

Communication networks, then, are the regular patterns of person-to-person contacts that we discern as people exchange information in a human social system. By observing the communication behavior of people we can infer who is informationally connected to whom, and

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thus, we can infer the communication network. Once we know the people who comprise the elements of the communication system and discern how they are arranged (i.e., the structure or network), we can describe how the overall communication system will operate and how it is related to other important variables.

Observing and inferring these regular patterns of human communication is not easy, but it is interesting and challenging. Because the task requires that we observe human communication and often assign numbers to what we observe, it falls within the proper domain of measurement. In this chapter we describe the measurement alternatives that are currently available and provide a summary of the current wisdom about their advantages and limitations. The selection of the appropriate network analysis method and computer program is also important. This chapter, however, concentrates primarily on the measurement process. (For a detailed review of network methods and programs, see Rice & Richards, 1985.)

The chapter is divided into three parts. The first section discusses properties of linkage data that have been used in network studies in general, and communication network studies in particular. The next section deals with two boundary specification problems: space and time. The third section focuses on various ways that network data are collected.

Properties of Network Linkages

The fundamental difference between network analysis and most other social science research is the emphasis placed on the relationship between two or more objects rather than the attributes of the objects. The objects, often called nodes in network analysis, may be individuals, roles, categories of individuals, groups, organizations, or even entire societies. Researchers in different disciplines have used network analysis to study such diverse phenomena as the transaction or flow of goods, money, information, power, influence, acquaintance, affection, and kinship patterns (Knoke & Kuklinski, 1982). While communication research may find one or more of these networks useful, the flow of information through communication networks is of primary concern.

Properties of Communication Linkages

The *strength* of a communication link is an important property of communication linkages. The strength of a link is a numerical description of the amount of the relationship between two nodes. There

are three typical measures of strength. First, in some cases simply the presence or absence of a communication link is of interest. Such a measure is referred to as *binary*. This approach would suffice, for instance, if the aim of the network analysis is only to identify the isolates (Reitz, 1983). To obtain information on a binary link between A and B, respondent A may be asked to respond to a question such as, "Do you talk with B?." Second, the research question may require information about the *frequency* of communication over a fixed period of time. To obtain information on the frequency, the question may read, "How often do you talk with B?" Response options could include monthly, weekly, daily, or several times per day. The third measure of strength is the *duration* of each interaction. For example, a network measure of duration might be, "The last time you talked with this person, how long did your conversation last? less than 5 minutes, 5 to 15 minutes, 15 to 30 minutes, 30 minutes to an hour, more than an hour." Alternatively, if information is sought on the average duration of the interactions, the question, "How long, on the average, are your interactions with B?" must be asked. Sometimes, a researcher is interested in a combined measure of both frequency and duration. Typically, interactions of short durations will be assigned lower strengths as compared to equally frequent interactions of longer durations.

In some cases, the strength may be weighted by perceptual variables, such as satisfaction with, or importance of, the communication linkage. In such instances, it may be more appropriate to use an ordinal scaling scheme rather than an interval or ratio level measure (Killworth & Bernard, 1974). Finally, a strength can be assigned based on the level of distortion that occurs during a communication between the two nodes, or the amount of time required for a message to be sent from one node to another (Edwards & Monge, 1975).

The second property of network relations is the *symmetry* of the link. A link is defined as symmetric if the two nodes share information, both giving and taking equally. In contrast, an asymmetric link is defined as one in which information is primarily given by one node to the other, such as when one person instructs another or one person reprimands another. Thus, it may be of interest to know if a communication link between two nodes, say, A and B, imples that, A sends a message to B (an asymmetric link), or if A talks *with* B (a symmetric link).

Closely related to the concept of symmetry of a link is a Property of network relations known as *directionality*. Directionality pertains to the flow of the substance of the relation from one person to another. Typically, there are two values to directionality. First a directional link refers to a link in which information or communication flows from person A to person B. A directional link can only be defined for an asymmetric relation. Second, an undirected link refers to one in which the direction of the flow of information or communication between two is unspecified. Undirected links occur only for symmetrical relations. For example, if A discusses politics with B, the link is undirected and they engage in a symmetric relationship. To obtain information on a symmetric link, an individual must be asked specifically to report undirected linkages. For example, "How often do you discuss politics with B?" If on the other hand, A informs B about politics, the link is directed and they engage in an asymmetric relationship. In such cases, individual A must be asked "How often do you talk to B about politics?"

A third property of network relations that may be of interest is *reciprocation*. Reciprocation is defined as the degree to which two individuals agree on the strength of the communication linkage between them. For instance, if A reports a high level of interaction with B, while B disagrees and reports a low volume of interaction with A, the link is said to have a low degree of reciprocation. As can be seen from this example, reciprocation is a property that is only defined for symmetric links. If information is required on the degree of reciprocation for links, it is imperative that the network question be posed to all members of the network,

Finally, a fourth property of network relations, proposed by Rice and Richards (1985) is *confirmation*. Confirmation is defined as the degree of agreement between two individuals involved in an asymmetric link. For instance, if A reports that he/she instructs B on how to conduct a network analysis and B indicates that he/she was taught how, to conduct a network analysis by A, the link is said to have a high degree of confirmation. Clearly, confirmation is a property defined only for asymmetric links. To obtain information on the degree of confirmation, it is necessary for the researcher to ask an additional question. For example, the question, "How often do you initiate communication with B?" must be accompanied with the question, "How often does B initiate communication with you?"

Content of Communication Linkage

The properties of network linkages described above provide a framework for studying a generic communication network. However, in practice, most researchers restrict their attention to specific forms of communication. In this section we examine ways in which network researchers have isolated or categorized the forms of communication which are relevant to the research question. First, a communication

network instrument may need to identify the *content* or *function* of the communication, based on the research questions being posed. For instance, one functional classification applied to messages in organizations distinguishes between production (getting the job done), innovation (exploring new alternatives), and maintenance (keeping the system and its components operating) (Farace, Monge, & Russell, 1977). In a social setting, studies on content-specific communication networks have been wide-ranging. For instance, research has examined communication networks pertaining to the diffusion of a specific innovation, to a particular hobby, and to taboo issues such as abortion or contraception (Rogers & Kincaid, 1981).

