

THE CONCEPT OF PROCESS IN
HUMAN COMMUNICATION RESEARCH

Thesis for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY
ROBERT BURTON ARUNDALE
1971



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This is to certify that the
thesis entitled

The Concept of Process in
Human Communication Research

presented by

Robert Burton Arundale

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Communication

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Date February 25, 1971

ABSTRACT

THE CONCEPT OF PROCESS IN HUMAN COMMUNICATION RESEARCH

By

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The concept of process is frequently applied in discussing communication, apparently because it identifies the important dynamic aspect of this form of behavior. However, the concept is only occasionally operationalized in research on human communication. To remove the discrepancy between discussion and research, it appears useful to examine the concept of process and its explication in detail.

At a basic level, the paper is concerned with time as a fundamental dimension of events, with the study of such events using the scientific method, and with the class of events termed "communication." These concerns are unified in the study of the concept of process as it relates to the discipline of communication. The major emphasis in the paper is to seek, as a step in theory building in communication, the means of explicating the concept of process.

A definition of communication as "a process of transmission of structure among the parts of a system . . ." appears both general and useful in this context. The concept of process is central in this definition, and if distinguished from related concepts can be defined as "all change over time of matter energy or information." The concept is important in its relationship to research designs and in its utility with regard to certain problems and concerns in human communication

research. Nevertheless, an examination of research reveals that the concept of process has not been widely operationalized. An explication of the concept appears needed to correct this discrepancy and to make the concept more available as a tool in research and theory building.

The first step in explicating the concept is to provide a constitutive definition. The paper does not consider a specific theory, so that it is necessary to provide not a unique definition but rather a set of approaches to constitutive definition. Such approaches may involve either verbal terms or mathematical terms, and the necessary and sufficient conditions for using the term "process" are stated in both forms. The approaches to constitutive definition also carry a number of implications for the form of theory which deals with communication events as processes.

The second step in explicating the concept of process is to provide an operational definition. Because no specific research problem is considered, it is necessary to develop a set of approaches to operational definition, rather than a single definition. Examination of these approaches results in a set of necessary and sufficient conditions for describing (or measuring) a process. These conditions have several direct implications for research techniques and certain indirect implications for analysis techniques.

The result of seeking the means of explicating the concept of process, i.e., of seeking approaches to constitutive and operational definitions, is a set of tools for dealing with the concept in specific theoretic and research frameworks. Such research is exemplified by

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work in language development, interaction analysis, and attitude change. In general, though, the principles discussed appear to apply fairly broadly in human communication research.

The general implication of the paper is that if theory building and research on human communication are to deal with events as processes, it will be necessary to use and to develop not only appropriate forms of theory, but also research and analysis techniques capable of dealing with the dimension of time. The use and development of such techniques will present many problems to the communication scholar, but will also provide an important class of information on change over time that is not now available. The concept of process is therefore important in human communication research, even though it is but one of several concepts which require careful study and explication.

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By

Robert Burton Arundale

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Communication

1971

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1971

Accepted by the faculty of the Department of Communication,
College of Communication Arts, Michigan State University, in partial
fulfillment of the requirements for the Doctor of Philosophy degree.

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ACKNOWLEDGMENTS

In Book II of The Prelude, William Wordsworth invokes the image of the teacher in considering the sources of what he had been taught:

Who knows the individual hour in which
His habits were first sown, even as a seed?
Who that shall point as with a wand and say
'This portion of the river of my mind
Came from yon fountain?' (ll. 204-208)

In acknowledgment of their help, in many different ways, in making this dissertation possible, I must mention several individuals. In particular, Jay Weston was a source of information as the seeds of the ideas herein began to form. David Berlo added critiques and encouragement as the ideas took initial shape. James Noonan's views on language as behavior in time revealed some of the value of the growing ideas. However, it remained for Clyde Henson to make me seriously question the status quo of communication research. He did so by showing me poetry, live and dynamic. His encouragements, together with those of Miles Martin, were most helpful. James Campbell, as well, provided encouragement and many important comments. The encouragements and help of all of these individuals has been invaluable, though in the final analysis, the encouragement and help of one stands paramount--thank you, Wendy, for making possible this small accomplishment.

Beyond all these I must acknowledge the work of my committee: Randall Harrison, Erwin Bettinghaus, and Hideya Kumata, as well as of many other friends both known and unknown who have spurred ideas, mentioned sources, been patient, and helped in other ways. Again, as Wordsworth suggests, it is difficult to point to all the sources of one's thoughts and work. Nevertheless, he points to Coleridge, as one of his teachers, and says of him what should be said of all scientists:

Science appears but what is truth she is,
Not as our glory and our absolute boast,
But as a succedaneum, and a prop
To our infirmity. No officious slave
Art thou of that false secondary power
By which we multiply distinctions, then
Deem that our puny boundaries are things
That we perceive, and not that we have made.

The Prelude, Book II, ll. 212-219

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INTRODUCTION

Most scholars engaged in the study of human communication will agree with Berlo (1960) in choosing the phrase, "the process of communication," to describe the focal point of their discipline. They will, of course, explicate the concept of communication in many different ways, devoting a great deal of time and attention to constructing viable constitutive and operational definitions. In this effort, they will frequently make use of the associated concept of process, but will, for the most part, avoid the task of constitutively and operationally defining it. This paper will attempt to offset this lack of attention, both in seeking the means of explicating the concept of process, and in considering its implications for theory and research.

Why study "process"? Why choose this concept for attention from among others? In very broad outline, because it appears to be a basic concept in the study of human communication, but one which is seldom examined either constitutively for use in theory or operationally for use in research. In narrower outline, there exists a large body of review and discussion (see Barnlund, 1968, pp. 3-29; Berlo, 1960, pp. 23-28; Bettinghaus, 1960, pp. 16-28; Harrison, 1969a; among others) which appears to agree both that communication behavior takes place across time, and that the temporal aspect of such behavior can be meaningfully expressed by identifying "communication" as a form of "process."

Theoretical formulations and research techniques in communication often

fail, however, to incorporate the concept in any particularly useful manner. The result is that a potentially large and important class of information cannot become available--information on how communication behaviors develop, evolve, and interact during the course of an event, or in short, on how they change over time. Because an explication of process appears to be a useful step in making this class of information more available, this paper will attempt to study "process," in particular, and to suggest a set of approaches and tools for incorporating the concept in theory building and research.

Several comments need to be made regarding this central concern with the concept of process. One comment is that the term "process," as it is frequently applied, has a very broad and complex usage (e.g., Berlo, 1960, pp. 23-28). This paper will narrow the broad usage of "process" by introducing a set of closely related concepts that are helpful in isolating the several different aspects of events often encompassed by the term. Such narrowing is not an "oversimplification" in any pejorative sense. It is, rather, an essential and useful step in examining the concept of process, both because it provides needed tools, and because it reveals that the broader usage of the concept of process may "hide" a number of complex and problematic aspects of events.

The narrowing of "process," and particularly the introduction of related concepts, leads to another comment. Although this paper will focus entirely on the concept of process, the concept is only one of many which require attention because of their importance in the conduct of theory building and research. It is the particular utility of the concept of process which dictates its choice from among others, but only

with the recognition that it is not, in the broader view, the only concept to be considered. Similarly, while this paper will focus almost entirely on that form of theory and research which incorporates the concept of process, there is no assumption, whatsoever, that such theory and research is the only form which has value. Indeed, many studies of human communication do not require the consideration or use of the concept, and clearly much valuable work has been done which has not incorporated it. The intent of the paper is not to disparage such studies, but to suggest additional approaches and tools for those areas of theory building and research on human communication where the concept of process must be considered and used.

Although the paper will be centrally concerned with only a single concept, a comment is still needed regarding the level of that concern. Quite clearly, the task of seeking the means of explicating the concept of process will involve consideration of a number of different approaches and tools for constructing constitutive and operational definitions. With the exception of one discussion of specific applications, however, this paper will not apply such approaches and tools, but will only suggest them and consider their implications for the discipline of communication as a whole. The actual details of applying the tools must be left to the individual scholar working in a specific framework of theory and research. If the distinction between theoretical and experimental studies is to be made, then, this study must needs fall with the former, though it will in no case lose sight of the latter.

One final comment, which also regards the level of concern with the concept of process. In a very broad sense, this paper will suggest

the need for extending current views on the conduct of theory building and research. The nature of the needed extension will be most evident in the discussions of the implications of "process" for theory and research, and will in many cases involve the refinement or development of techniques. Accordingly, while this paper will consider a number of problems and questions regarding the place of the concept of process in the study of human communication, it can be expected to uncover a great many more problems and questions at a lower level. There will, indeed, be much to add after the last sentence.

We shall begin studying the concept of process, then, in Chapter 1, by explicitly identifying several basic assumptions and directions, as well as by defining the concept of communication. This particular definition, like the others in the paper, is presented only as a point of reference, not as the "correct" or "true" definition. It is from the definition, however, that the paper develops its focus on the concept of process, and more specifically, on its importance, explication, implications, and use.

CHAPTER 1
THE UNIVERSE OF DISCOURSE

"Space and time are the framework in which all reality is concerned. We cannot conceive any real thing except under the conditions of space and time." So wrote Ernst Cassirer in An Essay on Man (1944, p. 42) in introducing a discussion of man's perception of space and time in the world about him. To be completely precise, of course, he would have had to speak not of man's perception of "space and time," but of his perception of "space-time," as Alfred North Whitehead showed, following the lead of Albert Einstein, some 40 years ago (1925, Ch. 7; 1929, Chs. 2, 10). The relationship of space to time does not, however, make it any less meaningful to emphasize either space or time, alone, in dealing with specific problems, whether problems of physics or of behavior.

1.1 Some Basic Assumptions and Directions

Accordingly, we shall be concerned primarily with time, and we shall take as given the statement that "all phenomena, as perceived by human beings, both occur, and can be measured, along a dimension of time."¹ Once again, in Cassirer's words, "Even time [like space] is first thought of . . . as a general condition of organic life.

¹That is, the assumptions made here will not be discussed at length. See, particularly, Gibson (1966), Kelly (1963, Ch. 1), and Whitehead (1925, Ch. 7; 1929, Chs. 2, 10).

Organic life exists only so far as it evolves in time. It [life] is not a thing but a process—a never-resting continuous stream of events. In this stream nothing ever recurs in the same identical shape (1944, pp. 49-50)." Life, then, is a moving succession of events in a dimension or "condition" of time—a "process" in Cassirer's terms.

If one accepted these four sentences from Cassirer without qualification, one would view life as a succession of unique events,² and would require that each event have a unique explanation. Such a person could not be a scientist, for his viewpoint would prevent him from accepting a single explanation for even as few as two events. The scientist would, of course, agree that individual events are unique, but he would add the crucial point that there are properties and patterns in events which are independent of those individual events and are therefore observable in whole classes of events (Dubin, 1969, p. 34). These independent properties and patterns are the core of the scientist's concern, both in his study of unique events, and in his attempts at explanation of events through theory.

We shall take the position of the scientist, here, with regard to uniqueness and repetition in events, and we shall assume that the scientist's primary goal is the building of theory to aid in the explanation, prediction, and/or control of events. As Rudner has phrased it, ". . . it is an ideal of science to give an organized account of the universe—to connect, to fit together in relations of subsumption, the statements embodying the knowledge that has been acquired (1966, p. 11)."

²"Event" is used here in the sense of a bounded interval of time.

Quite obviously, "the universe" for which the scientist gives an account in his theory is in most cases a "universe of discourse"; that is, some limited class of events which is identified either implicitly or explicitly by the scientist as the domain to which his theory applies. This somewhat smaller "universe" is frequently identified by a single concept³ whose definition plays an important role in two early steps of theory building. In the first step a scientist takes, the definition of the concept functions in specifying the particular properties and patterns in events which are of primary interest, the class of which events constitutes the scientist's universe of discourse (Dubin, 1969, Ch. 5; Rudner, 1966, p. 35). Also, in what is frequently a second step, the definition acts in specifying a set of key concepts which may be central in the theory building and for which the scientist must provide some form of explication.

The plan. - In the broad sense of an overall plan for this paper, we shall be concerned with the above two early steps in theory building: defining the universe of discourse and providing explication for key concepts. The universe of discourse here is that specified by the concept "communication," and we shall begin by devoting the remainder of Chapter 1 to the first step in theory building by defining and discussing aspects of this concept, and by considering the criteria for the choice

³We shall follow Rudner's usage of "concept," i.e., "terms denoting certain characteristics, or terms applicable to entities said to have certain characteristics (1966, p. 18n; cf. Kaplan, 1964, pp. 46-52)." In particular, we shall not distinguish "construct," or other typologies of terms, from "concept," noting both that such distinctions are utilitarian, not ontological (Kaplan, 1964, pp. 59-60), and that some authors (Berlo, 1967; G. R. Miller, 1967) use "concept" and "construct" as virtually interchangeable.

of the definition. An explicit definition is given not because the universe of discourse specified by "communication" is in great need of redefining, but because the plethora of such definitions makes a point of reference necessary. The definition formulated here is therefore not a theory or a model⁴ of communication, but only a first step in that direction. Once the universe of discourse has been defined, the scientist may then move on in the direction of either (1) the construction of parts of a theory, or (2), as is more likely for the communication scholar-scientist, the construction of a typology of events which may eventually be incorporated into a theory (Harrison, 1967b, pp. 2-3; Rudner, 1966, pp. 28-40).

Neither of these two general directions in theory building can proceed, however, without the important second step of providing explication for key concepts specified by the definition (Berlo, 1967, p. 2). We shall, in fact, beginning in Chapter 2, devote our attention primarily to ways of accomplishing this specific task in theory building. At that point we shall select from the definition of communication a single concept which unites the concerns expressed above in time as a dimension, with those expressed in the scientific study of events, particularly events in the universe of discourse of communication. That single concept--the concept of process--is chosen partly for reasons of length, but primarily because it is seen as a highly useful concept in the

⁴"Model" is used here in Rudner's sense of ". . . an alternative interpretation of the same calculus of which the theory itself is an interpretation (1966, p. 24)." The definition might be said to be a "descriptive model," but this usage has not been adopted here (cf. Brodbeck, 1959, p. 379).

conduct of research and theory building related to human communication. The concept itself, the criteria for its choice, and its current place in research will be discussed further in Chapter 2. As a major emphasis, then, we seek as a preliminary step in theory building in communication, the means of explicating a concept which is seen as useful in the further conduct of that theory building.

Because the general concern is with explication, it is important to note two steps or requirements in this task before returning to the definition of communication. A concept is said to be explicated, and hence admissible for use in observation, experiment, and theory, if and only if it has been provided with both an operational definition and a constitutive definition. The operational definition specifies a procedure, under specific conditions, whose performance by an investigator will identify (i.e., measure or generate) in nature a situation which is the referent of the concept. The constitutive definition, on the other hand, specifies a linkage to other terms in the code, language, or especially theory, which the investigator manipulates to produce propositions about the events under study (Berlo, 1967, pp. 2-4, 8, 11).

Operational and constitutive definitions of a concept are normally constructed and applied only when the concept is used within a specific observational, experimental, and theoretical framework (cf. Rudner, 1966, p. 20). However, because this paper will not deal with a single research and theory building situation, such as would be found in a report of an experiment, the specific conditions under which operational and constitutive definitions are applied will be absent. As a result, rather than discuss a single operationalization for the concept of process, we shall

consider both the general principles for operationalizing it, and the implications of these principles for research (and analysis) techniques. Similarly, instead of linking the concept to other terms of a specific, but premature, theory of communication, we shall link the concept to other terms of the language which might be used in a future theory of communication, and shall consider the implications of the linkages for the form of that theory.⁵ These approaches to an operational and a constitutive definition, respectively, constitute what was referred to earlier as a search for the means of explicating the concept under study.

In brief summary, then, we shall begin by defining the concept of communication, and by considering the choice of the definition, in order to identify both the universe of discourse and a set of key concepts requiring explication (Chapter 1). We shall select one of these concepts, that of process, for special attention, and shall discuss the concept itself, the criteria for its choice, and its current place in research in communication (Chapter 2). Since the "special attention" involves seeking means of explicating the concept, we shall consider approaches to both a constitutive definition (Chapter 3), and an operational definition (Chapter 4). Finally, we shall turn to examples of the use of the concept in research (Chapter 5), and to conclusions (Chapter 6).

⁵Whether a given term (concept) is a primitive, is derivable from other terms, or is unnecessary in a particular theory cannot be completely determined until that theory is fully formalized (Rudner, 1966, pp. 18-19, 47, 51-52).

1.2 A Definition of Communication

We shall use the term "communication" to refer to "a process of transmission of structure among the parts of a system which are identifiable in time and space" (Krippendorff, 1969a, p. 107).⁶ Since the properties and patterns in the events specified by this definition are not immediately obvious, it will be useful to examine each phrase and its key concept in detail. Each of these concepts should, ideally, be explicated,⁷ but as indicated earlier, space dictates that only one concept be considered at length. Consequently, the examination of each concept will be limited here to further definition, and to discussion and examples of its scope.

One additional point must be emphasized before examining the definition of communication in detail. Each definition in this paper is provided primarily to establish a point of reference and to identify the writer's usage. In no case is a given definition considered to be the "correct" or "true" definition, nor is the assumption made that the reader will adopt the usage indicated as the "correct" usage. Rather, each definition is considered to be an "equivalent verbalization," used only to reduce ambiguity; that is, it is not "the meaning" of the term.

⁶Definitions of communication abound. There is little value in reviewing these definitions here when reviews already exist, and probably even less value in creating a new definition (see Barnlund, 1968, pp. 3-14; Krippendorff, 1969a, pp. 106-109, and 1969b, pp. 5-6; see also Barnlund, 1968, pp. 17-29; Bettinghaus, 1960, pp. 16-28; Harrison, 1969a; Sarbaugh, 1968, pp. 1-2, on models of communication). The definition given here will be related to others, below, in the discussion of the criteria for its choice.

⁷No claim is made for the exhaustiveness of this set of concepts.

A process. - Krippendorff, in commenting on his definition, notes that "The notion of 'process' subsumes that of behavior or changes over time (1969b, p. 7)." More formally, "process" is used here, in J. G. Miller's sense, to refer to "All change [including movement] over time of matter—energy or information . . . (1965a, p. 209)." Hence, a communication event is seen as occurring along a dimension of time, and as having the characteristic that changes in the properties of the event take place between the points in time which are the boundaries of the event. There are, of course, a number of other possible uses of the term "process," many of which have a wider scope than the definition to be used here. Attention will be given to these other uses, as well as to the particular definition used here, early in Chapter 2.

Notice that the term "event" is paired with the term "communication" in the discussion above. Such usage is felt to be both useful, and consistent with Krippendorff's definition in two respects. First, he uses the phrase "a process," and hence identifies the properties of a specific situation, or unique event, which may be termed a communication event. The properties identified, however, are also present in a class of specific situations which may be termed communication events. The addition of the term "event" or "events," then, serves to indicate whether a specific situation or a class of situations, both labeled "communication," is being referred to (i.e., a "communication experiment," involves an event, while "communication theory" and "discipline of communication" involve classes of events).

Second, and perhaps more important, the use of the term "event" recognizes an important aspect of the study of any process. As defined

above, a process has no bounds, but in fact may be (and often is) considered to have continuity over all time. Obviously, no scientist can observe or study such a process, except as certain properties or patterns in the process repeat themselves over intervals of time which that scientist can recognize and delimit. These bounded intervals are events, as defined earlier, and it is these events which the scientist studies, whether or not he explicitly identifies the interval boundaries. That the choice of interval boundaries is arbitrary, and is established by the observer, not the event, we shall take as given. An event is then a specific portion of a process which may have continuity over time, as in fact communication may have. Yet since events are the "objects" or "situations" which a scientist studies, references to a "process" in this paper will be to a process as it takes place within a bounded interval (or event).⁸ Again, these points and others concerning the concept of process will be discussed further in Chapters 2, 3, and 4.

Examples of processes range from trivial to highly sophisticated. For example, the change in state from ice to water is a process (matter-energy), as is the fading of a color photograph in the sun (matter-energy and information). Similarly, the release of energy in a controlled nuclear reaction is a process (matter-energy), as is the formation of a single frame of a color television picture (matter-energy and information). Note that in the second two cases, the process referred to is the actual release or formation, not necessarily the complex nuclear power or

⁸Krippendorff's examples (1969a, pp. 108, 109; 1969b, pp. 5, 6) make clear that this usage of "process" is consistent with his, even though he does not specify this use.

television operations necessary to bring these processes about. But this distinction raises an interesting point. Are these latter, complex operations, incorporating many changes, to be considered as many individual processes (changes over time), or as one process? Usage here will tend toward the latter as the more general case, since this usage also includes references to single processes. Note also that in the above examples only one of the four processes is associated with communication. The reason lies in the additional concepts which form the definition of communication.

Of transmission. - The term "transmission" is used here to refer to the movement of matter-energy or information over space (cf. J. G. Miller, 1965a, pp. 194-199). As such, transmission is a form of process, but is more restricted in that process includes both the change of state and the movement of matter-energy (or information), whereas transmission includes only the movement of matter-energy. Movement over space usually involves movement in time, as well (the space-time relationship), and in certain cases the time dimension of the transmission is of primary importance.

Examples of transmissions are the flow of heat in a home heating system, the radiation of signals from a television transmitter, the flow of electrical energy in a power network, and the placement and discovery of the Rosetta stone. In the latter example, time is certainly the primary aspect of the transmission, although movement in space is involved, as well. Two of these examples are transmissions associated with communication, the reason being, in part, that they are transmissions of "structure."

Of structure. - Krippendorff notes in a highly technical, though very general definition that ". . . structure should be understood in the mathematical sense: as a many valued relation, as a complex pattern, as an above-chance distribution in a multi-dimensional space (1969a, p. 107)." "Structure," then, is used here to refer to the pattern or organization among the parts or units of some entity, as opposed to chaos or complete lack of organization. Krippendorff notes that the term "information," when used in sense of statistical information theory (hence, the opposite of uncertainty), is a possible substitute for the term "structure."

It is important to note, though, that the transmission of information (or structure, here), is always accompanied by the transmission of matter-energy, since information is always borne on "markers" [e.g., stones, ink and paper, chemical compounds, sound and electrical waves (J. G. Miller, 1965a, pp. 199 and 194)]. In the context of the definition, "structure" is used to refer to the informational or organizational aspects of a transmission, rather than to its matter-energy aspects (the markers). Such a use of the term to refer to information will henceforth be designated "structure_i" to distinguish it from the use of the term in Chapter 3 to refer solely to arrangements of matter in space. This latter use will be designated "structure_m."

Examples of structure_i are the arrangement of signals or pulses in a television transmission, and the linguistic patterns which appeared on the Rosetta stone. Likewise, the "code" of a DNA molecule is an example of structure_i, as are the patterns formed in the wide range of human bodily movements. Each of these four examples is one of

structure₁ associated with communication, but the reason is that each situation also fulfills the final qualification in the definition.

Among the parts of a system which are identifiable in time and space. - The first part of this long phrase is the most important, and revolves around the key concept of system. The term "system" is used here in the same sense in which J. G. Miller applies the term in general systems behavior theory (1965a). Since the concern in this paper will be with "concrete," rather than with "conceptual" or "abstracted" systems, the term "system" is used to refer to . . . "a non-random accumulation of matter-energy, in a region of physical space-time, which is non-randomly organized into coacting, interrelated subsystems or components (J. G. Miller, 1965a, p. 202)."

The emphasis on non-random organization in this definition of "system" refers in part to the "common properties" among the subsystems or components, some of which may be: proximity and similarity of parts, common information, fate, or duration, and maintenance of a single boundary ". . . over which there is less transmission of matter-energy or information than there is within the system . . . (J. G. Miller, 1965a, pp. 200, 214)." The "non-random organization" of a system also refer to the interrelationships between its sybsystems or components (the units). In Miller's terms: "The state of each unit is constrained by, conditioned by, or dependent on the state of other units. The units are coupled. Moreover, there is at least one measure of the sum of its units which is larger than the sum of that measure of its units (1965a, pp. 200-201)."

While this brief summary does some injustice to Miller's treatment of the concept of system, it should suffice for the present purpose of

examining the above phrase from the definition of communication. Given Miller's use of the concept of system, it is evident that the second part of the above phrase ". . . which are identifiable in time and space," may be considered an addition to the definition wholly for the sake of emphasis, since in Miller's usage a concrete system must be located "in a region of physical space-time." The first part of the above phrase, "among the parts of a system . . . ," is less easily disposed of, however, and raises an important point.

According to the first part of the phrase, communication takes place within a particular system, a terminology which will be followed here. This system may be, for example, the male and female of a species and the embryo at the point of conception (DNA is the structure_i transmitted to the offspring), or a client and psychiatrist conducting an interview (language, bodily movements, are the structures_i). Each of these situations can be readily identified as a concrete system within which there is transmission among the parts or subsystems. In each case, as well, the subsystems are also complex systems in themselves, at a lower level. On the other hand, it is somewhat less easy to identify the concrete system within which the transmission of structure_i takes place in either the discovery of the Rosetta stone, or the formation of a television picture. In these cases, the system which is most readily identified is the archaeologist or the television set; however, these systems are only parts or subsystems (at a lower level) of the systems within which the transmission takes place. These latter systems are composed of the maker and discoverer of the stone, and the television transmitter and receiver--systems which, despite their tenuous appearance,

are communication systems in the sense that the concept of system is used here.

These four very brief examples of communication systems can also be used in summarizing the key aspects of the definition of communication, before moving on from this consideration of specific phrases and concepts to a consideration of the definition as a whole and the criteria for its choice. Again, "communication" is used here to refer to "a process of transmission of structure_i among the parts of a system which are identifiable in time and space." In particular, the transmission of genetic material between generations of a species, the transmission of linguistic and kinesic patterns between individuals, the transmission of a combination of linguistic codes between people over millenia, and the transmission of a coded electro-magnetic signal from a transmitter to a receiver, are all events whose properties and patterns qualify under the definition to be termed "communication."

1.3 Criteria for Choosing the Definition

The choice of a particular definition or statement out of a set of possible alternatives requires at least implicit consideration of two factors. One factor is the range of alternatives to the definition or the statement, and the second is the set of criteria on which the choice is based. Because the choices made at certain key points in this paper have an effect on its outcome, we shall explicitly identify at these points both the range of possible alternatives, and the criteria for the choice among them. The first of these key points is the choice of the definition of communication--a choice made on the basis of two primary criteria, those of generality and utility.

Generality. - One aspect of the definition's generality can be seen in the broad scope of phenomena which it includes. This aspect is closely related to a second aspect of the definition's generality--the encompassing of the universes of discourse of a range of alternative definitions. The first aspect, the broad scope of phenomena covered by the definition, can be seen in part in the examples given above, to which might be added examples of the transmission of cultural patterns, of various persuasive messages, and of animal vocalizations, among others (Krippendorff, 1969b, p. 6). The reason for the definition's broad scope is, of course, that it identifies a fairly small set of concepts which specify only a limited number of properties and patterns in events (Dubin, 1969, Ch. 5).

Certainly, many investigators would not wish to consider such a broad scope of phenomena in their research, and would implicitly or explicitly narrow such a definition by restricting the scope of one or more of its key concepts. Such restriction could take several forms, and would be entirely valid, as long as the universe of discourse of any resultant theory were seen as similarly restricted. For example, an investigator might restrict the scope of the transmission involved to cover only "face-to-face" or "interposed" channels, or only decoding or encoding. The structure₁ could be limited, say, to written, spoken, or non-verbal, as well as to sub-categories within these (e.g., persuasive, informative, consumatory). Restrictions on the system are most frequent, however, and often begin with a restriction on type, as in human, animal, or machine. System restrictions may also be in terms of number of subsystems, as in "interpersonal," "mass," or "self"; in terms of

subsystem function, as in sender, receiver, or both; and in terms of various system or subsystem "states" like meaning, intent, awareness, effect, and attitude. These examples are, of course, only a few of the many possible ways of restricting the scope of the present definition of communication. They serve to emphasize, however, not only the generality of the definition itself, in terms of the phenomena which it includes, but also the generality of each of the concepts used in the definition.

The generality of the concepts used means, in particular, that the universe of discourse specified by the definition is sufficiently broad to encompass the domains of many alternative definitions of communication. Krippendorff has reviewed a number of such definitions (1969a, pp. 106-109; 1969b, pp. 5-6), and has found their domains to be included in the universe of discourse of the definition which he formulates.⁹ It is worthwhile to extend this review, as well as this second aspect of the present definition's generality, by briefly examining three other definitions of communication.

The definition given by J. G. Miller in his discussion of general systems behavior theory is similar in many ways to that used here:

"... the change of information from one state to another or its movement from one point to another over space (1965a, p. 198)."

"Information" is, of course, used here in the sense of structure_i, and since Miller does restrict "communication" to the movement of markers in space (1965a, p. 194), it is evident that his phrase "change of

⁹The definitions include those of Ashby, Deutsch, Gerbner, G. H. Mead, G. R. Miller, Wiener, L. White, and others.

information from one state to another" must involve some form of transmission. The systems context of Miller's remarks makes clear, also, that the transmission he refers to is one occurring within or between systems. He adds at a later point (1965b, p. 342-344), however, that an exchange of information between two systems is sufficient to create an "information boundary in space-time," i.e., a boundary which defines the larger system within which the communication takes place (see the discussion of the concept of system, page 16ff). When these factors in the context of Miller's definition are taken into account, it becomes clear that the universe of discourse he specifies is essentially identical with that specified by Krippendorff's definition.

A second definition of communication formulated recently by Berlo¹⁰ specifies the conditions under which the term may be applied:

If: two X's (in which X is a system),
 between which energy is transferred,
 that energy being informational and
 particularly a symbol,
 Then: communication.

Provided that J. G. Miller's comments on an "information boundary" can be applied here, this set of conditions resembles those given in Krippendorff's definition, i.e., "transmission of structure_i among the parts of a system." The one exception, of course, is that Berlo specifies that the structure_i have the characteristics of a symbol--a discriminable unit of matter-energy which bears information (hence, a sign) and which is used in place of, or as a substitute for, some other

¹⁰Personal communication, August 18, 1969. See also D. K. Berlo, The Process of Human Communication, forthcoming.

unit of matter-energy. In Berlo's treatment of the concept of symbol, however, it also appears that the ability to symbolize is largely restricted to human beings, so that the effect is one of limiting the type of system involved, as well. Given these restrictions on structure_i and on system, then, it is clear that the universe of discourse specified by Berlo's definition is encompassed by that of Krippendorff's definition.

The third definition is one formulated by Ackoff (1958), and shows a form of restriction beyond that of Berlo's definition:

If an individual I_b responds to a set of signs selected by I_a in a purposeful state, then I_a is the sender and I_b is the receiver of the message.

Several aspects of this definition should be noted. First, I_a and I_b may be the same individual. That is, a person may communicate to himself as in writing a 'reminder' to himself. Secondly, the sender of the message need not intend or desire to communicate to the receiver in order to do so. The interceptor of a message, for example, is communicated to, although unintentionally. Thirdly, the sender and receiver may be widely separated in time and space (1958, pp. 224-225).

Taking into account both these comments by Ackoff, and those made above concerning sign and symbol, it appears that Ackoff restricts structure_i and system in much the same ways as Berlo does. However, Ackoff chooses to identify an even smaller domain by including in his definition a subsystem attribute, i.e., the requirement of a "purposeful state."¹¹ The result is that the domain which he specifies is a subset of the universes of discourse identified by both Krippendorff's definition, and Berlo's definition.

¹¹"Response" is defined in terms of "purposeful state (1958 , p. 224)," therefore making "purposeful state" the key restriction.

Were it not for limitations of space, it would be worthwhile to examine a number of additional definitions of communication (Barnlund, 1962; Cherry, 1957; Fearing, 1953; etc.), both to expand the range of possible alternative definitions, and to establish more fully the generality of the present definition. It would also be useful to discuss one of a few definitions, such as that of Stevens,¹² whose domain is not encompassed by the present definition, but which instead specifies another set of phenomena. Space is limited, however, not only because this is not a review of definitions, but also because there is a second criterion in the choice of the definition to be considered.

Utility. - The broad generality of Krippendorff's definition, which is one factor favoring its selection, immediately raises the question of utility—a criterion which Berlo has termed ". . . the primary criterion for the efficacy of any scientific operation (1967, p. 4)." Is the definition perhaps too general to be useful? As Kaplan has pointed out, the making of a value judgment of utility in the "analysis of meanings" requires attention both to the particular context in which the "action" (the forming of a definition) is taken, as well as to "the purposes which the action as a whole is meant [sic] to achieve (1964, pp. 390-392, 42-46)." Consequently, if the present context were that of a specific research program, the definition (as it stands) would probably be too general to be of use, for it would fail in its purpose

¹²"Communication is the discriminatory response of an organism to a stimulus. This definition says that communication occurs when some environmental disturbance (the stimulus) impinges on an organism and the organism does something about it (makes a discriminatory response). If the stimulus is ignored, there has been no communication (Stevens, 1950, p. 689)."

of specifying a "workable" domain.

The context in which the definition is used in this paper, however, is that of the early steps in theory building, especially as that theory building occurs in the discipline of communication. The purpose of the definition in this context, then, is the identification of a universe of discourse, and a set of key concepts, which are broad enough to encompass a large portion of the set of phenomena which have in the past been labeled with the term "communication."¹³ Phrased in this manner, the purpose both requires that the definition integrate a set of phenomena which might otherwise be seen as disparate, thereby acting as a heuristic device, and requires that the discussion apply beyond the limits of any one specialized interest in communication. The definition of communication chosen earlier is judged as highly useful in fulfilling this purpose.

Generality and utility, then, are the two criteria in the choice of the definition given above from the range of possible alternative definitions.¹⁴ This choice of a general definition, with its requirement of broadly applicable discussion, requires that one final comment

¹³It is extremely important to note that the purpose of the definition is not to identify a universe of discourse and a set of concepts which encompass all phenomena labeled "communication." The definition chosen here, despite its generality, does in fact exclude many phenomena so labeled, as Krippendorff has been careful to point out (1969a, pp. 105-109; 1969b, p. 6, and especially pp. 23-26).

¹⁴"Observability" of the concepts employed, and hence of the events specified, is another possible criterion for consideration in such a choice. However, while the concepts used, and the events specified, are considered observable, this does not distinguish them from a great many other definitions which also meet the criterion.

be made before turning in the next chapter to the concept of process itself, the criteria for its choice, and its current place in research.

At points in this paper references will be made, implicitly and explicitly, to communication events in which at least one subsystem is a human being. Accordingly, references to "communication research" will in some cases be references to the more restricted area of human communication research, even though by definition, the observation of communication events, and the building of theory to explain and predict those events, is a much broader endeavor (Krippendorff, 1969a). Such restriction of reference is entirely a result of the writer's interest in human communication research, an area of research for which the discussion of the concept of process is seen as especially relevant. These references to human communication will, of course, be combined with references to other research areas such as telecommunication--an area for example, in which the concept of process is utilized almost implicitly. Regardless of the area referred to, however, care will be taken at all points, in keeping with the requirement above, to assure that the concepts and techniques discussed can be applied (in principle, at least, if not in utmost utility) to the range of phenomena encompassed by the present definition.

CHAPTER 2

THE IMPORTANCE OF PROCESS IN STUDIES OF HUMAN COMMUNICATION

In the previous chapter, the particular definition of communication to be used here was compared to several other alternative definitions. In each comparison, however, one key concept was inherent in the definitions which did not receive any special recognition. The concept was that of process, sometimes expressed as its subset, transmission. With the definition of the universe of discourse complete, it is possible in this chapter to examine this key concept of process in much greater detail. In so doing, it will be useful to examine not only the concept itself more closely, but also the criteria for choosing process from the alternative concepts, and the current place of the concept in research on human communication. Such a discussion leads directly to considering the means of explicating the concept in Chapters 3 and 4.

2.1 A Closer Look at the Concept of Process

Turning first to the concept itself, it appears worthwhile to examine its relationship to the concept of communication, to several other important concepts, and to three classes of research designs.

2.1.1 Process and Communication

In the many definitions of communication extant today (Barnlund, 1968, pp. 3-14), it has become almost commonplace to at some point

acknowledge that "communication is a process"--the definition chosen here being no exception. The same acknowledgment also appears frequently in the discussions of the various general models of communication events (Barnlund, 1968, pp. 17-29; Bettinghaus, 1960, pp. 16-28; Harrison, 1969a). This continual re-emphasis, of course, lends a great deal of the weight of experience to the identification of communication as a form of process. A definition, however, is merely a statement of equivalence expressed in verbal form, and is not sufficient, alone, to establish the relationship between the concept of communication and the concept of process.

Rather, the relationship between the two concepts will be established by returning to the early, basic assumption that "all phenomena, as perceived by human beings, both occur, and can be measured, along a dimension of time (page 5)." We shall assume that communication is included among these phenomena, or more precisely, following the convention established earlier (pages 6n, 13), shall assume that communication events are part of the class of phenomena¹ occurring and measurable over time. We shall also assume that all communication events involve some form of change, where the term "change" is used in its most general sense to refer to both the presence and absence of variation in some relevant property or properties of an event (see discussion in section 3.2). On the basis of these two assumptions concerning time and change, then, it is evident that communication events are part of the class of events termed processes, since the term "process" is used here to refer

¹All perceived phenomena being some form of matter-energy or information (see J. G. Miller, 1965a, pp. 193-194).

to "All change over time of matter-energy or information . . . (J. G. Miller, 1965a, p. 209)." It is this means of relating the concept of communication and the concept of process which forms the basis for statements in this paper that "communication is a process," or, in the more technically correct form to be used here, "communication events are processes."

2.1.2 Process and other Important Concepts

Such a discussion of the relationship between the concept of communication and the concept of process, however, may lead one to an objection of the form: "Doesn't the consideration of 'process' in the many definitions, models, and discussions of human communication involve something more than just 'change over time of some property or properties'?" The answer is "yes," for the term "process" is subject to a broad range of uses, particularly in the discipline of communication. It is worthwhile to review some of these uses, briefly, in order to extend the examination of the concept itself by showing its relationship to several other important concepts often "included" when the term "process" is used in its broad sense. The review will also serve to sharpen the definition used here. Once again, such a review is not intended to isolate a "correct" or "true" definition, but instead to provide a point of reference (see page 11).