Second, network analysis has also been used to answer research questions dealing with the differential effects of the communication *media* being used. One approach would be to study a network of verbal communication and compare it with one based on written communication. With the growing interest in effects of various communication technologies, a communication network instrument might distinguish between mass communication technologies (such as radio, television, and computer bulletin boards), various point-to-point communication technologies (such as telephone and electronic mail), and face-to-face communication (e.g., Rice, 1982).

While most studies focus on a single communication network, some studies attempted to study networks where individuals are connected by more than one form of linkage. Such relationships are referred to as multiplex linkages. It must be pointed out that, even though a network instrument may be able to collect data on multiplex relationships, their subsequent analysis may be limited by the analytic algorithms currently available. To date, almost none of the network programs using graph-theoretic algorithms can analyze multiplex networks. However Burt (1980) argues that algorithms using the positional approach allow the analysis of multiplex networks.

Boundary Specification

In this section, we address two issues. For what membership and over what duration of time are these relationships being studied? The first question would imply specifying a boundary in space, while the latter would require the specification of a boundary in the time domain. The boundary of a system, therefore, is defined by a set of criteria that result in the specification of membership over a particular period of time.

Space Boundary

The selection of a spatial boundary for the network is accompanied by very specific assumptions about the object of explanation. Consider for a moment, a biologist who observes an exotic collection of acquatic organisms in a petri dish through a microscope. After some focusing the biologist will zero in on a clear picture. However, this view of the acquatic world is largely determined by the order of magnification to which the microscope has been adjusted. The biologist could switch to a higher or lower power of magnification. By doing so, new levels of the acquatic community come into focus. Switching to a higher order of magnification would allow the study of cells within a single organism. A lower order of resolution might be appropriate to study colonies of organisms. Just as in this example the object of explanation (e.g., a cell or a colony) determined the order of magnification chosen, so also in network research the object of explanation (e.g., a department, an organization, or an industry) will determine the specification of a boundary.

Historically, network studies have often provided little or no theoretical rationale for their choice of system boundaries. Laumann, Marsden, & Prensky (1983) have argued that an error in the specification of the boundary can result in fundamental misrepresentations of the structure abstracted from an analysis of an ill-defined network. They propose that membership in a network could be based on any of three broad criteria. The first focuses on the people, the second on the relationship, and the third on a common activity.

In the first approach, all people having a common attribute, such as membership in an organization, club, or village, could be considered members. A variation is to include people recommended by knowledgeable informants. A large proportion of network studies in organizations fall into this first category. Laumann et al. (1983) have pointed out that in this approach the nodal characteristics have been fixed and cannot be studied. However, the patterns of participation and the levels of interconnectedness can be empirically analyzed.

The second alternative specifies people participating in a particular type of relationship. A variation restricts membership to those who have a minimum frequency of interaction in this type of a relationship. In this approach, the form of the network is fixed, but the nodal attributes and patterns of participation are free to vary.

Finally, some researchers (such as Pfeffer & Salancik, 1978) define the boundary of the system as a set of events or activities. For instance, Dahl (1961) chose to study only those members of the New Haven community elite who were involved in a controversy. In this case, the level of interconnectedness and the nodal attributes are both allowed to vary, while the participation in the event is empirically fixed.

Time Boundary

Let us return for a moment to the example of the biologist. After having chosen the appropriate level of magnification required the biologist would still need to decide on the duration of the observation. For some research questions, the biologist may need to make an observation at one point in time. In other cases, the observation may need to be made continuously for a long period of time. In still other cases, the observations may need to be made intermittently. The time intervals may vary from seconds to months, even years I Like the biologist, the communication scientist must also decide on the temporal boundary of the study based on the research question being posed.

As in other social science research, network analysis has traditionally been cross-sectional in design. However, since the objective of network analysis is to describe the structure based on patterns of interaction over time, all network analysis has a built-in time component. Cross-sectional network research has been classified into concrete-time network analysis and abstract-time network analysis (Edwards & Monge, 1975). Concrete-time network analysis is based on aggregating and reporting actual interactions over a specified period of time. (say, a week). For instance, the researcher may ask the question, “How often did you talk to A in the past week?” Abstract-time network analysis, on the other hand, requires the respondent to extrapolate from reality to provide estimates of interactions for a hypothetical or an average time period. For instance, the researcher may ask the question, “How often do you talk to A in a typical week?”

The choice of the duration of the time period in cross-sectional network analysis may affect the data collected significantly. Choosing too shot-t a time duration may leave the researcher with data too spat-se to ascertain patterns of communication. For instance, asking individuals to report the frequency of interactions in the past day may exclude all those linkages that occur less frequently than daily. On the other hand, choosing too large a time duration might mask any recent changes in the communication patterns. Further, the choice of the words “short” and “large” to describe the time durations is relative and varies with the context. This dilemma can be resolved individually for each study, based on the theoretical rationale of the process being examined, and by pretesting the instrument.

As with other cross-sectional research, cross-sectional network analysis is often not appropriate to capture change. Ironically, despite the fact that theorists of social structure have often described the unfolding of structure as a processual phenomenon, most network researchers have used cross-sectional instruments to measure network structure. Consequently, they have had considerable difficulty describing the process of network change. Fortunately, researchers have recently begun to correct this problem by conducting longitudinal communication network studies (Rice & Barnett, 1986).

There are two principal approaches to designing a longitudinal network instrument. The feature that distinguishes them is the timing of their administration. The first approach would be to aggregate the number of interactions (just as in the concrete-time network analysis) periodically. The time period would need to coincide with the duration for which the interactions were aggregated. The second approach would not collect data at equal intervals of time. Instead, the instrument would be used at specific stages. These stages, for example, the life cycle of an organization, or stages of the diffusion of innovations, may be theoretically determined (Monge & Miller, in press).