It will be useful, first of all, to set apart from consideration all uses of the term "process" in anatomy, law, and printing, as well as uses as an adjective or as a transitive or intransitive verb. As a noun, then, "process" is often used in its broad sense to indicate that the antecedents for an occurrence stretch back indefinitely in time, just as

its effects stretch forward indefinitely. In short, "process" may be used to indicate that an occurrence "really" has no beginning and no end (Berlo, 1960, p. 24; Sarbaugh, 1968, pp. 2-3). This aspect of an occurrence is frequently termed its "continuous" aspect, or, using the term to be adopted here, its "continuity." Again, as noted earlier, no scientist can observe or study an occurrence in its continuity, except as he divides that continuity into discrete portions termed "events" (page 13). "Process" will be used here, then, to refer to change over time within an event,² while the "continuity" of an occurrence will be noted by the specific use of that term.

Closely related to the use of "process" in its broad sense to indicate the continuity of an occurrence is its use to indicate two other aspects. One of these aspects is that while ". . . certain things may precede others, . . . in many cases the order of precedence will vary from situation to situation (Berlo, 1960, p. 25)." Rather than use the term "process" to describe this aspect of occurrences, the term "indeterminancy" will be applied, indicating that in most cases no single causal sequence can be determined. The second aspect is frequently expressed by Heraclitus' metaphor indicating that a man can never step in the same river twice, since neither man nor river will be the same again. Although decidedly unpoetic, this aspect of occurrences or events will be termed their "irreversibility," thus further

²Note that this usage is not necessarily synonymous with the use of "process" to refer to "a series of actions or operations definitely conducing to an end," as in "process of tool or steel making." Sequences of actions where the goal is of prime importance will be termed "procedures."

narrowing the range of usages for "process."

In its broad sense, "process" is also frequently used to indicate that each element or property of an occurrence affects all the others, i.e., they interact (Berlo, 1960, p. 24, 26; Sarbaugh, 1968, p. 3). This particular usage of "process" is especially evident in discussions such as that by Dubin in speaking of "processes of interaction among variables": "My emphasis on interaction is identical with that of G. Bergmann who speaks of 'process knowledge' and its interaction feature, which is the complete knowledge of the interaction among the variables of a system (1969, p. 10n)." Certainly interaction is an important aspect of an occurrence, and especially of the system involved in that occurrence. Because of its importance, the term "interaction," will be used as distinct from the term "process."³

Apart from "interaction" is another use of "process" in the broad sense to indicate a second important aspect of both an occurrence and the system involved in it. Berlo identifies this aspect in noting that "As any good cook knows, it is the mixing process, the blending, that makes a good cake; ingredients are necessary, but not sufficient (1960, p. 26)," or in other words, a cake has properties which are not evident from its ingredients. Clearly, such new properties may be generated in an occurrence or a system by the "procedure" (see note 2 above) which produced it. Nevertheless, such properties are

³Closely related is the interaction between the properties of an event and those of the observer. This particular interaction is usually identified or considered under the heading "relativity." Such usage is adopted here to avoid further confusion with either "process" or "interaction."

characteristics of the occurrence or the system itself, not of the "process" of production. As Bertalanffy has expressed it:

The meaning of the somewhat mystical expression, 'the whole is more than the sum of parts' is simply that constitutive characteristics are not explainable from the characteristics of isolated parts. The characteristics of the complex, therefore, compared to those of the elements, appear as 'new' or 'emergent' (1968, p. 55; see also Buckley, 1967, p. 42; J. G. Miller, 1965a, pp. 201n, 217; Rappoport, 1968, p. xvii).

Accordingly, instead of the term "process," the term "emergence" will be used to indicate that the whole of an occurrence or system exhibits properties which are not evident from its parts.

Finally, the term "process" is also used in its broad sense to indicate a third important aspect of both an occurrence and a system--one which is closely associated with all the other aspects noted above. That aspect is, of course, change over time in the properties of an occurrence or a system. Certainly a great proportion of the uses of the term "process" have this important aspect at their core, whether in indicating change over time alone, or change over time associated with continuity, or with interaction, or with other aspects. It is this single, key aspect of change over time which we shall adopt as the narrow sense or use of the term "process," a usage indicated, of course, by the narrow definition given earlier. Henceforth, any use of the term "process" in its broad sense will be avoided, unless indicated as such, in favor of the use of "process" in its narrow sense, combined with use of the terms mentioned above to indicate other aspects of occurrences.

The attempt here, then, has been to systematically narrow the sense or usage of the term "process" by introducing alternative concepts which are closely related to change over time, but which are possibly

better adapted to isolating certain aspects of occurrences often indicated by "process" in its broad sense. The narrowing has thus been done with a knowledge of what has been omitted, though with the recognition, as well, that no such treatment can hope to examine the full range of possible meanings for a term. The goal here is not exhaustiveness, but establishment of a clearer reference point for later discussion.

Two additional points about the use of "process" need attention before leaving this review of the term's relationship to other important concepts. One point is that the concepts noted above, e.g., continuity, indeterminacy, irreversibility, interaction, emergence, and process in its narrow sense, have all been mentioned at some time as characteristic of art, or of its production or appreciation. One is led to speculate whether in some cases "process" may have been applied in its broad sense where a reference might more suitably have been made to the "'art' of communication." The second point is that "change over time" can be discussed without using the term "process" at all. While this point is recognized, it is felt that "process," in its narrow sense, is both a highly useful organizing device in discussion, and fully in keeping with an important aspect of the common use of the term.

2.1.3 Process and Research Designs

In addition to the above examinations of "process" as related both to "communication" and to several other important concepts, it will be helpful to examine one other aspect of the concept itself: its relationship to three general classes of research designs. This relationship should indicate, in part, the nature of the concern with the concept of process in this paper. A few technical points, first, as a preface to

discussing these general classes of research designs.

In order to record change over time, or process, in a research situation, it is necessary (but not sufficient) to measure both the value of the variable(s) of interest, and the point in time at which that value is recorded.⁴ The time point is measured with respect to some convenient reference point, such as the time point of the first measurement taken. Time therefore becomes a variable which is measured with respect to other measurements.⁵

Ideally, a scientist might wish to record the change over all time during the interval of concern by measuring the value of the variable(s) continuously in that interval. But continuous measurement is not always necessary, or more importantly, not always possible for some variables. In either case, the alternative is to measure at a number of discrete points in time (usually regularly spaced) during the interval. The resulting information (data on the variable(s) and time) will provide either an approximation of continuous measurement, or, depending on the form of variation of the variable(s), the equivalent of continuous measurement. In the latter case, assuming that the criteria are met for frequency of measurement with regard to the particular form of variation,

⁴"Research situation" encompasses both "observational" research, and experimental research. The former case includes situations in which the scientist has no control or does not exert control over exposure to experimental stimuli. The latter case covers all situations where some control over exposure (as well as some randomization) can be applied, even though a true experiment may not be achieved, as in the "pre-" and "quasi-" experiments of Campbell and Stanley (1963).

⁵Time is measured as a linear flow, not as an "amount" or "quantity" (see Heirich, 1964, pp. 388-390).

the data contain sufficient information to both fully characterize and allow reconstruction of the continuous variation (Cherry, 1957, Chs. 4, 5; Pierce, 1961, Ch. 4). The criteria, and the required knowledge of the form of variation, will be discussed at length in Chapter 4. The key point here is that there is an intimate relationship between measurement at discrete (and measured) points in time, and the form of variation or change over time which can be characterized by that measurement.

With these technical notes as background, it is possible to look more closely at the concept of process as it relates to certain general classes of research designs. The three classes of designs to be discussed here have been established on the basis of a single characteristic of individual research designs--the number of "observation points" provided in the design. An observation point is a point in time in a research situation at which the relevant variables are measured, regardless of whether the measurement involves one or more specific applications of the measuring instrument(s). That is, if both a pretest and a posttest are given to two groups in a particular research design, there may be as many as four separate applications of the measuring instrument(s). There are, however, only two observation points (the pre and post points). The same holds true for replication of the design at a later time, i.e., there are only two observation points in the design, even though there may be many applications of the instrument(s) over an extended period. The three general classes of designs to be described below have been termed "point," "difference," and "process" designs, each term referring to the type of data which may be obtained from designs having, respectively, one, two, or three or more observation points.

It should be noted that no attempt will be made, here, to review individual research designs and to identify them with one of these three general classes. The nature of such a categorization should be evident from the discussion, and will be indicated more specifically later in the chapter. Of particular interest in considering each class will be the formalized observations or data gathered under those designs, the nature of the evidence which can be derived from those data by analysis, and the semantic interpretation of that evidence (Krippendorff, 1969b, pp. 2-5; see also Coombs, 1964, Ch. 1).

Point designs.-- The first general class of research designs includes those which measure variables at only one point in time in the research situation (it is assumed that the time point is recorded, also). The data gathered using designs with only one observation point may, of course, be subjected to a number of relevant analyses. Despite the form of analysis, however, such data (termed "point" data) can provide explicit evidence on only a single "state," or set of values of variables at one point in time.⁶ The scope of the semantic or theoretic interpretation of that evidence is thus formally limited to a concern with a single point in time.

⁶Except when a variable is known a priori as constant, or as having linear variation with a known slope, in some interval. Research which gathers data at one point, and depends on population norms, etc., for a reference point, probably involves "difference" data, as discussed below. Some research, however, gathers data at one point in time, and also asks, "What was the state at another point?" The question of whether such research produces point or difference data is a methodological and philosophical question beyond the domain of this discussion.

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Difference designs.-- The second general class of research designs--those with two observation points (e.g., pretest and posttest, with the time points recorded)--will produce data which are subject to a somewhat broader range of analyses than are data from point designs. The two observation points, of course, define the interval under concern, and the data gathered at these two points can provide explicit evidence not only on the individual states, but also on the differences between those states (such data are thus termed "difference" data). The semantic interpretation of the evidence produced by analysis of the data can likewise be extended to cover both the individual states and the differences between them.

Both point and difference designs are, of course, frequently used in testing predictions about the effects of independent variable(s) (experimental stimuli) on dependent variable(s). That is, given adequate experimental control, a difference in the dependent variable(s) between the experimental and control groups at the final observation point (the posttest) may be said to result from the manipulation of the independent variable(s). Conclusions of this form can be drawn both from adequate point designs and from adequate difference designs. The effect of the pretest in the difference design is, of course, to increase precision in the analysis. Note carefully that the term "difference," as used above, does not refer to the difference between the experimental and control groups at a single point in time, but rather to the difference between the states of a group or groups at two points in time.⁷

⁷Unless otherwise noted, the term "difference" will be used herein to refer to a difference between states at two points in time.

A difference between states at two points in time is, of course, one instance of change over time or process. That is, if difference data are presented on a graph which has time as the abscissa and variable value as the ordinate, the representation takes the form of a straight line over the interval defined by the two observation points.⁸ Such a graph illustrates a specific path or form of variation, i.e., one instance of change over time. Note, however, that in this paper we shall be concerned with change over time, or process, without restriction on the shape of the path or form of variation. Alternatively, in terms of a graph, the concern with process, here, will encompass all possible paths or forms of variation which may be drawn between the two values of a variable at the end points of an interval. The straight line path representing difference data is, quite clearly, only one special case in this more inclusive consideration of change over time.

It is apparent, then, that a difference design produces data which are capable of providing explicit evidence only on states at two points in time; i.e., no evidence is provided on states within the interval.⁹ The scope of the semantic or theoretic interpretation of difference data is therefore formally limited to a consideration of the

⁸Obviously point data cannot provide such a graph of change over time, unless the variable is known to be constant, etc., as described in note 6, above. Note that only a single variable is referred to here, although the principle applies to one or more variables (see discussion in Chapter 3).

⁹Except when there exists: (1) a priori knowledge that the change in a variable is linear in the interval, or (2) a priori knowledge about certain characteristics of the form of variation

two states and the differences between them--a consideration in terms of change over time or process is ruled out. More specifically, difference data do not provide evidence on the time relationship of the values taken by a variable, or on the time sequence of states within the interval. Hence, any attempt at a semantic or theoretic interpretation involving such a time relationship or sequence moves beyond the explicit evidence which can be obtained from the data.

Process designs.-- The evidence provided by difference data may, of course, be interpreted in statements noting that change (or difference) did occur, but it may not be interpreted in statements dealing with how that change occurred. The latter class of statements includes those dealing with the time sequence of states within an interval, with the path or form of variation (the time relationship of values), and more generally, with the change over time or the process involved.¹⁰ Interpretations of this nature may be made, however, from the information provided by research designs from the third general class. These designs measure variables not only at the two points in time which define the interval of concern, but also at one or more observation points (whose times are recorded) within that

involved. These characteristics are discussed in Chapter 4, and derive from the close relationship between measurement at discrete points in time and the form of variation which can be characterized by that measurement. Even provided the special characteristics are known, measurement at two points in time is an absolute minimum.

¹⁰No criticism of, or deficiency in, current research is implied here. See the comments above on the usefulness of point and difference data, and the comments on current research in the last section of this chapter.

interval. The data gathered using such research designs are termed "process" data and are subject to a rather broad range of analyses, the exact form of analysis depending in part on how the measurement at discrete points relates to the form of variation involved. That is, if the measurement approximates continuous measurement of the variation, the relevant analyses of the data will provide explicit evidence both on the sequence of states within the interval, and on the differences between them. Should the measurement completely characterize the variation (or be a continuous measurement of it), however, more powerful analyses will provide evidence on the full path or form of the variation within the interval.

In either case, the evidence produced by the analysis of process data permits a much broader scope of semantic or theoretic interpretation than does the evidence produced from difference data. Such interpretation includes consideration in terms of change over time or process, and might involve statements dealing with the sequencing of particular states and configurations, or with the appearance, operation, and decline of certain constraints and relationships. Such interpretations would apply both to observational and to experimental research, the latter providing additional information through experimental control and manipulation.

Process designs produce evidence which may be interpreted in terms of change over time or process because such designs are capable of operationalizing the concept of process. Specifically, the measurement or description of any path or form of variation, i.e., of any process or change over time, requires data on the variation to be

gathered at several points within the interval of concern. Since process designs (as they will be discussed in Chapter 4) are capable of specifying procedures, under particular conditions, whose performance will identify (measure and describe) in nature any path or form of variation, then by definition the designs are capable of operationalizing the concept of process (see page 9ff, and Berlo, 1967, pp. 2-4, 11). It is this third general class of research designs--those which operationalize the concept of process--which will be of primary concern, here, particularly as those designs apply to the study of communication events as processes.

Two further additions are needed in closing this discussion of the concept of process as it relates to these three general classes of research designs. One of the two is a note that while the interest in the concept of process does indicate an interest in time sequences, it does not imply an interest in making determinations of causality. Second, and more important, is a recognition that a fuller understanding and explanation of human communication events is not to be gained solely through attention to change over time or process. To say so would be absurd, since communication events, and especially the systems involved, are characterized by interaction and emergence, as well as by process. A fuller understanding will come only as these alternative concepts or aspects of events begin to be considered in combination in research on communication events.

In acknowledging this important point, however, it must also be acknowledged that each alternative concept or aspect generates unique problems when it is operationalized in research--problems

possibly better studied in isolation, before in combination. This factor, together with that of limited space, suggests that one concept be chosen from among the alternatives. That choice, in this case, is the concept of process in its narrow sense of change over time--a choice based primarily on the utility of the concept in the conduct of research and theory building in communication.

2.2. Criteria for Choosing the Concept of Process

Like the earlier choice of a definition (section 1.3), the choice of the concept of process as the focus for attention here is a sufficiently important choice to require identification both of the range of possible alternative concepts, and of the criteria for the choice among them. The choice of the concept of process from its range of alternatives involves, in effect, two choices from two different subsets of alternatives, although the criteria for the two choices are essentially identical. The choice from first subset has already been mentioned, i.e., the choice of the concept of process for attention when it is acknowledged that alternative aspects of events and of the systems involved, namely, interaction and emergence, are also important in research on communication. The choice from the second subset has been less explicit, i.e., the choice of the concept of process from the alternative key concepts in the study of communication. In the context of this paper, this second subset is comprised of the key alternative concepts introduced in defining the universe of discourse, namely, structure₁ and system.¹¹

¹¹Note that other concepts were introduced earlier in the initial considerations of the concepts composing each subset of

One criterion which affected the choice from the second subset of alternatives is worthy of brief mention. Process was chosen from this subset partly because the other concepts have received special attention in the past: structure; (C. Morris, 1968; Shannon, 1948) and system (Bertalanffy, 1968; J. G. Miller, 1965a), to mention only a few of the scholars. Beyond this criterion, though, there is only a single, primary criterion for choosing the concept of process from the two subsets of alternatives: the criterion of utility in comparison to the utility of the alternative concepts. In Kaplan's terms, again (see page 23), "Whether a concept is useful depends on the use we want to put it to (1964, p. 51)," that use, in the present context, being use as a tool in the conduct of research and theory building related to human communication. The basis for choosing a concept is therefore its possible utility as a tool in advancing knowledge about communication. Because the criterion is a broad one, it will be most expedient to deal with utility in two separate respects, first, in regard to general problems arising in building theory on the basis of research, and second, in regard to theory building and research in areas of new concern in the discipline of communication.

alternatives. Of the concepts mentioned earlier (page 28ff), in conjunction with the first subset, "relativity" is grouped here with "interaction." The other concepts, "continuity," "indeterminacy," and "irreversibility" are highly descriptive of an event or system, but are not characteristics or aspects directly affecting the values taken by variables, as are the concepts or aspects included here as the first subset of alternatives. The other concept mentioned earlier (page 11ff) in conjunction with the second subset is that of "transmission." As noted, however, the concept of transmission is less general than process and is encompassed by it (see page 14), so that its inclusion in the second subset of alternatives would be redundant.

2.2.1 Utility in Two General Problems

In the first regard, a concept would be judged useful if its application were important in avoiding certain general problems inherent in the building of theory from research. Two problems seem especially evident here, namely, the problems of spurious categorization and of prediction and understanding.

Spurious categorization.-- As background for the first problem, it is important to recognize that the scientist, in working toward his goal of building theory to explain and predict events, is at all times imposing his structurings on the natural world. He is not discovering structures "inherent" in nature (Berlo, 1960, p. 25; 1967, p. 2). It is important to recognize, too, that a fundamental part of any structure imposed by the scientist is the categorization which he makes of events in the natural world based on the properties he observes in those events (Berlo, 1967, p. 2). The scientist often begins with a fairly "primitive" categorization, but seeks to refine it through research on the properties of the events under study, whether that research be observational or experimental (see page 33n). His goals in the task of continually refining his categorization are to make it more useful, more consistent, and more predictive of events in nature (Berlo, 1967, p. 2). As the scientist progresses and his categorization moves from primitive to "sophisticated," he also advances in the direction of more comprehensive theory, and may eventually reach the point of fully formalized theory--the ultimate structure which he can impose.

Clearly, the social and behavioral sciences are, for the most part, still engaged in the early steps in formulating and refining their theories and categorizations of events (Rudner, 1966, pp. 28-40). If this statement can also be considered descriptive of the current status of theory building from research in the discipline of communication, then it is evident from the earlier discussion of the three classes of research designs that a potential problem exists in the early steps of categorizing communication events. Specifically, any categorization constructed on the basis of research on properties of communication events may be a spurious categorization if that research utilized designs which gathered data at only two observation points. Such a categorization might be spurious in the sense that it classifies events as similar only on the basis of similarity in difference data, even though it is clear that a set of events having similar overall differences may still exhibit several distinct paths or forms of variation. While spurious categorization may not necessarily be a frequent result of research which produces difference (or point) data, its obvious ability to frustrate the early steps of theory building demands that it be avoided.

Two counterarguments can be raised to the above, one of which states that the social or behavioral scientist carefully avoids spurious categorization by taking "other factors" into account when categorizing on the basis of research which provides only point or difference data. This argument of extra care is certainly one to be considered, but it is also subject to all of the criticisms that may be applied to interpretations beyond the explicit evidence provided by data. The other

counterargument states that the form of the variation or change over time within an interval or event "makes no significant difference" in the resulting categorization of events. Such an argument may well be valid in a particular situation, but it is crucial to note that it can be adequately supported only by first formulating an hypothesis to the effect that "variation within an interval makes no difference in categorization," and then conducting the necessary research--research which will require that data be gathered within the interval or event under consideration.

It is, of course, fairly obvious that the type of research needed to determine the presence or absence of spurious categorization is also the means of avoiding such categorization and its potential frustrations. That is, research which gathers data at points in time within an interval or event provides exactly the type of evidence on change over time which is needed to avoid the particular aspect of spuriousness considered here. As noted before (page 39), the particular designs used in such research would operationalize the concept of process, thus making that concept a highly central and useful one in avoiding the general problem of spuriousness in the categorization of events.

It should be noted that a parallel case for usefulness in avoiding spurious categorization could probably be built, as well, around each of the other concepts in the range of alternatives: structure_i, system, interaction, and emergence. Examining each of these concepts with regard to the problem of spurious categorization, then, it is apparent that a possible source of spuriousness might be the

failure to take into account various distinctions among events both in structure_i and in interaction. While such spuriousness is possible, its probability is seen as lower than in the case of process, primarily because both concepts are frequently considered in categorization and theory building: for example, on structure_i see Deutschmann (1957) and C. Morris (1968), and on interaction see Dubin (1969), among others.

A failure to consider differences in systems could be a possible source of spuriousness, too, except that J. G. Miller has noted (1965b, p. 337) that differences in the processes of systems are a primary basis for categorizing them--a point which reduces "system" spuriousness to "process" spuriousness. Finally, there is the possibility of spuriousness arising from the failure to consider emergence in events and systems. The concept of emergence presents a problem here, however, in that it requires examination beyond the little it has received (J. G. Miller, 1965a, p. 201n) in order that its implications with respect to spuriousness be clear. In the absence of such information, emergence will be considered, along with the concept of process, as a highly useful concept in avoiding the general problem of spurious categorization that is inherent in the early steps of building theory from research.

Prediction and understanding.-- Along with the problem of spuriousness is a second general problem inherent in theory building, especially as that theory building is conducted utilizing present research. This second problem has been recently discussed by Dubin (1969), and his words serve to express it best:

Theories of social and human behavior address themselves to two distinct goals of science: (1) prediction and (2) understanding. It will be argued that these are separate goals and that the structure of theories employed to achieve each is unique. I will not, however, conclude that they are either inconsistent or incompatible. In the usual case of theory building in behavioral sciences, understanding and prediction are not often achieved together, and it therefore becomes important to ask why. It will be concluded that each goal may be attained without reference to the other.

I mean one of two things by prediction [my italics]: (1) that we can foretell the value of one or more units making up a system; or (2) that we can anticipate the condition or state of a system as a whole. In both instances the focus of attention is upon an outcome.

As I employ the term understanding, it has the following essential meaning: it is knowledge about the interaction of units in a system. Here attention is focused on processes of interaction among variables in a system.¹²

The relationships between the goals of science and the analytical foci of attention in achieving these goals can be shown in a fourfold table like [Table 1].

Table 1. Scientific Goals and the Foci of Research (Dubin, 1969, p. 10)

		Goals	
		Understanding	Prediction
Analytical Foci	Interaction	X_1	
	Outcomes		X_2

¹²A "unit" in this instance is a variable, as in the quotation given earlier on page 30. It is well to note again, as in the earlier quotation, that Dubin's use of the term "process" is consistently confined to what has been termed here as "interaction."

At first glance one would normally be constrained to argue that the four boxes of the table are simultaneously populated. That is, to achieve understanding [my italics] of a social system, we need to know the interaction processes in it and the outcomes generated by these processes. Similarly, if we are to make accurate predictions [my italics] about social phenomena, we have to know the [interaction] processes built into these phenomena and the characteristics of all possible outcomes toward which the [interaction] processes move. This initial reaction is simply the assertion of a pious value position that bears little relation to the practices of social scientists. They actually operate in theory building and in doing research by working primarily in two of the four boxes, as indicated by the X entries in [Table 1]. What seems, in a logical sense, to represent the closure of the theory building-research cycle turns out to be largely ignored in the actual practices of theory building or researching (1969, pp. 9-11).

Dubin goes on to illustrate his statement about the actual practices of social and behavioral scientists in theory building, and then focusses on the two subproblems or paradoxes he sees associated with these practices. The first of these may be termed the paradox of understanding, which notes that it is possible to achieve understanding in science through knowledge of the interactions in a system, without being able to predict with precision the outcomes of events involving that system. The second paradox is termed the paradox of prediction, which notes that it is possible to predict with precision the outcome of an event, without an understanding of the interaction in the system involved.

Dubin discusses the reasons for the existence of each paradox, and in doing so establishes a firm basis for his claim that the two goals of science, understanding and prediction, are not often achieved together; that is, understanding focusses on interaction (X_1 in Table 1) and prediction focusses on outcomes (X_2 in Table 1), while the

other two cells remain vacant. Although Dubin notes that it would seem logical that these other cells be filled, and indicates by his presentations of the paradoxes that there may be some value in doing so, he does not discuss the characteristics of research and of the associated theory building which would fill the cells.

Certainly a detailed consideration of the characteristics of such research is beyond the scope of this discussion, too. However, it is possible to suggest at least one important step in the direction of gaining both (1) an understanding of the means by which the possible outcomes in events are achieved, and (2) the ability to predict with precision the nature of the interactions in the systems involved in those events (the two vacant cells of Table 1). In particular, note that theory building in these two cells requires, to a greater extent than the other cells, evidence on the path or form of variation, i.e., on the change over time, in an event. That is, theory building requires evidence on the processes (in the narrow sense) in a set of events which lead to particular outcomes and which are associated with particular types of interaction (cf. Buckley, 1967, p. 136). Research which is done utilizing designs that operationalize the concept of process provides just such evidence on processes and allows theory building to move in the direction of "filling" the vacant cells, or of closing the "theory building-research cycle." The concept of process, then, together with the concept of interaction, is vital in research if that research is to lead to more complete theory. Quite clearly, too, the concepts of process and of interaction are the most useful of those in the range of alternatives in avoiding the general

problem of restricted prediction and understanding that is inherent in building theory from present research.

2.2.2 Utility in Two New Concerns

In addition to the utility of concepts in regard to general problems arising in theory building, there is the equally important utility of concepts as tools in theory building and research in areas of new concern in the study of human communication. In this second regard, a concept would be judged useful if its application were central in development of theory and research relevant to the new area. It is, of course, impossible to review all of the new concerns in the field of communication in this limited space; hence, a choice is necessary. The two areas of human information processing and of system development appear to be particularly important, and have been chosen both because they are highly general in scope and because they have received relatively little study in the discipline, even though attention has been called to them.

Human information processing.-- It is worth noting, initially, that some question exists as to whether the universe of discourse of this new concern is greater than, equivalent to, or subsumed by that of human communication. The question will be answered here by noting that G. R. Miller (1969) has pointed out certain general problems common to both areas. Concerning one of these problems, in particular, Harrison (1967a, pp. 1-10) has emphasized that communication scholars need to redirect their attention to the important decoding aspects of human information processing, instead of concentrating so exclusively on encoding skills as they have done in the past. G. R. Miller has

been more specific: "Little is known about the complex process through which people select, interpret, and respond to information (1969, p. 61)." Miller expands his statement by adding a wide range of questions to be answered about how information processing occurs in human events.

The questions posed cover events such as those of seeking and disseminating information; of using information to influence, to decide, and to resolve conflict; and of using information to facilitate growth and development, among others (G. R. Miller, 1969, p. 62). Such events have in common not only the presence of some form of information, but also one other very basic property--each involves complex variation or change over time within the event. That is, information is input, "processed," and output, often with high frequency, during the course of any of these events. The complexity of this information processing during an event becomes evident, though, only when one considers that the human organism has distinct limits on the amount of information it can handle in a given time. In order to work within these limits, the organism may, for example, segment a larger input of stimulation or information into "chunks," and then handle the chunks as basic units--all of this while the information input is continuing (G. A. Miller, 1956, pp. 90-95; J. G. Miller, 1965b, pp. 349-350).¹³

¹³Note that "chunking" is only one of several ways which organisms have for coping with large inputs of information. Platt (1969), for example, discusses a number of alternative means appropriate to different situations.

Quite obviously, then, human information processing involves change over time or process as an integral aspect, even for a relatively simple event. Accordingly, much of the research which is done on information processing will have to employ designs which operationalize the concept of process, just as the associated theory will have to include the concept among its basic terms. It is this centrality of the concept of process which makes it highly useful in the development of theory and research on human information processing. In addition, of the other concepts in the range of alternatives, it is clear that structure, or information, is a central concept in this area, as well; hence, the two concepts are grouped here as equally useful tools in this new concern in the study of human communication.

System development.-- The second of the two new concerns is closely related to an important endeavor or goal in the discipline of communication: that of attending to "problematic situations" (Krippendorff, 1969a, p. 112), or of relating "the results of research to the operational problems of society . . . (Berlo, 1969, pp. 7, 16)." There are, of course, many different ways to attain this goal, among which is the area of new concern with the design and development of more effective communication systems, whether new systems or old ones (cf. Harrison, 1967a, p. 10; 1969b, pp. 4-5). Communication scholars have, of course, been called on frequently to consult on the problems found in communication systems, or to design components for existing or projected systems. The problems of the design and development of communication systems as systems have only begun to receive attention from such scholars, however, perhaps in part because they present a

number of new, difficult tasks and questions to the designer.

For example, in dealing with any system, the designer is immediately confronted with the often time-consuming task of specifying the goals of the system in a form suitable for later "performance testing." Once this task is complete, he is faced with several general categories of questions related to system design: How will the system maintain (or stabilize) itself? How will it terminate and what will be its life cycle? (Campbell, 1969; Harrison, 1967a, p. 9; 1969a, p. 88; 1969b, pp. 1-2). Such questions have not often been asked in past attempts at the design of, say, a teaching or interview situation which will also be an effective communication system. Yet such questions must be asked, and answered, if something more than speculation is to be given in response to questions like: Are the system outputs being properly minimized, maintained, or maximized? Or, is the system efficient with respect to the goals which were set, or to criteria like cost and effort?

These latter questions, and the hundreds of more specific ones which accompany them, are frequently difficult ones to answer, even when the system under design is fairly simple in comparison to a human communication system. In fact, the study of relatively straightforward systems reveals that the ability to find any answer at all to such questions depends heavily on the ability to describe or analyze two key aspects of the system involved: the relationships among system components, and the change over time or process which each component exhibits (Koenig, 1967). The concepts of system and of process are integral in these key aspects of systems and hence are central in the

theory, analysis, and research associated with system design and development. Quite clearly, considering the range of alternative concepts, these two are also the most useful for theory building and research in this new concern in the discipline of communication.

Because this review of new concerns could not be exhaustive, it has been the generality of these two areas, as well as the relative lack of study which they have received in the discipline, which has prompted their selection from among other foci of concern. It is important to note, however, that while the concept of process has utility in theory building and research in these areas of new concern in communication, it has utility only in combination with one of the other concepts from the second subset of alternatives: structure; and system. Likewise, in the earlier discussion of general problems in research, the concept of process had utility in avoiding each type of problem, but again, only in combination with a concept from the first subset of alternatives: emergence and interaction.

The fact that process occurs as a useful concept together with these other concepts only more clearly underscores the comment made at the end of the previous section. To wit, a fuller understanding of communication events will come in large measure only as concepts begin to be considered in combination in research. On the other hand, given that attention must be directed, for the present, to only one concept, it is the consistent utility of the concept of process that leads to its choice from among the other concepts as the most useful tool in the conduct of research and theory building in communication (Smith, 1967).

Beyond this discussion of the criteria for choosing the concept of process as the focus of attention, however, there remains an important unanswered question: What is the current place of the concept of process in research related to human communication? The answer to this question should not only expand on the importance of the concept of process already indicated in this chapter, but also open the way to considering the means of explicating the concept.

2.3 The Current Place of Process in Research

Given that the concept of process appears to be an important and useful concept in research and theory building in communication, it is worthwhile to examine the extent to which the concept has been incorporated in research. In view of the earlier discussion of the concept of process as related to general classes of research designs, this task can be seen as one of determining the degree to which studies concerned with human communication have used designs which operationalize the concept (see page 39). In other words, to what extent have process designs been used in communication research, with respect to point and difference designs?

It is of course clear that a precise evaluation of the extent to which a particular class of designs has been used involves a review of research far beyond the scope of this paper and of most books. Accordingly, a somewhat imprecise evaluation of extent must suffice--an evaluation based, in this case, on an estimate of the relative usage in communication research of a number of common observational and experimental research designs. As an aid in making this evaluation, it will be helpful to set up a classification scheme for the

basic designs currently used in research in disciplines like education, psychology, and communication. Such a scheme, and the resulting classification, is presented in Table 2, page 57. A brief description of the Table's two basic dimensions is in order before returning to the estimate.

2.3.1 A Classification of Research Designs

The horizontal dimension of Table 2, "Number of Observation Points," is drawn from the earlier discussion of three general classes of research designs (see page 34ff). The basis for classification on this dimension is, as before, the number of observation points provided in a particular design. Again, an observation point is a single point in time in a research situation at which variables are measured, regardless of whether the measurement takes place for one or more groups. Thus, "after-only" designs have one observation point, while "before-after" designs have two. Replication of a design at a later point in time does not increase the number of observation points, even when the replicated data is included in the overall analysis. Likewise, when a particular basic design is repeatedly conducted with a single group (designs 8 and 9, Appendix A), the number of observation points is not increased, but remains as given in the basic framework.

As noted earlier, a point design with only a single observation point (first column of Table 2) will produce what were termed "point" data. A difference design with two observation points (second column) will produce "difference" data. Process designs with three or more observation points (third column) are those which are capable of producing data that characterize the form of variation within an interval,

Table 2. A Two-Way Classification of Research Designs.

Nature of Research Design ^a	Number of Observation Points		
	One (t_1)	Two (t_1, t_2)	Three or More ($t_1 \dots t_n; 3 \leq n < \infty$)
	Point Designs	Difference Designs	Process Designs
Pre-Experimental	One-Shot Case Study (1) Static Group Comparison (3)	One-Group Pretest-Posttest (2)	---
True Experimental	Posttest-Only with Control Group (6)	Pretest-Posttest with Control Group (4) Solomon Four-Group (5)	Pretest-Posttest with Control and Time Extension (Howland)
Quasi-Experimental	---	Equivalent Time-Samples (8) Equivalent Materials (9)	Time-Series (7)
	Counterbalanced (11) (Includes Latin Square; may have two observation points)	Nonequivalent Control Group (10) Separate-Sample Pretest-Posttest (12, 12a, 12c)	Separate-Sample Pretest-Posttest with Time Extension (12b) Multiple Time-Series (14)
		Separate-Sample Posttest with Control Group (13) Institutional Cycle--Patched-up (15) Regression-Discontinuity (16)	
Non-Experimental	Correlational, ^b Retrospective Pretest, Ex Post Facto (Campbell, 1963, pp. 64-66, 70)	Two-wave Panel (A) (Campbell, 1963, pp. 67-69)	"Multiple-wave" Panel (B) (Lazarsfeld, 1938, 1948)

^aThe vertical dimension is that given by Campbell and Stanley (1963), including the distinction of "pre-" and "non-" experimental "designs." The numbers (letters) in parenthesis refer to the Campbell and Stanley volume, and (or) to the schematic presentations in Appendix A. Factorial designs are considered to be extensions of designs (4) and (6).

^bA correlational design is one in which data are collected for the sole purpose of establishing a correlation between certain factors. Note that correlational statistics (of all types, including partial correlation, multiple regression, and factor analysis) are analytic techniques, as is systems analysis, (Carroll, 1968, pp. 11-13). Such analytic techniques are not entered in a table of data collection procedures or designs (see Coombs, 1953, p. 495).

i.e., the process. It is important to note, though, that three observation points are not always sufficient to adequately characterize a particular form of variation. The minimum number of points needed is, instead, intimately related to the form of variation involved, and may be any number up to infinity (∞), or continuous measurement.

The vertical dimension of Table 2, "Nature of the Research Design," is taken from Campbell and Stanley's (1963) discussion and classification of common, basic research designs. Although these authors are primarily concerned with designs which might be applied in educational research settings, their compilation draws on, and appears applicable to, many diverse research interests. While no claim is made, here, for the exhaustiveness of their presentation, the authors do attempt to be moderately comprehensive, and have included the basic designs most frequent in communication research.

The basis for classification on this dimension is the degree to which a particular design approaches a true experiment. The latter is taken by the authors to be one in which the researcher has both full control over the exposure to experimental stimuli (i.e., the manipulation of independent variables), and the ability to randomly select who will be exposed (i.e., to establish adequate experimental control) (1963, p. 34). The true experimental designs are described briefly in the second row of Table 2. The "pre-experimental" designs in the first row are those which have ". . . such a total absence of control as to be of almost no scientific value (Campbell, 1963, p. 6)." The "quasi-experimental" designs indicated in the third row, however, include

some degree of experimental control, but fall short of the full control of the true experiment. The designs included in the fourth row are discussed by Campbell and Stanley, with one exception, but are not given a generic name. They have been termed "non-experimental" designs, here, following common practice.¹⁴

The brief descriptive titles which have been given to each of the designs in the body of Table 2 are those assigned by Campbell and Stanley. A full description of each design is given in their volume, along with a schematic showing each design's key features. For ease of reference, these schematics have been reproduced in Appendix A, and are keyed to Table 2 by means of the numbers in parenthesis. It is worthwhile noting that Campbell and Stanley consider factorial designs to be extensions of designs (4) and (6) (1963, pp. 27-31). Note, too, that they do not consider research "designs" which involve replications to be separate, basic forms of designs, even when the data from the replications are included in the overall statistical analysis. For this reason, together with that above regarding observation points, replicated designs are not included in the table.

2.3.2 Relative Use of Research Designs

The result of combining the Campbell and Stanley dimension describing the nature of a research design, with the dimension

¹⁴Clearly, other classifications of designs are possible, as for example those by Cox (1958), Kirk (1968), Lindquist (1953), and Trolldahl (in press). Each such classification, however, reflects a particular focus of interest in its choice of dimensions. For the purposes of the analysis to be made here, the dimensions which have been selected appear to be the most highly relevant and useful.

categorizing the number of observation points, is the particular two-way classification of common, basic research designs shown in Table 2. Again, the classification has been set up as an aid in determining the degree to which studies of human communication have used designs which operationalize the concept of process. More specifically, the classification is to be used in evaluating the extent to which research has used process designs, with respect to point and difference designs. Such an estimate of relative usage can be made most directly by examining Table 2 and noting the relative prevalence in research of certain types of designs. Such an examination reveals that the designs most frequently used in human communication research are point and difference designs, rather than process designs.¹⁵

While a number of exceptions to this general pattern of use do exist (and will be discussed below), it is evident that both past and present comment on the "state" of communication research lends support to this estimate. In his 1959 article, for example, Berelson notes that in its first twenty-five years human communication research was characterized by techniques such as content analysis, sample survey, and both "quasi-natural" and laboratory experiment. An examination of the research which Berelson considers in his comments reveals, however, that these different techniques, whether in observational or experimental research, were seldom employed with process designs.