The time span of longitudinal studies would be governed by the nature of the phenomena being studied. Researchers interested in microphenomena, such as interactions during a group discussion, would conduct their study over a relatively short time span. On the other hand, those interested in macrophenomena, such as formation of alliances, or maintenance of stratification, conduct their studies over fairly large time spans (Barnes, 1979).

Data Collection

Methodologies for the collection of communication data were developed more than half a century ago. Different techniques were utilized in laboratory and field settings. Further, they either relied on self-reports or on external observers to provide the data. The external observer could range from a participant observer to a mechanized monitor keeping logs. In the next few pages, these techniques are briefly described, with special emphasis on the assumptions and limitations accompanying each technique. (For more detailed descriptions of these techniques, see Farace et al., 1977, Rogers & Kincaid, 1981).

Laboratory Studies

Laboratory data collection techniques were developed by Bavelas (1948, 1950) and Leavitt (195 1). Working in a small-group laboratory, they imposed a variety of communication network configurations on their subjects. The configurations allowed some of the subjects to communicate directly, while preventing direct communication between others. The subjects (rarely more than five) were then given a task, while the experimenter measured the number of interactions between the members in the group before a certain decision or outcome was achieved. These interactions were often in the form of written messages exchanged by members connected in the specified network, These researchers, therefore, primarily used data collected by external observers.

There are several fairly stringent limitations to this technique. First, laboratory groups are typically small, and extrapolating findings to larger groups may not be valid (Farace et al., 1977). Second, the laboratory group is a closed group in a closed system, and findings in such a setting may not be applicable to groups which are embedded in larger systems (e.g., Cohen, Robinson, & Edwards, 1969; Bernard & Killworth, 1979). Finally, most laboratory groups do not have a history of working together, and hence may not reflect communication patterns that are associated with groups which have been in existence for some time (Fortes, 1957).

Traditionally, experimental techniques have been used to study outcomes of imposed networks. This approach, however, does not permit researchers to study easily the processes whereby networks emerge (Monge and Eisenberg, in press). This shortcoming reflects a deficiency in the way the technique has been used and does not represent an inherent limitation of the experimental approach.

Field Studies

Techniques to collect network data from the field itself have existed since the first half of this century. Two traditions have developed within field studies. The first relies on self-report of communication activities through sociometric surveys or diary studies. The second relies on data collected either by an observer in the field or by unobtrusive methods.

Self-report using sociometric techniques. Moreno (1934) was among the first to develop a self-report technique for the study of communication networks. He proposed a sociometric-based survey questionnaire to collect network data. Barnes (I 954) and Bott (1955, 1957) used sociometric network data for the first time to explain individual behavior, The technique was also used by anthropologists from “the Manchester School’: (Rogers & Kincaid, 1981, p. 95) in their study of small networks (e.g., Mitchell, 1969; Boissevain & Mitchell, 1973; Boissevain, 1974).

The self-report technique is most closely related to conventional social science survey techniques. The members of a system are asked to report on their interaction with each of the other members of the system. In some cases, they are provided with a roster, listing all the members, while in other cases they are asked to recall the names of all the people with whom they have interacted. The former technique is referred to as "recognition" or "aided-recall," while the latter is referred to simply as the "recall" technique.

Following the lead of Barnes (1954) and Mitchell (1969), researchers have proposed the use of network instruments in conjunction with instruments that describe social attributes of the individual. The incorporation of network items in traditional social science surveys is described by Burt (1984). These items provide information on the demographics of the respondent's significant contacts and the level of communication between the respondent's significant links.

The use of network items in conjunction with the standard social science survey enables the use of social variables to predict network attributes of the individual. For instance, respondent background variables such as socioeconomic status, have been used to determine network range—the degree to which an individual's contacts are socially diverse (e.g., Laumann, 1978; Fischer, 1982). It is also possible to study the extent to which network variables, such as range, can be used to predict sociometric variables such as stress, leadership skills, reliance on stereotyping (Burt, 1984). Finally, it is possible to include network variables as an interaction term, For instance, in a study conducted by Ruan, and reported by Burt (1984), "interpersonal environments of especially close sexually homogeneous people created significant sex bias in the respondent's opinion" (Burt, 1984, p. 309). The General Social Survey, one of the nation's largest sociological data bases, included network items in its questionnaires for the first time in 1985.

Self-report using the diary technique. A second form of self-report technique is referred to as the diary (or duty) study. Among the early researchers who used this technique were Burns (1954), Hinrichs (1964) and Farace and Morris (1969). In this technique each individual is requested to keep a diary for a specified period of time. During this period of time they are expected to report their interactions with each other person immediately. Variations of this technique allow for the diary entry to be made at specified time intervals, which may be fixed or random.

The two approaches described above have one feature in common.

They both rely on the individual to provide the information. Hence, they are likely to be influenced by the individuals' perceptions of their interactions. Before deciding whether this is an asset or a liability, it is important to identify specific ways in which this influence can occur.

First, the nature of data obtained may be determined by the salience of the communication being studied. Salience is the degree to which the topic of communication is central or relevant to the individual. For instance, asking people to report their conversations on sporting issues may not elicit perfect recall if sports is not a salient issue for those people (Richards, 1985).

Sudman and Bradburn (1974) proposed two outcomes related to the salience of the communication. The first, telescoping, refers to misremembering the date on which an event occurred and including it in the time period being discussed. Sudman (1985) points out that this problem is especially germane to events of low salience in short time periods. The problem of telescoping can be significantly reduced by the use of abstract-time network analysis rather than concrete-time network analysis. By doing so, the exact date on which a communication occurred is less pertinent than the "typical" frequency of that communication. If the respondents were questioned about acquaintance patterns over a long period of time, telescopinig is not likely to result in a severe problem. However, in such cases, the second outcome, namely omission, is likely to be an issue. Omission occurs, in such cases, because "the less recent the last meeting, the more likely respondents are to forget" (Sudman, 1985, p. 131).

Second, the *sensitivity* of the content may also be a determining factor. Sensitivity of the content is reflected in the degree of reticence expressed by an individual in disclosing information about that issue. This problem is especially serious when the study is related to taboo issues, such as abortion or contraception. Even in an organizational setting, people tend to underreport communication on personnel issues as compared to production issues (Burns, 1954). Bradburn, Sudman, and Associates (1979) showed that larger errors were associated with responses to questions that were considered threatening. Higgins, McClean, & Conrath (1985) also found that personal phone calls, even when not prohibited, were often not reported. The problem was further accentuated when the personal call was to someone outside the organization. The collection of data on sensitive issues is greatly facilitated by assurances of confidentiality or anonymity. For data collected by interview, a good rapport between the interviewer and the respondent is crucial (Rogers & Kincaid, 198 1).

Third, the *specificity* of the communication also influences the data that respondents provide. Asking about too specific a content topic might yield a network that has too few links to be of any use. Rogers and Kincaid (1981) cite a study by Braun (1975) in which most of those sampled in the five Colombian villages in his study simply did not discuss the two specific issues dealt with in the network instrument. On the other hand, too large or ambiguous a topic might yield a network that could be saturated and inaccurate (McCallister & Fischer, 1978).

Fourth, the *directionality* of communication may also affect what is reported. As mentioned earlier, a directional communication link refers only to communication initiated by the respondent. Since a higher status is often associated with the receiver than with the initiator of a communication (Blau & Scott, 1962), initiated communication may be under reported. Higgins et al. (1985) provide empirical evidence supporting this hypothesis.

Fifth, the *total volume* of communication is also likely to influence the respondents' perceptions of their communication patterns. Webber (1970) showed that individuals who received a large volume of communication often underestimated their communication with specific individuals. On the contrary, those with a small net volume of communication overestimated their communication activity.

Sixth, individual *characteristics* of respondents also affect their perceptions of their communication interaction. Individual characteristics were first suggested as a mediating variable by Webber (1970). More recently, Sudman (1985) found evidence that respondent characteristics affected recall of network size. In particular, errors were greater among older respondents, among those with higher education, and among those who had been with the organization for a longer period of time. No evidence was found for differences based on gender, marital status, or supervisory status, though Webber's (1970) study contradicted the latter findings.

Finally, the respondents' perceptions are mediated by the *size* and *structure* of the instrument itself. Interviewee fatigue, a concern of most social science research, may become a very serious problem in network instruments. In a typical sociometric-type survey, respondents are confronted with the task of naming and/or providing information on their relationships with each other. Therefore, their task is directly related to the size of the network. The task is enlarged if information is requested on the mode of communication used, the initiation pattern, and the volume of communication'in each of many content categories. Conrath, Higgins, & McClean (1983) suggest that a self-recording diary should require no more than five to 10 minutes per day to complete. In their study each subject logged their communication for a period of one week. The diary was open-ended and "the data gathered included: the identification of the othet party to the communication, who initiated it, the estimated elapsed time in minutes and the mode used" (Conrath et al., 1983, p. 178). Erickson, Nosanchuk, & Lee (198 1) recommend that a survey listing could be as high as 150, but not higher than 200. Knoke and Kuklinski (1982) note that a list of 130 names should take about 15 minutes to complete.

There have been many attempts at simplifying the task of the respondent. The appropriate simplification depends on the nature of the questions being posed. One solution, suggested by Laumann (1973), was that each individual be asked only about their three most important contacts. Such an approach was criticized for not being able to identify "the strength of weak ties" (Liu & Duff, 1972; Granovetter, 1973; Rogers, 1973). The "strength of weak ties" refers to the informational strength associated with weak sociometric ties. A weak tie between two individuals, A and B, signifies that with the exception of their link, there exists little overlap between members of their respective personal networks (Rogers & Kincaid, 1981). Collecting data on only three important contacts would ignore sociometrically weak ties, that are informationally rich. Exclusion of these ties would significantly hinder efforts at describing the true communication structure of the network. Empirical evidence of this problem was provided by Killworth and Bernard (1974). They recommended that individuals should be asked to report on at least seven, rather than three contacts. Further refinements described by McCallister and Fischer (1978) and Fischer (1982) allow collection of detailed information on up to 30 individuals within 20 minutes.

A second solution does not place any limit, such as three or seven, on the number of contacts to be reported by an individual. Instead it facilitates the gathering of information on a large number of an individual's contacts. Generally it does so by providing closed coding schemes. A self-recording diary used by Conrath et al. (1983), for instance, required no more than four to eight check marks, besides identifying the communication contact. They collected information on the initiator, the mode used, the elapsed time, and the process involved, Erickson et al. (1981) make several recommendations on improving the response to a sociometric network instrument. These include the making of a brief statement of purpose, including the respondent's name on the list, and pretesting the questionnaire to detect any ambiguities.

Participant observation; *full* time/intermittent. The field studies discussed so far have all relied on individuals to report their own communication. However, there are a number of techniques that rely on external observers to provide the data. Observational techniques were first used in the famous Hawthorne studies of the 1920s and 1930s (Roethlisberger & Dickson, 1946; Davis, 1953). In these studies, trained participant observers recorded the communication behavior of the subjects.

Participant observation is a technique that grew from the anthropological tradition and often uses ethnographic techniques. One study using this technique in communication network analysis is Marshall's (1971) observation of the communication in the diffusion of two innovations in an Indian village. Bernard and Killworth (1973, 1977, 1978), Killworth and Bernard (1974) and Bernard, Killworth, and Sailer (1980) have also reported the use of participant observation in describing the communication that occurred on two ships, two offices, a women's prison, students in a fraternity, and faculty, graduate students and secretaries in a graduate program. In all these cases, a "trained" person observed verbal interactions for a specified period of time.