The relatively small use of process designs is also evident in Krippendorff's (1969b) recent discussion of communication research.

¹⁵Among the designs in Table 2, numbers 4 and 6 are certainly heavily used in experimental research, as are correlational "designs" in observational research.

In his article, Krippendorff analyzes the nature of the data which has been produced by past communication research, and finds that the bulk of such data do not fulfill even the minimum requirements he establishes for "communication data" (1969b, pp. 14, 34). While there are several different requirements for acceptability as "minimum" communication data (Krippendorff, 1969b, pp. 23-33), it appears that one which is only occasionally satisfied is that requiring the data to provide information on ". . . the sequence of states of the system . . ." (1969b, p. 28; see also pp. 21, 23, 26)." Since process designs are the only ones capable of providing such information, it is apparent that such designs have been little used in communication research.

While Berelson's and Krippendorff's comments on research do support the estimate of relatively small use of process designs with respect to point and difference designs, they provide no basis for evaluating extent or magnitude of use. One means of gaining such information is to consider briefly various past uses in human communication research of each of the process designs. In examining these exceptions to the general pattern of use, it will be helpful for purposes of later discussion to distinguish both between observational research and experimental research (page 33n), and between the data collection procedure or design, and the analysis of the data which is produced.¹⁶

¹⁶The second distinction has already been discussed (see page 34ff), and is consistent with the distinction made by Coombs: "The method of collecting data determines what information they contain, but the method of analysis defines this information . . ." (1953, p. 495)."

Pretest-posttest with time extension design.-- The first design noted in the third (or process) column of Table 2 is one which Campbell (1963, pp. 31-32) associates closely with Hovland, et al., a point which makes clear that the research reviewed by Berelson in 1959 did include at least some studies using process designs. This particular design has been termed here the "pretest-posttest with control group and time extension" design, and has been used by Hovland and others (see review in Hovland (1953, Ch. 8)) in experimental research on attitude effects over time. A similar posttest only design has been used by Insko (1964) in a study of primacy-recency effects. Typically, the data collection using this design involves three observation points, although four or more might be used in a large study. The analysis of the data generally considers the time dimension inherent in the data, since it is usually of primary importance in the study.

Time series designs.-- The "time series" design noted next in the third column, and the "multiple time series" design noted below it, are sufficiently similar to allow joint consideration. While these two designs appear to be little used in communication research in their "pure" forms (those presented by Campbell and Stanley, 1963, pp. 37-43; 55-57), there are several areas of research relevant to communication which make use of closely related designs. Such designs can be found particularly in the areas of interaction analysis and language behavior, as well as in research in "ecological psychology," and in arousal. A brief look at each area is in order before returning to the consideration of other process designs.

Within the broad scope of interaction analysis research, there are a number of observation techniques whose sampling schemes tie them closely to the time series designs. These techniques include those of Harrison (Verbal-Non Verbal Interaction Analysis, 1969b), Lennard and Bernstein (Clinical Sociology, 1969), Lindsley (Conjugate Programming, 1969), Scheflen (Context Analysis, 1966), Bales (Interaction Process Analysis, 1950), Chapple (Interaction Chronograph, 1948), Ekman (1957), and Flanders (Interaction Analysis, 1967). For the most part, the research which has been done using these techniques has been observational research, owing to the purposes for which they were developed (Frahm, 1969). However, work using the latter four techniques (Bales, Chapple, Ekman, and Flanders) has included experimental research, and certainly all of the techniques are potentially useful in such research.

Although there is some danger of overgeneralization when considering these interaction analysis techniques as a group, they typically involve a data collection procedure which samples an on-going behavior at a number of points in time. The distribution of these points varies from essentially continuous sampling (Chapple, Lindsley, Scheflen), to short, regular intervals (Flanders, Harrison, 3 sec.; Ekman, 12 sec.), to intervals determined by the characteristics of the behavior itself (Bales, Lennard and Bernstein).¹⁷ Such sampling

¹⁷Note that the sampling, not the recording, of the behavior is of prime concern here. That is, on-going behavior is often recorded on film or tape in such techniques for use in later study. While such recording involves "sampling" (angle of camera, 16 to 30 frames per second), this is not the sampling which produces data for analysis (unless each frame of a film is analyzed separately). See Ekman (1969, p. 298) for further discussion.

procedures clearly link the "designs" used in these techniques to the time series designs. Not infrequently, however, the analysis of data produced by these techniques either partially or completely removes the time dimension inherent in the data. This is especially true of the interaction matrices produced using the techniques of Harrison and Flanders, and is often the case with the analyses of data produced by the other techniques. Of particular interest in the context of this paper, however, are occasional analyses such as those by Frahm (1970), Lennard and Bernstein (1969, pp. 70-77), and Lindsley (1969), which directly take the time dimension into account.

The broad range of research in language behavior also includes a number of studies which make use of designs closely related to the time series designs. Of the two research interests which are of special concern here, the area of developmental linguistics is perhaps the one most fundamentally concerned with the dimension of time (Smith and Miller, 1966). In particular, much of the work reported by Brown and Bellugi (1964), Erwin (1964), and Templin (1966) has been in the form of longitudinal studies, with the primary intent of observing and describing various aspects of language development in children. Such studies normally involve data collection procedures which sample the developing behavior at intervals ranging from two weeks (Brown and Bellugi), to six months (Templin). The analysis of the resulting data does, of course, generally take the time dimension into account since it is a primary concern.

In addition, some of the research which has been done in the area of extralinguistic aspects of language behavior has also involved

a concern with the time dimension. In particular, Mahl and Schulze (1964) have noted a number of both observational and experimental studies concerned with the expression of anxiety through changes over time in such non-verbal, vocal features as voice quality (pitch), interruptions of continuity, silent pauses (non-fluencies), and speech rate, as well as in certain temporal characteristics of interaction. Studies of these particular extralinguistic features have frequently involved data collection procedures which sample the language behavior either at regular intervals, or at intervals determined by certain characteristics of the behavior. Again, it is the sampling procedure which links the designs used in these extralinguistic studies, as well as those used in the language development studies, to the time series designs. Unlike the case for language development, however, the analysis of data from extralinguistic studies often removes the inherent time dimension. Among those studies which do consider time are ones like that of Mahl and Schulze (1964, p. 60) using a device such as the Interaction Chronograph, and ones like those of Mahl (1963), observing emotional expression; of Starkweather, et al. (1969), studying non-verbal, vocal expression of mood; and of Matarazo (1966, pp. 157-158), experimenting with interruption behavior.

In addition to the two areas of interaction analysis and language behavior, there are two other areas of research which demand brief attention because they include designs related to the time series designs. One such area is that termed "ecological psychology" by its proponents, Barker (1968) and Wright (1967). Research in ecological psychology is entirely observational and employs a technique which

attempts to record as much as possible of an on-going behavior in its actual context. The recording of the behavior is therefore essentially continuous, although the analysis divides or samples the behavior in terms of natural "units" (Barker, 1968, pp. 11-17). The analysis of the data produced does frequently consider the time dimension, but often in a qualitative rather than a quantitative form, as in the small group studies of Jordan, et al. (1963).

Perhaps more important with regard to the study of communication, however, is the research in the area of human arousal, particularly as evidenced in the work of Berlyne (1960, 1965). In very general terms, much of the experimental research done in this area of human information processing has examined the relationships between arousal (in several forms), and various situations in the environment such as conflict, surprise, etc. Other similar research such as that by Greenberg (1970) has examined changes in EEG activity during the learning of speech and non-speech stimuli. The data collection procedures used in such studies generally involve either continuous or small-interval sampling of the on-going behavior, a feature which of course links them closely to the time series designs. The data analysis, as well, frequently takes the time dimension into account.

This brief digression into research in the areas of interaction analysis, language behavior, ecological psychology, and arousal reveals, then, that research in human communication has made some use of research designs which are closely related, though not identical, to the time series designs noted in the third column of Table 2. In addition to the time series designs, however, there are two other process designs which

require discussion.

Separate-sample with time extension design.-- The design described in the third column by the title, "separate-sample pretest-posttest with time extension," is one which is occasionally employed in sample survey research. This particular design is a variation of a more basic design noted in the second column, and has an advantage in that it may be used to control for the effects of history, maturation, and other temporal trends (Campbell, 1963, p. 53). However, while the more basic "separate-sample pretest-posttest" design has been used in research in human communication (Star, 1950), the time extension design appears to have found little application.¹⁸

Multiple wave panel design.-- The final design noted in the third column of Table 2 has been termed the "'multiple wave' panel" design. This particular distinction among panel designs is not a common one, although the nature of such designs (as opposed to "two wave" designs) is evident in Lazarsfeld's early discussions of the panel technique (1938, 1948; see also Zeisel, 1957, pp. 215-254). The multiple wave panel design has been used in communication research (Lazarsfeld, 1944), and is one of the designs included in the research to which Berelson refers in his review (1959). Despite this use, however, the two wave design has clearly remained the predominant design whenever panel techniques have been employed (see Campbell, 1963, p. 67; Lazarsfeld, 1948; Zeisel, 1957, pp. 215-254).

¹⁸Campbell (1963, p. 54) notes that these designs, as a group, are frequently used primarily to gain generalizability or accessibility to respondents.

Perhaps conspicuous by their absence in this consideration of past uses of process designs in communication research are the two broad areas of diffusion and psycholinguistics. Clearly the time dimension is of fundamental importance in theory dealing with the diffusion of innovations (Rogers, 1966, p. 30; 1967, p. 8; forthcoming, Ch. 2). It is evident, however, that much of the research in diffusion depends on designs involving one or at most two observation points (Rogers, 1966, p. 30), often supplemented by recall (see page 35n and Rogers, 1967, p. 8).¹⁹ The same is true for studies of the diffusion of news events, often patterned on the studies by Deutschmann and Danielson (1960) which utilized a single observation point. While an exception to this general pattern appears in a report by Kivlin, et al. (1968), analyzing data from the third phase or observation point of a major study, it is evident that research in diffusion has made little use of process designs.

A similar comment might be made about several different research interests in the area of psycholinguistics (excluding language development and extralinguistic phenomena), particularly as that field has been reviewed by Osgood, Sebeok, and Diebold (1965). While much of the theory and research in this area is not inherently concerned with the dimension of time, certain interest areas such as sequential psycholinguistics would, at first glance, appear to hold time as central.

¹⁹Systems analysis has been proposed as a means of freeing diffusion studies from dependence on one or two observation points (Carroll, 1968, p. 13). Systems analysis, however, is an analytic technique, not a data collection procedure or research design.

Closer examination (Osgood, 1965, pp. 93-125 and pp. 228-234) reveals, however, an overriding emphasis on the statistical structure of messages and particularly on transitional phenomena, rather than on time relationships. Accordingly, the research done in this interest area is frequently observational and analyzes spoken or written records to establish probabilities of occurrence and of transition. Experimental work, as for example that by Howes (1954), is likewise often concerned with establishing probabilities.²⁰ A similar lack of emphasis on the time dimension can be found in the psycholinguistic research interests which Osgood, Sebeok and Diebold (1965) termed "synchronic" and "diachronic" psycholinguistics. Exceptions do occur, of course, in which the time dimension is considered in such research, but in general the area of psycholinguistics, like that of diffusion, has made little use of process designs.

Clearly this relatively brief discussion of past uses (and non-uses) of process designs in human communication research is neither exhaustive nor comprehensive. It is not exhaustive both because of the limits of space, which force a focus on broad areas of research rather than on individual studies, and because of the difficulty of setting limits on what is or is not relevant to the study of human communication.²¹ In this latter regard, it is important to note that while a

²⁰It is worthwhile noting that the Cloze procedure (Taylor, 1953, 1956), which is a frequently used tool in sequential psycholinguistics, does, in effect, collect data over a time dimension in a manner not unlike that found in the time series designs. However, the analysis of such data typically removes any time dimension present in the data.

²¹It is evident, however, that a great number of the studies mentioned above do not meet the requirements for producing minimum

distinction has been made between observational and experimental research, both are considered relevant in this context. This brief discussion of past uses of process designs is not comprehensive in the sense that much more could be added to the consideration of each area of research, especially with regard to the purposes for which the research was performed. It is because such purposes often do not require a consideration of the time dimension that a distinction has been made between the data collection procedure used in research and the analysis of the data produced, the latter being keyed to purpose, rather than to research design.

These two broad limitations do not, however, prevent the above discussion of research from serving as a basis for evaluating the extent of use of research designs from the general class of process designs. That is, while it is evident from the above discussion that process designs have been used in certain areas of communication research, it is clear that these particular areas by no means comprise the mainstream of such research. Within the larger body of human communication research, then, the use of process designs can be seen to be relatively small in comparison to the use of point and difference designs--an evaluation consistent with the information provided by both Berelson's (1959) and Krippendorff's (1969b) comments on the state of communication research.

This evaluation of the relative use of process designs clearly supports the estimate made earlier by examination of Table 2 that communication research has depended to a large extent on point and

communication data, as identified by Krippendorff (1969b, pp. 23-33).

difference designs. In slightly different terms, it is evident that studies of human communication have made only small use of designs which operationalize the concept of process.²² Why the "state" of communication research should be thus restricted is a matter of some interest, given both that the concept appears to be a useful one in research and theory building, and that a number of scholars have made calls for research and theory which deal with communication events as processes--Barnlund (1968, p. 23), Chronkite (1969, pp. 128-133), Krippendorff (1969b, pp. 34-35), Schefflen (1968, p. 45), and the Speech Association of America (Kibler, 1969, p. 35), to mention but five.²³ A brief consideration of why the concept of process has not been more evident in communication research is therefore appropriate, and will serve as a preface to an overview of the central concerns of this paper.

2.3.3 A Bigger Picture

The question of why communication research has made only small use of designs which operationalize the concept of process is one which can prompt lengthy speculation. It is not the purpose here to delve into "causes," except to suggest three very general, yet relevant factors. The first, of course, is that a concern with the concept of process is not necessarily central in all human communication research, just as it is not necessarily central in all research done in the other

²²In fact, the use of designs which operationalize process is somewhat smaller than it appears from the preceding discussion. That is, not all of the above uses of process designs meet the minimum requirements for characterizing a process (see page 33 and Chapter 4), though they are capable of doing so under certain conditions.

²³One is reminded of Mark Twain's proverbial comment concerning discussion of the weather and failure to act.

areas of communication (e.g., telecommunication) which are encompassed by Krippendorff's definition (see page 11ff). In some cases, then, point and difference designs may be entirely sufficient for research in human communication. For those cases in which process is central in research, however, it is quite apparent that the concept has not always been operationalized.

This situation may exist in part because of a second general factor; namely, the extreme complexity of human communication events. Communication scholars have often noted the difficulty or impossibility of adequately modeling communication events, especially with respect to the "process," in its broad sense, which is involved (Berlo, 1960, p. 25). From this point of view, change over time or process, in its narrow sense, is only one of many aspects to be considered in modeling a communication event, a point which may account for some of the lack of attention to the concept in the construction of communication models. Failure to adequately deal with the concept in building models would then certainly be reflected in a lack of concern with process in research based on such models.

A third and perhaps most cogent factor in the failure to consider the concept of process, however, revolves around what Kaplan has called "the law of the instrument"--the idea that a research technique, once made available, will occupy the center of attention. Kaplan expresses it delightfully in the sentence, "Give a small boy a hammer, and he will find that everything he encounters needs pounding (1964, p. 28)." That is, the presence of a set of research designs of considerable power and advantage over other modes of inquiry into human communication may have

so occupied researchers that designs which would operationalize the concept of process may not have been sought out, or even recognized as lacking. Certainly if words or concepts can limit what their users perceive in events, the heavy use of point and difference designs may also have limited researchers both in viewing and in studying communication events.

Whatever more factors may be adduced, it is evident that except for a relatively small body of work, communication events have not been studied as processes. More succinctly, the current place of the concept of process in human communication research is a small one. Such an evaluation, based as it is on a consideration of the relative use of research designs, is not of itself a sufficient reason for selecting the concept of process for special attention in this paper. This particular reason is, however, one of the four which together have determined the selection. The other three reasons deserve brief mention, once again.

A second reason for the selection, mentioned several times in this chapter, is the important place of the concept of process in definitions and discussions of communication. Scholars have continually pointed to the concept as a vital one both when defining their universes of discourse, and when discussing basic concepts, as well as research, theory, and models. A third reason for the selection is that operationalization of the concept in research can provide information which is needed in theory building. That is, operationalizing the concept as indicated above can provide information on the sequences of states occurring in an event, or, more generally, on the form of variation

or change over time of key variables in that event. That such information should be provided by the research upon which communication theory is built is perhaps one of Krippendorff's primary concerns in his recent article on data in communication research (1969b). The fourth and primary reason for selecting the concept of process for special attention, however, is its utility in the conduct of research and theory building. As discussed earlier, the concept appears useful not only in avoiding certain problems (like spurious categorization) encountered in research, but also in dealing with new concerns (such as human information processing) arising in the discipline of communication.

It has been the burden of these first two chapters, then, to develop and consider the reasons for selecting the concept of process for special attention. Again, the concept is but one of several aspects of events which must be considered in research (see page 40). Given the limits of space, however, it is the broad utility of the concept in the conduct of research and theory building in communication which has lead to its selection. It will be the burden of the remaining chapters to focus on the concept of process, alone, and to consider the means of explicating it for further use in research and theory building (see page 9ff).

Because an explication requires both a constitutive and an operational definition, the first step in what follows (Chapter 3) will be to discuss approaches to a constitutive definition. More specifically, consideration will be given to a number of possible links between the concept of process and other verbal and mathematical terms which might

apply in a future theory of human communication. Also, since the form of a theory depends on the nature of the terms which comprise it, it will be appropriate to consider the implications which the approaches to a constitutive definition have for the form of theories dealing with communication events.

The second step (Chapter 4) will be to discuss approaches to an operational definition of the concept of process. That is, drawing on the information provided in Chapter 3, consideration will be given to the requirements which must be met if a research design is to produce data which adequately characterize a given form of variation or change over time. Designs which meet these requirements are, of course, operationalizations of the concept of process. In addition, given these requirements, it will be appropriate to consider the implications they carry both for research techniques, and for analytical techniques.

Such discussions of approaches to both constitutive and operational definition of the concept of process will require the consideration of terms and techniques drawn from a number of sources outside the discipline of communication. While each of these research tools may find some future place in the study of human communication events, they will not be presented here as suggested replacements for present research techniques. Rather, they will be presented as potential additions to present techniques in order to expand the range of those techniques to fill the "hole" or vacant spot in the classification of research designs (column 3, Table 2, page 57).

In addition to the consideration of approaches to constitutive and operational definition, it will be helpful to consider both

examples of research which takes the concept of process into account (Chapter 5), and certain broader implications of the concept's explication and place in research (Chapter 6). These two chapters, together with the two devoted to explication, will, in a broad sense, serve to develop the earlier point that research which considers communication events as processes will provide information on how those events occur, not just on whether or not they did occur.