There are several potential problems with research that uses a participant observer. First, it is physically impossible for a single observer to be everywhere all the time. As a result, a single participant observer cannot comprehensively document all interactions in the system. Two solutions have been suggested to overcome this problem. In some studies the system is observed intermittently. For instance, in one of the studies by Bernard et al. (1980), the observer walked through the office at 15-minute intervals. However, this interval may be too large and could therefore provide an inadequate description of communication activities within the time period (Rogers & Kincaid, 1981). A second solution would be to use more than one observer, so as to observe communication at two or more places at the same time, at more frequent time intervals, or both. However, in these cases, the different observers must be trained to encode communication in a standardized way (Richards, 1985).

Second, observational studies may require the collection of data over a large period of time. This may present some very exacting demands on the researcher. For instance, Marshall's (197 1) study of communication patterns in an Indian village, required the observer to stay in the village for a year.

Third, Richards (1985) argues that an observer is not likely to record all that is observed. This is because "only a small subset of the total range of behavior is significant" (Richards, 1985, p. 1 16). As a result, the recorded behavior may not mirror the actual behavior with sufficient accuracy. This criticism is closely related to the larger argument presented by Richards that observers will, as a rule, not

be cued in to the context surrounding the interactions they observe. Richards argues:

> What is of interest with the outside observer approach to measurement is the actual behavioral sequences in which the Participants engage. It is not necessary for there to be anything behind that behavior. Because internal events such as feelings, Perceptions and the like are not considered in the processes of collecting and analyzing, or interpreting the data, this might be called the "external event" view. (p. 116)

One way of minimizing this problem would require the observer to gather information on the content being discussed, the duration of the interactions and possibly the directionality and symmetry of the communication. However, any attempts at gleaning information of this nature 'may result in the observer being perceived as overly obtrusive.

Fourth, these studies require the presence of an outsider, the observer. Two strategies have been used to minimize this problem. In one strategy, the observers are included in the network and are therefore participant observers. For instance, Bernard and Killworth (1978) included themselves in the communication network on board the ship they were studying. The second strategy is to keep the observer as unobtrusive as possible. One way of accomplishing this goal is to allow the observer to make only infrequent "walks" through the system being studied. This would certainly help to keep the observer less obtrusive, but, as mentioned earlier, there are problems associated with observations that are too infrequent. Further, neither of these strategies is particularly effective in preventing the differential effects of an obtrusive observer on different forms of communication. For instance, it is less likely for two or more individuals to discuss a sensitive organizational rumor in the presence of an observer than it is to discuss routine task-related issues.

Observational data using unobtrusive methods. There are a growing number of studies that collect observational data with strategies that resolve some of the problems described above. Typcially, this is achieved by studying some "trace" left by communication interactions. In the case of computer-mediated communication (Rice, 1982), it is possible for researchers to monitor a large amount of information about the communication. The information could include complete transcripts, the dates and times of the communication, the duration, as well as information about who initiated the communication. Killworth and Bernard (1976) monitored the communication of a group of deaf persons via teletype. Bernard et al. (1980) unobtrusively monitored communication of 44 HAM radio operators over a 27day time period by recording the conversations they held over the public air waves. Higgins et al. (1985) monitored telephonic communication in an organization using a Traffic Data Analyzer (TDA) attached to the office's local PBX (private branch exchange), Other studies have relied on appointment calendars and inter- and intra-organizational mail envelopes.

Burt (1983) has proposed an unobtrusive technique for gathering network data from archived documents such as court records and newspapers. In an example of the technique, Burt used information in newspaper reports of events. The actors were categorized based on specified typologies. Therefore, Burt studied types rather than individuals. The prominence of the association between categories of actors (a linkage strength) was determined by the proportion of the news reports that discussed a relationship between actors in different categories. It is important to note that the network data derived from these records were based on the assumption that "actors embroiled in the same events are more likely to have relations with one another than actors involved in different events" (Burt, 1983, p. 163).

There are three main advantages associated with these techniques. First, they are not likely to influence the communication patterns being observed. Second, they often provide detailed descriptions of the interactions, and these could be used to provide context to the communication. Third, unobtrusive monitors can often be used to obtain data from very large systems and over long periods of time at a minimal cost. As a result, it is possible to study archival records about communication among individuals who may be inaccessible, even dead. Further, there is a great deal of flexibility on the time periods and time intervals used in archival studies (Burt, 1983).

However, the unobtrusive techniques discussed above are not without shortcomings. In addition to Richard's (1985) criticism described above, there are four further problems that must be considered. The first shortcoming stems from the fact that unobtrusive techniques lend themselves only to certain types of communication network studies. The examples provided above illustrate this selection bias. Most of these examples relied on technology to provide information on technologically mediated communication such as electronic mail. Clearly, these techniques are of great use in understanding the communication structure associated with various technologies. However, there remains the difficulty involved in teasing out those findings that are common to all forms of communication from findings that are unique to the use of specific communication technologies.

Second, unobtrusive studies of technologically-mediated communication would be greatly enhanced if they were combined with data on other forms of nonmediated communication such as face-to-face dicussion. Obviously, many communication network studies may need to incorporate communication via the various existing media. Unfortunately at present, disparity in the quality of data received from the different sources hinders its utility,

Third, even research that is confined to a single communication technology often discovers that the technology is not as "cooperative" as desired. Rice and Borgman (1983) describe three' problems associated with collection of computer-monitored data. Monitoring a large system and converting the raw data into an analyzable form often involves high cost and time investments; further, they often require a high level of computer expertise on the part of the researcher.

Fourth, there remain a large number of unresolved ethical issues related to the use of technologically monitored data. Researchers so far have studied communication that occurs in the public domain. Monitoring HAM radio operators was one such example. However, data from public domain communication may have limited generalizability. This problem has diminished as organizations seeking to improve the effectiveness of their communication-technology systems allow researchers access to data within their offices (Rice & Borgman, 1983). One of the compromises struck by many of these researchers is to restrict information monitored to exclude the content of the communication. However, this strategy is at best only a compromise. There remains a modest but significant invasion of privacy, coupled with data that is now even more bereft of context.

Sampling Procedures Used in Field Studies

In our discussion of experimental techniques for data collection it was pointed out that generalizing the findings of an experiment to a large social system was a serious problem. In this section we examine ways to generalize the findings of a field study. Ideally, a researcher would like to collect data from all members within the boundaries specified. Studies which collect data from all members of the system utilize what is referred to as saturated sampling or a census. For example, many organizational studies define a single organization as the population and collect information from all members in the organization as the sample. (A more valid interpretation of this procedure is that the population of interest is the network in all organizations and that the particular organization being studied is a sample of one. Obviously, it is not easy to generalize to such a large population on the basis of a single sample.) However, in large social systems, such as a village, collecting information from all members may become extremely unwieldy. In such cases, sampling techniques are often used to collect information from a few of its members and then extrapolate to all members in the system.

Sampling techniques have been routinely used in survey-based social science teseatch. The notion of sampling in network research was first proposed by Moreno and Jennings (1938). However, the development of procedures remained primitive. The development of sampling techniques can be traced to two different analytical approaches used to study network models. The first analytical approach, referred to as the "relational" approach, describes the intensity of relationship between pairs of actors. The second analytical approach, referred to as the "positional" approach, focuses on the pattern of relationships between positions or role-sets. These positions may be occupied by one or more individuals who share a set of social attributes (Burt. 1980).

Sampling techniques in network research based on the relational approach have been used to estimate the density of a large system from a sample. The density of a system is defined as the ratio between the *actual* number of links that people report using to the total number of possible links that can exist between all members in the system. They have also been used to identify and study the flow of messages in a system. Network research based on the positional approach, on the other hand, has developed techniques to estimate the relationship between different social positions based on network items and general sociometric variables.

Sampling Techniques Based on the Relational Approach

Estimation of system characteristics. It is often unwieldy to collect network information from all members in the network. In many of these cases, the aim of the research is to obtain an estimate of the level of connectedness of the entire network, that is the density of the network. An appropriate sampling procedure to provide density estimates was developed by Proctor (1967) and Frank (197 1). They described "the sample selection scheme, giving an estimator, finding its bias and variance, and finally giving an estimator of variance" (Proctor, 1979, p. 313). Granovetter (1976) also provided a formula for the confidence interval of density estimates. However, the formula assumes the presence of multiple equivalent random samples. Erickson and Nosanchuk (1983) support the use of multiple network samples for two reasons. First, multiple samples (six, in their study) allow

researchers to assess the amount of bias introduced by pragmatic problems associated with the administration of a network instrument, such as missing names. Second, multiple samples provide some description of the sampling distribution.

This procedure is appropriate only if the objects of explanation are characteristics of the system as a whole. The procedure fails to provide estimates at the individual level, such as individual network involvement (Morgan & Rytina, 197'7).

"Snowball Sampling". Another frequently used network sampling technique is called "snowball sampling" (Goodman, 1961). This technique requires the initial identification of a random sample of members in the system. The researcher then asks these respondents to report their communication contacts. Those individuals named as communication contacts in this phase are now included in the sample. They are referred to as first-stage respondents. The researcher next obtains information about the communication contacts of these first-stage respondents, generating in the process a group of second-stage respondents. The researcher might then repeat the process several times until only some small number of new respondents is added to the sample. The typical exponential increase in the sample as the process continues resulted in the technique being named "snowball sampling."

The snowball sampling technique has been used to study the process whereby communication of specific issues occurs within a social system. Snowball sampling can also be used to provide information about the way in which individuals influence and at-e influenced by others.

Like other sampling techniques, snowball sampling cannot capture the complete network structure. However, its success can be judged by its ability to adequately, and parsimoniously, provide a description of the entire network structure. In survey-based sampling procedures this judgment is often made on the basis of specific criteria such as the standard error of the estimates. In the case of snowball sampling, Frank (1979) has discussed the merits of alternative variance estimators, for example, the Horvitz-Thompson variance estimator and the Sen-Yates-Grundy variance estimator using a constant-probability Bernoulli sampling design. (A constant-probability Bernoulli sampling design is normally a good approximation of simple random sampling.) Despite considerable research (e.g., Holland & Leinhardt, 1975; Wasserman, 1977; and Capobianco, 1972, 1974) estimation problems continue to remain formidable. For instance, in the absence of rigorous algorithms, there is little certainty about the number of stages that must be conducted in a snowball sampling procedure in order to obtain an adequate description of the population. The distortion that may result from insufficient sampling continues to remain a serious concern. A hypothetical example of how insufficient snowball sampling could incorrectly identify opinion leaders is provided by Knoke and Kuklinski (1982).

Sampling Procedures Based on the Positional Approach

As was mentioned earlier, the aim of sampling in this approach is to help understand the relationship between positions or role-sets in the system. This procedure was first proposed by Beniger (1976) and further developed by Burt (1981). In this procedure the researcher collects data from a random sample. Each respondent is required to furnish information on the attributes of the people they contact for specific issues. The respondents also provide information on their own attributes. It is clearly not the aim of this sampling procedure to provide estimates of individual linkages among people. In fact, the actual names of the individuals need not be collected. Instead, this sampling procedure helps provide infromation about the likelihood of there being a relationship between two "positions." The "positions*' may be defined by the presence of one or more attributes. For instance, Laumann (1979) discusses the likelihood of a marital relationship between members of the Protestant working class (PWC) and the Protestant middle class (PMC) and compares it to the likelihood of a marital liaison between a PWC and a Catholic working class (CWC). In communication research, this procedure could be used, for instance, to describe the likelihood of communication between doctors in surgery and pediatrics, and compare it with the likelihood of communication between doctors and nurses in surgery.

Clearly, the efficacy of this sampling procedure is determined largely by the selection of the attributes that are used to define the positions. The inclusion of irrelevant attributes might result in unwanted differentiation, while the exclusion of a crucial attribute might cause undesired aggregation of people in the same position.