It must be emphasized again, though, with respect to the phrase "how those events occur," that the interest in the concept of process in this paper is not motivated by a desire to determine how events "really" occur, i.e., to determine causal bonds. Instead, the interest stems from a desire to determine how, or in what manner, events take place, i.e., to determine certain characteristics of the sequences or "paths" over which they develop. This latter form of information is seen as lacking to a large extent in human communication theory and research to date, yet at the same time as vital and useful in that theory and research. The concern in this paper, then, is to provide a basis for the development of research tools to be used in providing this missing information. Such development and eventual use does not promise to be easy, both because of the effort involved, and because, like any change, the overall effect may be to alter both the ways in which events are studied, and the very content of those studies. In this case, however, the potential change should prove to be highly beneficial to the study of human communication.

CHAPTER 3

APPROACHES TO A CONSTITUTIVE DEFINITION

The previous chapter has indicated that the concept of process or of change over time is an important and useful one in the conduct of research and theory building related to human communication. The choice of the concept for special attention on the grounds of its importance and utility leaves the task of explicating it for use as a tool in research and theory building. As indicated, the first major step in this explication will be to provide approaches to a constitutive definition of the concept of process. Chapter 3 will be devoted to that step, as well as to an examination of the implications which the approaches have for theory. Chapter 3 will lead to a consideration of approaches to an operational definition in Chapter 4.

3.1 Nature of the Definition

As mentioned earlier, in Chapter 1, a constitutive definition of a concept specifies linkages to other terms in the code, language, or theory which the investigator manipulates to produce propositions about the events under study (see page 9ff and Berlo, 1967, pp. 3, 8). It was noted in the same discussion, however, that a formal constitutive definition can be formed only in the context of a specific theoretical framework, a situation which does not apply here because no attempt is made herein to build a theory of communication. As a result, rather than attempt to link the concept of process to the terms of some specific,

but premature, theory of communication, the concept will be linked instead to a set of terms which might have a place in future theories. In other words, the attempt will be to suggest various approaches to a constitutive definition by providing a set of links to various verbal and mathematical terms which might be utilized in future theories of communication. These suggested approaches not only provide the tools for forming constitutive definitions in specific theoretical frameworks, but also hold a number of important implications for the form of theory dealing with communication events.

Because the concept of process has received only relatively small attention in the study of human communication, it will be necessary in suggesting approaches to a constitutive definition to draw on information from a number of disciplines outside that of communication. Specifically, disciplines such as biology, mathematics, sociology, thermodynamics, and system theory and analysis will serve both as sources of information, and as sources of terms with which the concept of process is to be linked. The choice of information and of terms from these various disciplines will be eclectic, but will in all cases be a choice based on the criteria of consistency, generality, and above all, utility. The judgments on all of these criteria, and especially on utility, will be made in the context of potential use of the information or of the term as a tool in theory building related to human communication.

Despite this necessary eclecticism in choosing information, it will be fairly obvious in what follows that a relatively heavy dependence has been placed on the discipline of system theory and analysis. The dependence is not complete, however, in the sense that system theory

and analysis might be said to form a higher level theoretical framework underlying the discussion (despite the absence of such a framework avowed above). The disciplines of communication and of system theory and analysis do overlap, as is evident in the definition of communication considered earlier (page 11ff). Such a statement, however, does not indicate isomorphism of the disciplines, as should be evident from a study both of the criteria below for using system theory and analysis information, and of the "non-system" information and terms introduced in sections 3.2 and 3.3. The discipline of system theory and analysis is, then, a separate body of information as is mathematics or thermodynamics, but is more heavily exploited below because of its particular consistency, generality, and utility in the present concern with the study of human communication.

System theory and analysis is a broad-ranging discipline which concerns itself with phenomena characteristic of all forms of systems, both living and non-living. The discipline has drawn on concepts from many different fields, including those mentioned above, and has shaped this information into a single approach.¹ Among the concepts which are central in system theory and analysis are several which have been introduced earlier, in particular, concepts such as process, interaction, and emergence (page 33ff). That these important concepts from the present

¹It is perhaps misleading to consider "system theory and analysis" as a single approach, when in fact it appears to have at least three distinct "sub-disciplines" (Arundale, 1968). These sub-disciplines share a number of key concepts and approaches, however, and it is in this sense, as well as for clarity of presentation, that the discipline will be treated herein as single entity.

paper are also central in system theory and analysis makes this discipline particularly consistent with and appropriate to the concerns of this paper. In addition, the ability of system theory to deal, in an internally consistent manner, with the many types of systems in which communication occurs (page 16ff), reveals that it has the generality and scope necessary for use as a tool in building communication theory. Finally, because it is extremely fruitful in generating theory and research, and because it provides a wide range of tools for such study, system theory and analysis is an especially useful tool in the study of human communication.² It is the particular importance of system theory on the basis of these criteria which leads to the somewhat heavier dependence upon it, as a source of information, than upon other disciplines. Nevertheless, the attempt to suggest approaches to a constitutive definition of the concept of process will remain eclectic, drawing information and key terms from a number of disciplines on the basis of the criteria mentioned.

Again, as implied in the above, there will be no attempt in this chapter to build a single constitutive definition, or a unique set of

²There are, of course, a number of more extensive discussions of the overall utility of system theory and analysis as a tool in theory building and research (Bertalanffy, 1962, pp. 1-20 and 1968, Chs. 8, 9; Buckley, 1967, p. 39; Harrison, 1967a; and Rappoport, 1968, among others), all of which are relevant here. Note particularly that there will be no discussion in this paper of the basic concepts of system theory, in particular, the concepts of system, subsystem, suprasystem, component, matter-energy, information, interaction, emergence, etc., except as these have already been discussed in sections 1.2 and 2.1. Such concepts are nevertheless of some importance, herein, and a familiarity with one or more of the basic works on system theory has been assumed (Bertalanffy, 1968; Buckley, 1968; and especially J. G. Miller, 1965a, 1965b).

links to other terms. Rather, a number of potentially useful approaches to such a definition will be suggested and discussed. To do so, it will be helpful to divide the remainder of this chapter into three parts. That is, since verbal terms are more common than mathematical terms in theory building in communication, attention will be focussed in the second section on the verbal aspects of constitutive definition. However, because mathematical terms have a potential importance in dealing with the concept of process, and because they provide a different perspective, the third section will focus on the mathematical aspects of constitutive definition. These two discussions of approaches to a constitutive definition in two different "languages" will not only provide a number of tools for dealing with the concept of process in theory building and research, but also lead to a consideration of the necessary and sufficient conditions for the use of the term "process." In addition, since the form of a theory depends on the nature of the terms which comprise it, the fourth section will focus on the implications which these approaches to a constitutive definition have for the form of theory which deals with communication events.

3.2 Verbal Aspects of Constitutive Definition

Because theory in the discipline of human communication is most often expressed in verbal terms, the first major step in approaching a constitutive definition of the concept of process will be to consider links between this concept and a number of verbal terms which might have a place in future theories of communication. Quite clearly, the various linkages considered below are a subset of those which might be

discussed. Hence, the particular subset which has been included represents a choice of terms, in this case on the basis of their potential utility as tools in theory building related to communication. The discussion of these verbal aspects of constitutive definition falls conveniently into three parts. First, an examination in some detail of the verbal definition of the concept of process. Second, a consideration of the ties between this concept and several other closely related terms. And third, a brief discussion of several "kinds" or "types" of processes in an attempt to provide additional useful terms for dealing with different aspects of change over time. Because of the large number of terms and definitions introduced in this section, Table 3, page 83, has been included both as an outline and as a glossary useful for reference purposes.

3.2.1 The Verbal Definition of Process

As indicated from the outset by the Introduction, the central concern of this paper is with the concept of process, a concept which was defined verbally early in Chapter 1 as "All change over time of matter-energy or information . . . (J. G. Miller, 1965a, p. 209)." This definition or verbal equivalence statement has, of course, had the effect in subsequent discussions of making the terms "process" and "change over time" almost completely interchangeable. As was noted in early Chapter 2, the concept of change over time, as the central concern, could be discussed without recourse to the term "process," a possible advantage since the latter term is used in a number of different ways. However, because the element of change over time is common to these many alternative uses of "process," the term has been retained as a

Table 3. Outline and Glossary of Verbal Aspects of Constitutive Definition^a

3.2.1 The Verbal Definition of Process

<u>Process</u>	All change over time of matter-energy or information (within a bounded interval).
<u>Time</u>	A continuum of one dimension which is divisible into equal units, those units being ordered unidirectionally under the assumption that the entropy of the universe is always increasing.
<u>Matter-energy or information</u>	Defined as in system theory and analysis (see J. G. Miller, 1965a, pp. 193-199).
<u>Change</u>	A difference (including a difference of zero) in the value of a variable over two or more points in time.

3.2.2 Process in Relation to other Terms

<u>Structure_m</u>	The static arrangement of a system's parts at a moment in three dimensional space. Structure _m is therefore a system's configuration at any one instant or point in a process.
<u>Function</u>	The transient and reversible changes, often repetitive, that constitute behaving or functioning. Function is thus a subset of process involving reversible change.
<u>Purpose</u>	The internally determined control process of a system which maintains at least one of its variables at a given steady state value.
<u>History</u>	The enduring and irreversible changes, often progressive, that constitute becoming or development. History is thus a subset of process involving irreversible change.
<u>Evolution</u>	A subset of history in which the basic event is one of mutation.

3.2.3 Types of Process

General Descriptors:

<u>Reversible</u>	A process, which once having taken place, may be retraced so as to leave no change in either the system or its surroundings.
<u>Irreversible</u>	A process which may not be retraced without changing the system or its surroundings.
<u>Static</u>	Processes in which the value of the variable under consideration does not change over time.
<u>Quasistatic</u>	Processes in which the deviation from the static situation is infinitesimal, so that the process may be treated as static with essentially no error.
<u>Cyclic</u>	Processes in which a variable changes from some specific value or state, only to return eventually to that same value or state.

Specific Descriptors:

<u>Morphostatic</u>	Processes which tend to preserve or maintain a system's given form, organization, or state. Such processes maintain the values of variables within specific "ranges of stability," and are often termed "dynamic equilibrium" processes. These processes are often convergent, and may be either reversible or irreversible.
<u>Morphogenetic</u>	Processes which tend to elaborate or change a system's given form, structure _m , or state. Such processes move the values of variables outside of ranges of stability and hence are "non-equilibrium" processes. They may be divergent, and can be either reversible or irreversible.

^aThe sources of these definitions are given in the discussion.

useful organizing device for discussion, to be used only in the narrower sense of its definition as "change over time."

As a first step in considering the verbal aspects of constitutive definition of the concept of process, it will be helpful to examine this verbal definition of the central concept in greater detail. The effect will be to link the concepts of "process" and of "change over time" to a number of other important terms. Note again that no attempt is made here to identify the definition given as the "correct" or "true" definition (page 11). That is, J. G. Miller's definition is but one of several equally serviceable definitions for the term "process" in its narrow usage. Other definitions could be used in its place with similar results, as exemplified below. Miller's definition has been chosen here because of its generality with respect to other definitions of "process."

The individual terms. - If one examines each of the terms in Miller's definition, it becomes apparent that the key word in this, and certainly in most definitions of "process," is the term "time." Above all else, the concept of process serves to call attention to the dimension of time, from among the many different dimensions of phenomena which might be attended to. The concept of time is a basic concern in this paper, as indicated in section 1.1, and has been the focus of considerable scholarly discussion (Reichenbach, 1956, 1958; Whitehead, 1925, Ch. 7, and 1929, Chs. 2, 10; etc.) Space prevents a review of this lengthy and involved discussion concerning "time," but does not preclude a more precise definition of the term. "Time" will be used here to refer to what is sometimes called "astronomical time": a

continuum of one dimension which is divisible into equal units, those units being ordered unidirectionally under the assumption that the entropy of the universe is always increasing. This latter qualification is an aspect of "thermodynamic time," as discussed by Bertalanffy (1968, p. 231), and reflects Eddington's statement that entropy is "the arrow of time (Bertalanffy, 1968, p. 151)."

While "time" is an important term in the definition of "process," it is not synonymous with it, in that "process" also refers to "change . . . of matter-energy or information." The concepts of matter-energy and of information, as used here, encompass all entities in the universe, and have, like time, been the foci of extended discussion, much too voluminous to review here. The two terms have been and will be used as they have been defined in the discipline of system theory and analysis (J. G. Miller, 1965a, pp. 193-199; see also note 2, above). Of much greater importance in examining the definition of the concept of process is the term "change."

As it appears in Miller's definition, "change" is used in its broadest sense; that is, the term refers not only to the presence of change or difference, but also to its absence. To clarify this seeming contradiction, it is helpful to consider again the representation of a process on a graph; i.e., if time is the abscissa and variable value is the ordinate of a graph, then a line on this graph represents a process and indicates the successive values of the variable at successive instants in time. On such a graph, there will generally be some identifiable change or difference between the values of the variable at any two given instants in time. The amount of change or difference

would be found, of course, by subtracting the two values of the variable. Note however, that in the special case where the values at the two instants are equal and the subtraction yields zero, it is still meaningful to talk of a "change" or "difference" between the values. In this case, the amount of change or difference is zero, but the two terms "change" and "difference" have remained the same, having been used in this second instance in their broadest senses.

Exactly the same situation obtains in Miller's use of the term "change" in the phrase "change over time." That is, the usage covers not only the case where a difference in variable value is present over two points in time, but also the special case where the difference is zero. The potential confusion of this broad usage can perhaps be cleared by considering briefly another definition of "process," in its narrow sense, which does not employ the term "change." This particular definition is drawn from the discipline of thermodynamics and utilizes both the concept of a path or form of variation, and the concept of a "state" or a set of values of variables at a single point in time (see discussion on page 35ff). According to this definition, "process" refers to "the path of the succession of states through which the system passes . . . (Van Wylen, 1959, p. 17)," the dimension of time being implied, as is frequently the case in the physical sciences due to its ubiquity. When defined in this manner, the concept of process can be seen to encompass all paths or lines which might be drawn on a graph such as that above, including paths or lines parallel to the time axis. Such a parallel line, translated into terms of

Miller's definition, would be considered to show zero change or difference. Thus, the two definitions of "process" are equivalent in encompassing both the presence and absence of change.

Additional comments. - In addition to this consideration of each of the terms in Miller's definition, it will also be helpful to examine three other important points regarding the verbal definition of the concept of process. The first point or comment is that the term "process" is a completely general term, as evidenced by the presence of the word "all" in the phrase "all change over time" That is, the variable which is plotted on the ordinate, in the graphic representation, can be any variable. Hence, if the variable is one of space, then the process which is represented is one of "movement." Similarly, if the variable represents the total amount of some substance, then the process is one of "growth," and so on. The concern here, again, will be with variables related to communication and particularly to human communication--a bias mentioned earlier (page 25), and reflected throughout the discussion.

The second comment is closely related to the first, and reflects a different aspect of generality in the concept of process. As mentioned in the discussion of "process" in section 1.2, the term is used in this paper to refer both to situations in which a single variable changes over time, and to situations in which multiple variables change over time. The latter case is the more general one, and would be represented graphically by several separate paths or lines, all extending through the same time span on the abscissa but each representing a different variable plotted on the ordinate. Because of its

simplicity, the single variable case is the most appropriate for explanatory purposes, and has been used above and will be used below. The simplicity gained in these uses does not bring a loss in generality, since the principles discussed for the single variable case can be directly extended to the multiple variable case, and since the primary interest in this paper is in the relationship of variables to time, not necessarily to each other.

The third, and perhaps most important comment regarding the definition of "process" is closely tied to the discussion in section 2.1 of the "continuity" of an occurrence. As defined by J. G. Miller, a process has no bounds and may be viewed as extending indefinitely in time, i.e., as having continuity. It is clear, however, that no human observer can study a process in its continuity. The observer is forced, instead, to divide that continuity into segments which he is capable of observing, the division being either implicit, through the limits of perception, or explicit through the identification of specific bounds in time. The need to segment the continuity of occurrences is particularly pressing for the scientific observer, who can discriminate properties and patterns in a process only to the extent that such properties and patterns repeat themselves over intervals of time which he can recognize and explicitly delimit.

These implicitly or explicitly segmented intervals of time were earlier termed "events" (page 13), and because this segmentation or bounding of occurrences is basic to science, all reference to a process in this paper will be to a process as it takes place within the bounds of an event. Such a restriction of the term "process" to

events is at variance with Miller's definition, but is seen as useful in its consistency with the behavior of human observers in dealing with the continuity of occurrences. Note also that references in this paper to a process or change over time, in the interval between two time boundaries, assumes that those boundaries are set by the observer, not by the event.³

These three comments on various aspects of the verbal definition of "process," together with the consideration of the individual terms in the definition, constitute a somewhat more detailed examination of the verbal expression of the concept of process. Such an examination is only a first step in considering the verbal aspects of constitutive definition. A second step of at least equal importance is that of considering the ties or links between the concept of process and several other closely related terms which have potential importance in communication theory.

3.2.2 Process in Relation to other Terms

Within the discipline of system theory and analysis, "process" is one of two key concepts used in the characterization of systems (J. G. Miller, 1965b). The other concept, that of "structure," is closely related and is used to refer to "the static arrangement of a system's parts at a moment in three dimensional space (J. G. Miller,

³Note that this comment is considerably more general in scope than the discussion of Watzlawick, et al., in considering the concept of punctuation of events (1967, pp. 54-59). These authors are primarily concerned with a participant's punctuation or bounding of communication events, whereas in the present case, a "participant" is only one type or class of observer.

1965a, p. 211)." In other words, because an instant (moment) has no dimensions in time, the arrangement of a system's parts in space at a particular instant can be considered as fixed and unchanging. It is this arrangement which is the structure of a system. Any change in this structure would involve some span of time and would become a consideration of process (this use of the term "structure" is the same as that by Rappoport, 1968, p. xx; see also Gerard, 1968, pp. 52, 56).

The use of the term "structure" presents a potential confusion, however, in that it was introduced and used earlier (page 15) to refer not to an arrangement of matter-energy, but to information. The distinction between these two uses of the term will be made by attaching the subscript "m" or "i," so that "structure_m" will refer to "the static arrangement of a system's parts at a moment in three dimensional space," while "structure_i" will refer to the pattern or organization among the parts of an entity which is the informational aspect of that entity when it is under study by some observer. Note that the presence of structure_i implies the presence of structure_m, since information is always borne on markers; however, the reverse is not necessarily true. That is, a completely random distribution of matter-energy is one possible form of structure_m, but is one which may well bear no structure_i for an observer (depending on his particular frame of reference).

Because the relationship between structure_m and process is very close, in the sense that structure_m can be identified only at some specific instant in a process, J. G. Miller makes several important

clarifying points in his discussion of the two concepts. In particular, regarding the analysis of a system:

Any subsystem . . . is identified by the process it carries out. It exists in one or more identifiable structural units of the system. The specific, local, distinguishable structural units are called components. . . . There is no one-to-one relationship between process and structure_[m]. One or more processes may be carried out by two or more components. Every system is a component, but not necessarily a subsystem, of its suprasystem (J. G. Miller, 1965a, pp. 218-219).