Reliability and Validity of the Data Collected

In the past decade there has been a great deal of debate surrounding the reliability and validity of data obtained from different techniques. The debate was triggered to a large degree by a series of studies by Bernard, Killworth, and their colleagues in the late 1970s (Bernard & Killworth, 1977, 1978; Bernard, Killworth, & Sailer, 1980, 198 1, 1982, 1984). They pointed out significant differences between the communication reported by the individuals (perceived communication) and the communication reported by othet recording techniques. Based on these findings, they questioned the validity of self-reporting techniques for describing network characteristics and communication behavior. There have been two lines of criticism of the Bernard, Killworth, and Sailer (hereafter designated BKS) studies.

The first group of critics accept the fact that there may be significant differences between actual communication and reported communication. However, they argue that this difference should be expected and does not undermine the utility of perceived data; They attribute the differences to the fact that perceived communication, unlike actual communication, is mediated by the individuals' beliefs, perceptions, and interpretations. They suggest that collection of data on perceived communication permits the inclusion of context, which they argue, is of paramount importance (Richards, 1985).

Second, there are those who argue that the differences proposed by BKS were in fact not as significant as suggested. They point to differences as being artifacts of the methodology used. For instance, Romney and Faust (1982) report a significant structural similarity between the communication patterns that were reported and those recorded by observers in one of the BKS studies. Romney and Faust defend their findings by suggesting that BKS "were looking for error" while they were "looking for regularities*' (Romney & Faust, 1982 p. 300). As a result, the null model for Romney and Faust was one of "pure chance association" between the two forms of data, while the null model used by BKS was one of "perfect association.*' Burt (1983) has shown that the "evidence presented by Bernard and his colleagues does not warrant their conclusion . . . Of course, rejecting their methodology is not the same as accepting the hypothesis that cognitive and behavioral relations are one and the same," (pp. 299-301).

A partial resolution of this debate may be obtained by a closer examination of the metatheoretical orientations of network scholars. Richards (1985) has proposed that the controversy stems from two opposing epistemological paradigms. The dichotomy follows from "the time-honored controversy in the social sciences between nominalist and realist views of the ontological status of social phenomena" (Laumann et al., 1983, p. 20). The realist view has alternatively been referred to as "objectivist," "positivist," or "functionalist," while the nominalist view is sometimes labeled "subjectivist," "interpretivist," or "cognitive constructivist" (Richards, 1985; Putnam, 1983).

Notwithstanding the plausibility of this dichotomy, most theories in social science draw upon assumptions that are not unequivocally nominalist or realist. A theory may, for instance, propose that a phenomena is best explained in terms of a set of antecedent variables, some of which may be considered "subjective" while others would be regarded as "objective." Further, there is often considerable debate as to the degree of "objectivity" or "subjectivity" of the variables considered.

Therefore the two approaches described above represent two "ideal" and opposing viewpoints that are rarely obtained in network research. They are useful insofar as they represent the logical extremities of a continuum. Most theories and research, we argue, lie not at one or the other end of these extremities, but somewhere on the continuum between them. It seems logical, then, to propose that any evaluation of the quality of data would depend jointly on the technique used and the metatheoretical position of the researcher on the objective-subjective continuum.

The arguments presented above apply broadly to the study of human communication networks. Within the domain of measurement in particular, the *above* debate can be couched in somewhat different terms. In the next few paragraphs we introduce and define a few concepts used in measurement theory. These concepts will then be applied to examples from network research.

As was mentioned earlier, measurement of human communication networks entails the assigning of numbers to observed phenomena, based on certain rules. The numbers assigned to these phenomena are referred to as observed responses. All of the data collection techniques described in the previous section, therefore, provide the researcher with observed responses.

According to measurement theory observed responses are generated by an underlying theoretical variable. The observed responses represent an attempt at measuring the "true score" on a theoretical variable, X. The difference between the true score and the observed response is defined as measurement error. Hence,

Measurement error = True Score on X − Observed Score on X

or,

Observed score on X = True Score on X + Measurement error.

Let us examine for a moment the nature of the "true score." In the social sciences there are a large number of behavioral responses for which there exist, at least in theory, a verifiable true score. For instance, the amount of time an individual spends communicating on the telephone is a behavioral response which is verifiable. Sutcliffe (1965) calls a verifiable true score a Platonic score.

However, there are a large number of variables for which it would be meaningless to conceive of a real "true score" that is verifiable. Most cognitive or affective responses fall in this category. Sudman and Bradburn (1974) refer to these as psychological states. Bohrnstedt (1983) points out that, in these cases, a Platonic true score makes little sense because "true psychological states can only be inferred indirectly" (p. 71). True scores belonging to this category are often referred to as non-Platonic scores or classical true scores.

We now see how these concepts are used in an example from communication network research. Suppose two studies, A and B, asked each individual in a group to report the number of times they initiated a telephonic communication with each of the other members in the group. Clearly, the observed responses in the two studies would be identical. To estimate the measurement error associated with the studies, the nature of the true score must be sought. The first study conceived the true score to be a Platonic. true score, that is, actual behavioral data on the number of times the individual initiated communication. These obtained values can be verified, at least in principle, by the *use* of a system like the traffic data analyzer which records all calls at the PBX (Private Branch exchange, see, e.g., Higgins et al., 1985). The second study, however, may estimate the true score to be somewhat different. Despite the fact that the question elicited information on discrete behavioral acts, this study assumes that the information provided by the respondents would actually be based on their perception of the ongoing relationship with each other individual. This perception is no longer a Platonic true score since it cannot be verified, at least in theory. It is important to recognize, therefore, that the two studies using the same observed responses may be attempting to measure two different true scores based on the study's theoretical assumptions. Therefore, the measurement errors incurred by the two studies will not be identical.

From a measurement perspective, therefore, any debate on the accuracy of data using different techniques must begin by identifying the true scores being sought by the researcher. Having identified the nature of the true score, measurement theory provides two ways, reliability and validity, in which one can assess the quality of the data.

Reliability

Reliability, in general terms, refers to the degree to which an instrument consistently measures the same variable in the same way at one or more points in time. Operationally, it is defined as the ratio of the variance in the true score to the variance in the observed response (Bohrnstedt, 1983).

Reliability measures can be of two types. The first, a measure of stability, requires the administration of the instrument at more than two points in time. First, we examine a measure of stability, under the assumption that the true score remains constant over time. Under this assumption, the correlation of the items at two (or more) points in time provide a measure of stability. However, in many cases, the assumption that the true score remains constant over time may not be true. In these cases, there have been many attempts to isolate real change from the lack of reliability. All these approaches require the collection of data at a minimum of three points in time. (For a detailed description of these methods and their assumptions, see Bohrnstedt, 1983.)

There have been very few instances in communication network research where the stability of an instrument has been assessed. However, the growing interest in longitudinal network studies would provide an opportunity to measure the stability of an instrument while simultaneously hypothesizing change in the true score components of the scores.

The second approach used to assess reliability is with a measure of equivalence. This method requires the administration of two or more items (or scales) at one point in time that are assumed to be measuring the same true score. An estimate of reliability, in such cases, is computed in terms of the number of items used and the covariance between the items. (For a detailed description of specific algorithms and the accompanying assumptions, see Cronbach et al., 1972).

Traditionally, in network research all variables are single-item scales. However, based upon arguments provided by Weinshall (1 966) and Hesseling (1970), Conrath et al. (1983) present a measure of reliability of the linkage between pairs of individuals. The estimate is computed from reports of communication provided by both members of the pair. However, based on out earlier discussion, we suggest that this measure of reliability will only hold for those cases where the values repotted by the two individuals are assumed to measure the same underlying score. Conceivably there could be a research question that examines the differences in perceptions by two individuals of the same communication and therefore cannot make the above mentioned assumption. In such cases, the technique proposed by Conrath et al. (1983) should not be used.

In addition to Contath et al's estimate of reliability there are four other alternative strategies that can be used. Fitst, if two or more data collection techniques ate used to yield measures of the same underlying score, a measure of equivalence can be obtained. For instance, combining a sociomettic-based survey with an unobtrusive traffic data analyzer can provide two measures of a single underlying variable, say, telephonic communication. Clearly, in this study the sociomettic surveys would elicit information specifically on telephonic communication; Further, the study would assume that the survey responses would provide a measure of actual (rather than perceived) telephonic communication. Second, if the respondent is asked to report on a series of sociomettic questions measuring the same underlying communication variable, a measure of equivalence can be computed. This second approach may run into respondent resistance if people are requited to fill in responses to many items for each of a large number of contacts. Third, in the case of data gathered by observation, measures of equivalence can be estimated by comparing the data obtained by two or more different observers ot coders of the same event (Butt, 1983). Finally, for studies using archival data, the reliability of the linkages can be estimated by using data collected from two separate archival sources that describe the same variable, for example, two newspapers.

In the past, most network researchers have not attempted to assess the reliability of their measures. Mote recently, network analysts have raised several concerns about the reliability of these measures and have called for a "systematic research attempt to determine the quality of network measurement" (Rogers & Kincaid, 1981, p. 120). Computing a measure of reliability is one way of determining the quality of network measurement.

Validity

Validity is conceptually defined as the degree to which an instrument measures the theoretical construct it has been designed to measure. Operationally, the correlation between the observed response and the true score is defined as the theoretical validity. Empirical validity, on the other hand, is defined as the degree to which an instrument measures an underlying theoretical variable as well as another instrument measuring the same underlying variable. Therefore, operationally, empirical validity is the correlation between two observed responses measuring the same true score (Bohtnstedt, 1983).

The relationship between the validity and reliability of a measure is an important one. For a measure to be theoretically valid, it must also be reliable. In fact, as Bohtnstedt (1983) has shown, the theoretical validity of a measure is exactly equal to the square root of its reliability. On the other hand, a measure that is reliable is not necessarily empirically valid.

We began this section with a brief discussion of the debate, triggered by the BKS studies on the reliability and validity of data obtained by different techniques. We also said that the criticism that has been made against the BKS studies falls into two categories. First, there were those who felt that there was no reason why they should have expected similar results because the different techniques were measuring different underlying variables. Second, there were those who agreed that the reason they did not obtain similar results was because of methodological problems. For instance, their tests of similarity for the data obtained from different techniques were considered too conservative (Romney & Faust, 1982).

The first criticism has already been discussed extensively in this section. To summarize, therefore, the validity of data comparing two or more different techniques can only be conducted if one assumes that the same underlying theoretical variable is being measured by the different techniques.

The second criticism, however, makes the assumption that a single underlying theoretical variable can in fact be measured by different techniques. The use of multiple measures to study a system of variables is referred to as triangulation. Only a handful of network studies have adopted triangulation procedures (e.g., Lievrouw, Rogers, Lowe, & Nadel, 1986). Campbell and Fiske (1959) proposed the use of a multitrait-multimethod matrix to study the degree to which different data collection techniques yield similar results for the same theoretical variable, that is, convergent validity (Campbell, 1954), and the degree to which the same data collection techniques yield different results for different theoretical variables, that is, discriminant validity, Confirmatory factor analytic methods (Fink & Monge, 1985; Jöreskog, 197 1; Werts, Jöreskog, & Linn, 1972) provide statistical criteria for establishing convergent and discrimant validity (Alwin, 1974; Bohrnstedt, 1983; Schmitt, Coyle, & Saari, 1977). Using this method, it is possible to simultaneously study the difference between the variables being measured and the effect of the measurement techniques being used. In the short term this approach would help resolve the debate generated by the work of BKS. In the long term, its continued use would contribute to the development of network measurement.

Conclusion

The measurement process, as presented in this chapter, necessitates that the researcher make a large number of informed decisions. Each of these decisions, it was shown, is directly related to the nature of the research question being posed and the assumptions of the researcher. The consequences and limitations accompanying each of these decisions are, as yet, only partially understood, and it continues to remain the focus of a great deal of research and debate. In this chapter we have attempted to capture the essence of the findings as well as the spirit of the debate, in order to provide a basis for future progress in the measurement of communication networks.

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