Structure_m and process in a given system are therefore not completely independent, but neither are they isomorphic. As Miller suggests, "It is notoriously hard to deduce process from structure_[m], and the reverse is by no means easy (1965a, p. 219)."

Note particularly that in the above quotation, Miller is using "process" in its most general sense, a usage which in this case includes at least two other concepts which also demand attention, namely function and history. The concept of function is often treated as synonymous with process, although in Miller's usage it is not, being somewhat more specific. Function is definitely a form or aspect of process, but carries an additional reference to ". . . the transient and reversible changes [my italics], often repetitive, that constitute 'behaving' or functioning (Gerard, 1968, p. 52, see also pp. 55-56)." Alternatively, in Miller's terms, "Process includes [as a subset] the on-going function of a system, reversible actions succeeding each other from moment to moment (1965a, p. 209; first italics mine)." Again, this definition of "function" is similar or identical to that employed by Rappoport in his use of the term "functioning" (1968, p. xx). The concept of function thus carries the added

specificity of "behavior," or of the "regulation" of system states over time by means of reversible changes in some or all of the system variables. This added specificity in the concept of function ties it to the concept of purpose, but it is especially important to note that the two terms are distinct. Miller defines "purpose" as " . . . the internally determined control process [my italics] of the system which maintains [at least] one of its variables at a given steady state value (1965a, p. 232, see also Gerard, 1958, p. 128)."

This link between the concepts of process and of function is important not only in itself, but also as background for the relationship between process and the concept of history. History is also a form or aspect of process, but again is more specific in that it refers to situations in which there are ". . . enduring and irreversible changes [my italics], often progressive, that constitute 'becoming' or development (Gerard, 1968, p. 52, see also pp. 54-55)." Again in Miller's alternative terms:

Process also includes [as a subset, the concept of] history, less readily reversed changes like mutations, birth, growth, development, aging, and death; changes which commonly follow trauma or disease; and the changes resulting from learning which is not later forgotten. Historical processes alter both the structure and function of the system. . . . History, then is more than the passage of time. It involves also [the] accumulation in the system of residues or effects of past events . . . (1965a, p. 209; first italics mine).

The initiation, growth or development, learning, pathology or disease, decay, and termination of a system--in short, the phases of its life cycle--are therefore all forms of process. Much more specifically, however, to the extent that they involve irreversible changes they

are also aspects of the history of a system (J. G. Miller, 1965b, pp. 372-378). This additional specificity in the concept of history ties it to the concept of evolution. Miller considers evolution to be an aspect of history (and hence of process), but is quite specific in noting that the basic event in evolution is one of ". . . mutation, a process which is ordinarily irreversible . . ." (1965b, p. 370; see also pp. 369-372)." Note particularly that Rappoport (1968, pp. xx) employs the term "evolution" to encompass both "history" and "evolution," as those terms are used here. The distinction made here between the concepts of history and evolution is seen as valuable and useful, however.

Briefly, again, "History, or becoming, . . . is a regular change, normally progressive, in a system along the time axis; function, or behaving, is a repetitive perturbation along this secular trend; and structure_[m], or being, is the instantaneous status (Gerard, 1968, p. 54)." These three concepts, and those tied to them, are all linked to the concept of process or of change over time. They are highly important and useful concepts in the characterization of any system, and given that communication occurs within systems (see page 16ff), are concepts which are potentially useful tools in communication theory building, as well. Each of these terms and their links to the term "process" could be considered at greater length, as they are in the discussions by Gerard (1958, 1968), Rappoport (1968), and J. G. Miller (1965a, b) which have been cited (see also Bertalanffy, 1968). Because such works are available, however, it appears more useful to move on to the third step in considering the verbal aspects of constitutive definition of "process."

.3 Types of Processes

It will be helpful to examine briefly several different terms which describe various "kinds" or "types" of processes in a system--the purpose being to provide means for dealing with different aspects of "forms" of change over time. Each of the terms to be considered below serves to modify the concept of process in some manner, so that taken as a group, they illustrate another aspect of the generality of the concept. Note that the descriptive terms chosen here will not be those which identify processes according to specific system functions, such as "input," "internal," or "output" processes. Instead, it appears more useful, in view of the concerns of this paper, to discuss terms which describe the kinds or types of variation which may take place in the values of a system's variables. It will be helpful to group such terms into two categories: general descriptors and specific descriptors.

Two of the five highly general descriptive terms have already been used above, namely, "reversible" and "irreversible." The term "reversible" is used in the discipline of thermodynamics to refer to ". . . a process, which once having taken place, can be reversed and leaves no change in either the system or surroundings (Van Wylen, 1959, p. 127)." J. G. Miller sharpens this definition by alluding to the mathematical description of a process: "If the equation describing a process is the same no matter whether the temporal variable is positive or negative, it is a reversible process: otherwise it is irreversible (1965a, p. 209; see also the discussion herein, section 3.3)." Clearly, then, an "irreversible" process would refer in

thermodynamic terms to a process which could not be reversed without changing the system or the surroundings. As noted above, it is reversible processes which are associated with the concept of function, while irreversible processes are associated with history.

The three other highly general descriptors which deserve mention are "static," "quasistatic," and "cyclic." "Static" processes have already been alluded to in the discussion of the term "change." They are processes in which the value of the variable under consideration does not change over time; i.e., in which the line or path of variation in the graph of a process is parallel to the time axis. A "quasistatic" process is one in which the deviation from the static situation is infinitesimal, so that the process may be treated as static with essentially no error (Van Wylen, 1959, p. 18). Lastly, a "cyclic" process is one in which the change in the value of the variable exhibits "cycles," a cycle being a situation in which a variable changes from some specific value or state, only to return eventually to that same value or state (cf. Van Wylen, 1959, p. 18).

The remaining descriptive terms to be considered are somewhat more specific than those mentioned above, and can themselves be usefully divided into two groups. The first group is descriptive of what can be termed "morphostatic" processes--those which ". . . tend to preserve or maintain a system's given form, organization, or state (Buckley, 1967, p. 58)." The second group is descriptive of "morphogenetic" processes--those which ". . . tend to elaborate or change a system's given form, structure_[m], or state (Buckley, 1967, p. 58)."

Morphostatic processes are frequently described by the terms "homeostatic" and "steady state." That is, they are processes in which the values of variables are constantly fluctuating or changing, but are maintained within limits or "ranges of stability" by means of negative feedback (J. G. Miller, 1965a, pp. 224-229).⁴ Such fluctuating or changing variables are often thought of as remaining in a "dynamic" or "flux" equilibrium. One specific type of morphostatic process is that which is termed "convergent." In this type of process, the value of the variable under consideration approaches some equilibrium value, whether by means of a decreasing cyclic oscillation about the equilibrium, or by means of a cyclic or non-cyclic trend toward that value from a single direction (see Lennard and Bernstein, 1969, pp. 13-14).

Morphogenetic processes do not have as well developed a terminology as do morphostatic processes. They might be termed "non-homeostatic" or "non-steady state" processes, in that they include situations in which the values of variables move away from equilibrium values and outside ranges of stability, often as a result of positive feedback. Morphogenetic processes are "non-equilibrium" processes, and might be more specifically termed "divergent" processes. The

⁴Space forbids a more detailed discussion of the basic concepts involved here (see note 2). Complete discussions may be found in Miller, as well as in Bertalanffy (1968), and Buckley (1968). It is important to note, with regard to Miller's discussion, that the part of section 12.1 which is contained on p. 224 makes several statements which are inconsistent with the remainder of his discussion, especially pp. 225-226. Reference to the other works is particularly helpful in clearing this inconsistency.

term "divergent" would include situations in which the value of a variable moves away from an equilibrium, either through an increasing cyclic oscillation about the equilibrium, or through a cyclic or non-cyclic trend away from it.

It is important to note that both morphostatic and morphogenetic processes can be either reversible or irreversible. That is, despite the usual association of morphogenetic processes with irreversible change (e.g., history, development, evolution, etc.), there is no necessary connection between the two: a morphogenetic process may be reversible. Likewise, despite the normal association of morphostatic processes with reversible change (e.g., function, regulation, etc.), a morphostatic process may in some cases be irreversible (see J. G. Miller, 1965a, pp. 209, 224).

These descriptors of certain specific kinds and types of processes, together with the various more general descriptors, might well be discussed at somewhat greater length and could certainly be expanded in number (see Buckley, 1968, Pts. V and VI). Some additional descriptive terms will be added in the next section, but as potential tools in theory building in communication, the terms considered above appear to be the most useful of the verbal terms which might be chosen. This criterion of potential utility has, again, been used throughout this section in choosing the various terms which have been linked to the concept of process.

In summary, the discussion of the linkages which have been selected has encompassed not only an examination of the verbal definition of "process," but also a consideration both of the ties between

this concept and three other key concepts, and of the various kinds of types of processes. In short, the discussion has covered a number of different verbal aspects of constitutive definition. The task of suggesting approaches to a constitutive definition of the concept of process cannot be restricted, however, wholly to suggesting linkages to verbal terms. Linkages to mathematical terms need to be considered as well, since they, too, have a potentially important part in future theories of communication.

3.3 Mathematical Aspects of Constitutive Definition

While theory in the discipline of human communication has not often been expressed in mathematical terms, such terms are important and useful, not only for themselves, but also for the perspective they are capable of providing if they can be employed in theoretical formulations. The second major step in approaching a constitutive definition of the concept of process, then, will be to consider linkages between this concept and a set of mathematical terms which may have a place in future theories of communication. In keeping with the previous section, the attempt in considering such linkages will be to describe how "process" and its associated terms are generally formulated and treated in a mathematical terminology. This attempt to establish links to mathematical terms should yield a number of useful insights into the constitutive definition of the concept of process.

Again, as in the previous section, the linkages considered below are a subset of those which might be considered--in this case, a subset which has two inputs. Clearly, one group of terms which needs to be considered in mathematical form is the set chosen in the previous

section on the basis of the potential utility of the terms as tools in communication theory building. These terms will be considered here, together with a small number of additional terms chosen by the same criterion. It is important to note that a comprehensive discussion of many of the terms chosen would require rather extensive mathematical derivation. Because such derivation is not in keeping with the basic purpose of this section, these particular terms will be discussed briefly, but with special attention to additional sources of information.

The discussion of the mathematical aspects of constitutive definition can be divided into three parts. First, an examination of the mathematical definition of the concept of process, as well as of the mathematical form of a number of old and new descriptive terms. Second, a brief discussion of the mathematical aspects of the ties between "process" and its related concepts. And third, a consideration of certain forms for expressing a process and of the means for finding functional representation. Because of the large number of terms and definitions introduced in this section, Table 4, page 100, has been included both as an outline and as a glossary useful for reference purposes. In addition to the above parts of the discussion, it will be appropriate to summarize briefly the discussion of the verbal and mathematical aspects of constitutive definition. Accordingly, a fourth part will be included in this section, examining in both verbal and mathematical terms the necessary and sufficient conditions for the use of the term "process."

Table 4. Outline and Glossary of Mathematical Aspects of Constitutive Definition^a

3.3.1 The Mathematical Definition of Process

<u>Process</u>	A function of the general form $v = f(t)$. (A variable as a single-valued function of time.)
<u>t</u>	Time: a continuum of one dimension which is divisible into equal units, those units being ordered unidirectionally under the assumption that the entropy of the universe is always increasing.
<u>Reversible</u>	A process whose equation is the same no matter whether the temporal variable is positive or negative.
<u>Irreversible</u>	A process whose equation differs depending on whether the temporal variable is positive or negative.
<u>v</u>	A variable: any property of a unit or relationship within a system which can be recognized by an observer, which can potentially change over time, and whose change can potentially be measured by specific operations. The variable may be a single variable or a vector of several variables.
<u>f</u>	A function: a correspondence between two variables such that a value of one depends on a value of the other, as determined by some rule of relation. A function encompasses both the presence and absence of change, and in this context is considered to apply only within a bounded interval, $t_x \leq t \leq t_y$.
<u>Static</u>	$v = k$, where k is a constant.
<u>Quasistatic</u>	$v = c$, where $0 < c - k < \epsilon$, and k is a constant, with ϵ being some small deviation around k within which v can be considered essentially constant.
<u>Cyclic</u>	$v = f(t)$ where v has the same value at two points in time, say t_a and t_b , and $a < b$.

Additional Terms:

<u>Discrete</u>	A process in which the variable t appears as an integral multiple of a least quantity.
<u>Continuous</u>	A process in which the variable t may take on any value in its range.
<u>Morphostatic</u>	Processes, often including feedback "mechanisms," in which the value of a variable is maintained within a range of stability, $0 < v - m < r$, where m is an equilibrium value and r is the limit of deviations around m within which the system remains stable. Processes may be reversible or irreversible, and can be convergent.
<u>Morphogenetic</u>	Processes in which the equilibrium value of a variable, and its range of stability, are altered from previous values. Processes may be divergent, and can be either reversible or irreversible.
<u>Stochastic</u>	A time dependent probability process. Actually a specific class of functions which makes certain assumptions about the events described.

3.3.2 Process in Relation to other Terms

<u>Structure_m</u>	The static arrangement of a system's parts at a moment in three dimensional space. Structure _m is the evaluation, at a particular point in time, of the function $(x, y, z) = f(t)$ where x, y, z are positions on the axes of a three dimensional physical space.
<u>Structure_i</u>	A many-valued relation, a complex pattern, an above chance distribution in a multi-dimensional space.
<u>Function</u>	A form or subset of process in which the changes are reversible (as defined above). Function encompasses the morphostatic or regulatory processes of a system, to the extent that they involve reversible change. Note this use of the term is distinct from that used in defining the symbol "f" above.
<u>History</u>	A form or subset of process in which the changes are irreversible (as defined above). History encompasses the morphogenetic processes of a system, to the extent that they involve irreversible change.

^aThe sources of these definitions are given in the discussion.

3.3.1 The Mathematical Definition of Process

Again, the concepts of process and of change over time have been treated as almost completely interchangeable in this paper. As a result, the examination of the mathematical definition of the term "process" will involve a consideration of the terms "change over time," as well. The discussion will link both of these concepts to a wide range of mathematical terms, and will result in a "translation" of a number of the terms introduced in the previous section as descriptors of a process.

In order to formulate the mathematical definition of the concept of process, it is necessary to refer to the representation of a process as a line on a graph in which time has been plotted as the abscissa and in which the value of a variable has been plotted as the ordinate. The mathematical representation of a "process," quite simply, is the equation describing this line. The general form of such an equation, which would correspond to using the phrase "change over time" as a general definition of "process," is:

$$v = f(t) \qquad (1)$$

where v is the variable under consideration, expressed as some function of t , or time.⁵ The function may take any form consonant with the notation of calculus and analytic geometry (Thomas, 1953, pp. 1-20). As does the line in the graphic representation, the function serves

⁵Quite clearly, "function" is not used here as it was in section 3.2.2. See the discussion below of the mathematical definition.

to indicate successive values of v for successive values of t . The mathematical definition of "process" or of "change over time" is therefore quite brief in its general outline, and requires expansion to make the value of this particular representation more clear.

One important comment needs to be made before examining the individual terms in this mathematical definition of the concept of process. Specifically, it is important to distinguish between the adoption of a mathematical terminology, as above, and the use of a mathematical model of some event or events. That is, the present adoption of a mathematical representation of a process is, fundamentally, a translation of the verbal terms used previously into mathematical terms. Such a step is no different from the translation of verbal terms into graphic "terms," as has been done already, and in particular, makes no assumptions regarding the nature of any events which may come under study.

The use of a mathematical model, on the other hand, does make the assumption that the specific function which is employed has the same characteristics as the event under study. In this sense, mathematical modeling is no different from any other modeling, i.e., the assumptions of the model must be clear and must conform to the events. The function noted in equation (1), in particular, is not a mathematical model. It is, instead, a general function, or perhaps more clearly, an indicator of a general form which functions may take using this particular mathematical notation.

The above choice of the notation of calculus and analytic geometry is, therefore, a choice of a particular mathematical

"language" or terminology, as well as of a set of conventions for forming "sentences" or expressions. The content of those sentences or expressions is not restricted by the presence of assumptions, although as in any use of a language system, certain contents may be more conveniently expressed in a different language. The particular choice of notation is based on the broad generality and especially the utility of calculus and analytic geometry for the present concerns with human communication.

The mathematical terminology. - As was the case for the verbal definition of "process," one of the key terms in the mathematical definition is the variable t , or in this case, time. Ordinarily, of course, the mathematical notation would not restrict the variable t to representing time, much less a particular "kind" of time. However, given the concern in this paper with the concept of process, particularly as that concept applies to the concrete systems in which human communication takes place, the variable " t " will be defined here as "astronomical time," exactly as this concept was defined earlier (page 84).⁶ The important consequence of this definition of " t ," or time, is that equation (1) expresses v as a "single-valued" function of t (Thomas, 1953, p. 14). That is, for each t , there will be associated only a single (though not necessarily unique) value of v .

Aside from the restriction to time, there are no other restrictions on the variable t , as, for example, on its sign. Specifically,

⁶See J. G. Miller (1965a, p. 203) for a discussion of the concept of "variable" as it applies to a "concrete" system.

the presence of a plus or a minus sign in association with "t" does not carry the meaning of time running forward or backward. The sign may be particularly important in another sense, however, for "If the equation describing a process is the same no matter whether the temporal variable is positive or negative, it is a reversible process; otherwise it is irreversible (J. G. Miller, 1965a, p. 209)." Thus, the equation $v = t^2$ represents a reversible process, since $v = (+t)^2 = (-t)^2$, while the equation $v = t^3$ is an irreversible process, since $v = (+t)^3 \neq (-t)^3$.

Along with the variable t in equation (1), the variable v is also of importance. Unlike the case with t , however, no restrictions will be placed on the nature (or name) of this variable. Defined in a manner consistent with the definition for t , above, " v " refers to "Any property of a unit or relationship within a system which can be recognized by an observer . . . , which can potentially change over time, and whose change can potentially be measured by specific operations . . . (J. G. Miller, 1965a, p. 203)." As a consequence of this definition, the variable is completely general, and may refer, for example, to some matter-energy or informational property of a system, or to some relationship between such properties. As a result, the concept of process in its mathematical form, as in the verbal form, is completely general, even though the concern here will be primarily with variables related to human communication.

As it is expressed in equation (1), variable v represents only a single variable as a function time, rather than the more general multiple variable case. To extend the mathematical definition of

process to this more general case, the variable must be treated as a "vector" of several variables, each identified by a numerical subscript. Equation (1) would thus be rewritten as:

$$\begin{bmatrix} v_1 \\ v_2 \\ \cdot \\ \cdot \\ \cdot \\ v_n \end{bmatrix} = F(t) \quad (2)$$

where the capital F represents a function which is understood to contain vector components. The vector $[v_1, v_2, \dots, v_n]$ is likewise normally represented by a capital V, unless the particular mathematical operations require the enumeration of the individual variables. Equation (2) might therefore be rewritten as $V = F(t)$. Note that each of the variables $v_1, v_2, \dots, v_n$ is, nevertheless, a function of the same variable t--a situation which would be represented, on a graph, by 1, 2, or up to n lines, all extending through the same time span on the abscissa, but each representing a different variable plotted on the ordinate. Because of its simplicity, the single variable case will generally be used for explanatory purposes, given that the principles for the single variable situation are directly extendable to the multiple variable situation.

In addition to the variables t and v, the function itself is of some importance in the mathematical definition of the concept of process, since it is the function which describes the nature of the change in the variable v which occurs over time. The term "function" is defined in its mathematical sense as "A correspondence between two variables such that a value of one depends on a value of the other,

as determined by some rule of relation . . . (J. G. Miller, 1965a, p. 202)." The nature of the function or rule is of course not restricted, except that the functions considered here will be those which follow the notation of calculus and analytic geometry (see discussion of functions in Bellman, 1965).

As was the case in the discussion of the verbal definition of "process," a mathematical function also applies in the broadest possible sense, encompassing both the presence and absence of change or difference in the variable v . That is, given the single-valued function, $v = f(t)$, there will generally be some change or difference between the values of v at two points in time. In the special case where the two values of v are identical, however, the function is still considered single-valued, but the two values are termed "non-unique," and of course exhibit a "change" or difference" of zero.

The concept of a function continues to apply even when the variable t is "absent" from the equation $v = f(t)$. That is, in the special case of a static process, the representation of a process on a graph reduces to a line parallel to the time axis, normally expressed mathematically as $v = k$, where k is some constant. The equation $v = k$ is, nevertheless, still considered to be a valid form of the equation $v = f(t)$. A quasistatic process would generally be represented by a similar equation, $v = c$, where $0 < |c - k| < e$, the e representing some small deviation around k , within which v can be considered essentially constant. A cyclic process would be one in which some value of v occurred at two points in time, say t_a and t_b , where $a < b$.

Again, as in the discussion of the verbal definition, a mathematical function in a general form such as $v = f(t)$ is not considered to be bounded in time, but to apply over all time ($-\infty < t < +\infty$). In practice, however, many functions are bounded, even though the bounds may not be explicit, and many mathematical operations require the consideration of bounds. For these reasons, and because the segmentation or bounding of occurrences in time was seen earlier as basic to science, all mathematical expressions of a process herein will refer to a process as it occurs within some bounded interval. Such a bounded interval or event is indicated by identifying the limits on the range of values t may hold, as for example in $t_x < t < t_y$, or in $t_x \leq t \leq t_y$. The first case is normally termed an "open" interval, while the second is a "closed" interval (Thomas, 1953, p. 14); the length of the interval, T , is clearly $T = t_y - t_x$. The restriction of the mathematical definition of "process" to bounded intervals is perhaps at variance with the general treatment of functions such as $v = f(t)$, but is seen both as useful, and as consistent with operations in science.

Additional terms. - In addition to this consideration of the terms which comprise the mathematical definition of process and which are closely tied to it, it will be helpful to consider the mathematical form of several additional descriptive terms, both new and old. Two very important new terms, "discrete" and "continuous," are descriptive of two kinds or types of process, or more specifically, of the kinds or types of values which the variable t may take on. A "discrete" process can be defined as "A process in which the variables appear as integral multiples of a least quantity," while a "continuous" process is considered to be "A process in which the variables may take on any

values within their ranges (Bryne, 1967, p. 5)." When applied to the variable t in the equation, $v = f(t)$, these definitions indicate that in a discrete process, t will take on one of a set of values, $t_1, t_2, \dots, t_k, t_{k+1}, \dots, t_n$, where $t_{k+1} = t_k + \Delta t$, and Δt is an arbitrary, but constant interval of time. In a continuous process, on the other hand, t may take on any value within its range, or in this case, within the interval $t_1 \leq t \leq t_n$.

Whether the mathematical representation of a process is termed "discrete" or "continuous" depends not on any inherent characteristic of the occurrence under study, but on the manner in which the variable v is measured. That is, measurement of v at a number of separate, but regularly spaced points in time requires representation in a discrete form, whereas measurement at all points in time during the interval of concern will permit representation in a continuous form (as well as in a discrete form). Accordingly, as is often the case in studies of human communication, the occurrence under study may be, in itself, a continuous process. However, because of the measurement technique involved, the eventual mathematical representation of that process may be in a discrete form. Functions of the general form, $v = f(t)$, can be treated as either discrete or continuous, although the representations and techniques used in each case will vary somewhat (see discussion below in section 3.3.3).

Several other descriptive terms introduced in the discussion of verbal aspects of constitutive definition also can be interpreted in mathematical form. Morphostatic processes, for instance, were described earlier as ones in which the value of a variable fluctuated

around some equilibrium value, but within a range of stability. Such a range of stability might be indicated mathematically as, $0 < |v - m| < r$, where v is the variable value, m is the equilibrium value, and r is the limit of deviations around m within which the system remains stable. While the actual forms are too complex to treat here, a function representing a morphostatic process would generally incorporate some type of feedback "mechanism" to maintain the stability of variable v . This mechanism would "feed back" part of the system's output to its input, and thereby act to counter any deviation of v from m , as long as the deviation remained less than r . Beyond r , the feedback mechanism might fail to operate or another mechanism might come into play, depending on the particular function (see discussions of the mathematical treatment of feedback in Koenig, 1967, pp. 366-402, and in Milsum, 1966, Ch. 2, *passim*, and Ch. 11). The more specific type of morphostatic process which was termed earlier, "convergent," likewise has a mathematical interpretation, but one which is too lengthy to develop here (see Thomas, 1953, Ch. 16; Spiegel, 1958, Ch. 5).

Like morphostatic processes, morphogenetic processes also can be interpreted in mathematical form, although the interpretations are possibly more complex and varied, and are in some respects less well developed (Maruyama, 1963). More specifically, the concept of a range of stability about an equilibrium value is not of particular importance in the formulation of morphogenetic processes, except in the sense that such processes may come into operation if a variable moves outside its range. For example, a given function might incorporate both a feedback mechanism to maintain a given equilibrium, as well as an

additional mechanism to establish a new equilibrium, m_{new} , and a new range, r_{new} , should the variable v ever move outside its original range. The latter mechanism, if brought into use, would qualify as a morphogenetic process.

Because of the complexity and variation in representations of morphogenetic processes, certain sub-classes of them have been treated separately. Perhaps most notable in this respect is the work by Thompson (1942; see also Bertalanffy, 1968, pp. 60-63, 171-184), concerned in part with the mathematical treatment of growth or development. Learning (which is not forgotten) is likewise a sub-class of morphogenetic processes which has been treated mathematically (see Luce, et al., 1963; V. 1, Pt. 2; V. 2, pp. 1-126, 206-265; V. 3, pp. 101-203). Those morphogenetic processes which are specifically termed "divergent" also have a definite mathematical interpretation, vis-à-vis convergent processes, but again, development of the interpretation is too lengthy to be usefully included here (see Thomas, 1953, Ch. 16; Spiegel, 1958, Ch. 5).

This discussion of the mathematical form of these several additional descriptive terms could be expanded to include a wider range of terms which describe processes by reference to their specific mathematical characteristics. Among the most important of these terms would be "stochastic," a stochastic process being one which may be ". . . intuitively regarded as a time-dependent probability process (Fararo, 1968, p. 246)." In this case and in others, however, an extensive discussion would be required in order to move much beyond an intuitive understanding (see the excellent discussions of stochastic

processes by Fararo, 1968; Parzen, 1962; and Snell, 1965). Note, too, that stochastic processes are a class of specific functions which do make assumptions about the characteristics of the events under study (see page 102).

Again, it is not the purpose of this section to reproduce the derivations of the various mathematical terms used to define or describe a process. Rather, the attempt is to indicate how the concept of process and its associated terms are generally formulated and treated in a mathematical terminology. Note, too, that the above discussion of the mathematical definition of the concept of process and of the mathematical form of several different descriptive terms is only a first step in considering the mathematical aspects of constitutive definition. The second step of considering the mathematical aspects of the ties between process and its related concepts is also important.

3.3.2 Process in Relation to other Terms

In the earlier discussion of verbal aspects of constitutive definition, the concept of process was linked not only to the descriptive terms considered in their mathematical form above, but also to three other closely related terms of importance in system theory and analysis. These three terms, "structure_m," "function," and "history" need to be considered here, too, both for their own importance, and because their ties to the concept of process reveal some interesting points about the mathematical expression of processes in systems.

The first of the three terms, "structure_m" was defined earlier as "the static arrangement of a system's parts at a moment in three

dimensional space (J. G. Miller, 1965a, p. 211)." In a concrete system, therefore, structure_m is the arrangement of matter-energy, apart from any considerations of information or structure_i . If one wished to consider the structure_m of a given system, he would be forced to describe the system by a function of time such as:

$$(x, y, z) = f(t) \quad (3)$$

where x , y , and z are positions on the axes of a three dimensional physical space. Such a function represents the process normally termed "movement," in this case, movement in all three dimensions. Given such a function, the structure_m of the system would be described mathematically by the values of the variables at a specific point in time, say t_a . Such values would be fixed or constant at a particular point in time, but not necessarily over an interval of time, hence the confining of structure_m to particular instants in time.⁷

In basic outline, then, the concept of structure_m has a fairly straightforward relationship to the concept of process, even though the study of mechanics, which treats the "statics" and "dynamics" of matter-energy arrangements, can be extremely complex. It is important to note that the distinction between structure_m and structure_i is often somewhat blurred. Structure_i , as noted in section 3.2.2, is always embodied in some form of matter-energy marker, but clearly for many purposes the matter-energy aspects of the marker are of little

⁷See Koenig (1967, Ch. 4) for a different, though compatible treatment of the "structure" of a system. Koenig's treatment focusses primarily on structure_i , even though it derives such information from "physical systems."

or no concern. Indeed, many discussions of the various aspects of system organization are primarily considerations of structure_i, almost totally without the observer's consideration of any matter-energy embodiment (Rappoport, 1966, pp. 8-9; Ashby, 1968). Again, structure_i was defined "mathematically" in section 1.2 "as a many valued relation, as a complex pattern, as an above-chance distribution in a multi-dimensional space (Krippendorff, 1969a, p. 107)," but a more detailed mathematical development is clearly not within the scope or purposes of this paper (see Shannon, 1963, pp. 3-91).

"Function," the second of the three terms to be considered, was discussed earlier as a form of process, but one which carried the additional specificity of ". . . the transient and reversible changes, often repetitive, that constitute 'behaving' . . . (Gerard, 1968, p. 52)." Again, the distinguishing aspect of the concept of function is this association with reversible change (see page 104). "Function" is therefore a subset of the more general term "process." In addition, to the extent that reversible change is involved "function" encompasses the morphostatic processes which regulate and control system operations. The importance in a system of these morphostatic aspects of function has meant that their formulation in mathematical terms has received considerable attention, not only from the specific point of view of concepts such as feedback, homeostasis, purpose, and equifinality (see Bertalanffy, 1968, pp. 75-80, 124-124), but also from the general point of view of the concept of control (see Milsum, 1966).

The third of the three terms, "history," was also considered earlier as one form of process. "History" is more specific than

"process," and forms a subset of it, in that it refers to the ". . . enduring and irreversible changes, often progressive, that constitute 'becoming' or development (Gerard, 1968, p. 52)." The key aspect of the concept of history which distinguishes it from function is the association with irreversible change (see page 104). As a result, to the extent that irreversible change is present, "history" encompasses the morphogenetic processes of initiation, growth, learning, decay, etc. The particular importance of growth and learning as aspects of the history of a system has singled them out, in particular, for formulation in mathematical terms (see Bertalanffy, 1968, pp. 60-63, 171-184; Luce, et al., 1963, *passim*; and Thompson, 1942). A detailed discussion of the mathematical formulation of these two aspects of the history of a system is, however, beyond the scope of this paper --a comment which applies to the various aspects of function, as well.

Briefly, again, history, in its association with irreversible change; function, in its association with reversible change; and structure_m, in its association with single instants in time, are all tied to the concept of process. That is, each of the concepts, when considered in its mathematical form, involves a function of the general form, $v = f(t)$. The concepts are distinguishable from one another by the results of a particular operation on t ; in particular, isolating a single value of t to determine structure_m, or substituting positive and negative values of t to separate reversible from irreversible, and hence function from history. The concepts of structure_m, function, and history have other important characteristics, in addition, but operations such as these on the variable t reveal much about the

complexity of the mathematical expression of the concept of process, despite its seemingly very simple form, $v = f(t)$.

This discussion of the ties between the concepts of process and the related concepts of structure_m, function, and history, is one part of the attempt to indicate how the concept of process and its associated terms are treated mathematically. The earlier discussion both of the mathematical definition of "process" and of the treatment of the different descriptive terms is part of this overall attempt, as well. There remains, in addition, a third part to the task of considering the mathematical aspects of constitutive definition. In particular, it will be helpful to consider two broad aspects of the mathematical expression of the concept of process.

3.3.3 Process and its Mathematical Expression

While the verbal expression of the concept of process is relatively straightforward, its mathematical expression involves certain "difficulties" which should be discussed briefly. The two aspects of expression to be considered below both concern the "forms" of expression of a process. The first aspect deals with the expression of time as discrete or continuous, and with the relationship between the two, while the second aspect concerns the general problem of finding a mathematical equation or function which will express a given process.

Discrete and continuous expressions. - As noted in the discussion of the mathematical definition of "process," the variable t in the equation, $v = f(t)$, may be expressed in either a discrete or a continuous form. The form chosen has an effect both on the nature of the functional representation, and on the techniques used to manipulate

the function. If time is treated as discrete, the variable t may take on one of a finite set of values, any two of which are related by the expression $t_{k+1} = t_k + \Delta t$, where Δt is the interval between successive time points. If one were to evaluate the function to obtain values of the variable v in this discrete situation, he would make an evaluation only at each individual time point, a situation which might be generally expressed as follows:

$$\begin{aligned}
 v_{t_1} &= f(t_1) \\
 v_{t_2} &= f(t_2) \quad \text{or} \quad v_{t_2} = f(t_1 + \Delta t) \\
 &\vdots \\
 v_{t_k} &= f(t_k) \\
 v_{t_{k+1}} &= f(t_{k+1}) \quad \text{or} \quad v_{t_{k+1}} = f(t_k + \Delta t) \\
 &\vdots \\
 v_{t_n} &= f(t_n)
 \end{aligned} \tag{4}$$

The consequence of treating time as discrete, therefore, is that the variable v also takes on discrete values.

Very frequently in dealing with a process, however, one is faced not with the problem of evaluating a function at different points in time, as above, but with the problem of predicting the value or "state" of the variable v at the next point in time, given the value or state at the current point (see Krippendorff, 1969b, pp. 23-28, and Carroll, 1968, pp. 35-37). Such prediction involves finding a new function which will express $v_{t_{k+1}} = f(t_{k+1}) = f(t_k + \Delta t)$ as a function of $v_{t_k} = f(t_k)$, or, in a considerably simplified, but equivalent notation, $v(t_{k+1}) = v(t_k + \Delta t)$ as a function of $v(t_k)$. Such a new function may be represented in general form by the function g in

the equation:

$$v(t_k + \Delta t) = g \left[v(t_k) \right] \quad (5)$$

which, in verbal terms, would be a prediction of the state at the next point in time, given the present state (and assuming such a prediction is viable).⁸ An equation such as (5) is termed a "difference" equation, and is treated or manipulated using a special class of mathematical techniques appropriate to such discrete time representations ("difference" equations have no necessary relationship to "difference" designs). The scope and application of these techniques cannot be discussed here, but are treated in introductory form by Bellman (1965, pp. 491-496) and Goldberg (1958), and in more detailed form, especially as applied to systems, by Cuénod (1969) and Koenig (1967, pp. 179-183).

On the other hand, if time is treated as continuous in dealing with a given function, the representation of that function and the techniques used to manipulate it will be somewhat different. In this case, the variable t may take on any value in its range, $t_1 \leq t \leq t_n$, with no restriction on the interval between values. If one were to evaluate the function, $v = f(t)$, for the value of v in this continuous situation, he would face no restriction on the time point or points he selected. The consequence of treating time as continuous, then, would be that the variable v might well also exhibit continuous variation.

⁸Note the following very important point. Equation 5 is, effectively, a model or specific class of functions. As such, it makes assumptions about the event under study, as described. These assumptions are not the only possible assumptions, and specifically are not inherent in the notational system. Many other models can be formed having different assumptions.

The treatment of time as continuous also brings certain changes in representation when one is concerned not with the problem of evaluation, but with the problem of "prediction." In this case, the nature of the prediction itself is altered slightly as a result of the change in the treatment of time. That is, the situation of predicting the value of a future state given the current state becomes, in the continuous time case, a situation of determining the rate of change in the value of a state given the current state. The latter determination involves a function which will express the rate of change in v , or $v' = f'(t)$, as a function of $v = f(t)$, i.e., in the simpler notation, $v'(t)$ as a function of $v(t)$. Such a function is represented in general form by the function D_t in the equation:

$$v'(t) = D_t[v(t)]$$

or, with a more common notation added:

$$v'(t) = \frac{dv}{dt} = D_t[v(t)]. \quad (6)$$

In verbal terms, the function D_t is the "derivative" of v with respect to t , and expresses the rate of change in v at any given instant in time.⁹ An equation such as (6) is termed a "differential" equation, and is treated or manipulated using the techniques of differential and integral calculus. The scope and application of such techniques is much too broad to consider here, and will be left to introductory texts

⁹Note, again, that equation 6 is, in effect, a model or specific class of functions, and assumes that the event under study has characteristics which allow "rates" to be determined in this manner. Other functions could be formed to fit other characteristics (see note 8, and page 102).

such as Thomas (1953). Additional discussions of interest can be found in Bellman (1965, pp. 496-502), and with particular application to systems, in Koenig (1967), and Milsum (1966).

Thus, the variable t in functions of the general form, $v = f(t)$, can be expressed as either discrete or continuous. The two expressions require separate techniques for handling the different representations, although in large part these techniques parallel one another. Such a parallel is not particularly surprising when one considers that the two expressions of time actually merge in the basic definition and operation of differential calculus. It will be helpful to examine this relationship between the two expressions.

Very briefly, in the representation of a process on a graph, where time is treated as discrete, the slope of a line connecting any two adjacent points can be found by dividing the change in v between the two points by the corresponding change in t , i.e:

$$\text{slope} = \frac{v_{t_{k+1}} - v_{t_k}}{t_{k+1} - t_k} = \frac{\Delta v}{\Delta t} \quad (7)$$

However, Δv can also be expressed in terms of the function $v = f(t)$, so that $\Delta v = f(t_{k+1}) - f(t_k)$, or, alternatively, $\Delta v = f(t_k + \Delta t) - f(t_k)$. Substituting this expression into equation (7), and dropping the k at the same time, would result in an expression for the slope entirely in terms of the function, t , and Δt :

$$\text{slope} = \frac{f(t + \Delta t) - f(t)}{\Delta t} \quad (8)$$

If the size of the Δt were very small, the discrete time representation of a process would closely resemble the continuous time representation, and the slope expressed by equation (8) would apply

over only a very small interval of time. In the limiting situation, when the size of Δt approached zero ($\Delta t \rightarrow 0$), the discrete representation would merge with the continuous representation, and the slope would become the slope, or rate, at a single point in time. Such a limiting process, in fact, defines the derivative and is usually expressed as follows:

$$v'(t) = \frac{dv}{dt} = \lim_{\Delta t \rightarrow 0} \frac{f(t + \Delta t) - f(t)}{\Delta t} . \quad (9)$$

Equation (9) is the basic definition or operation in differential calculus (Thomas, 1953, pp. 23-25), and is the tie between the expression of time in discrete and in continuous form.

The manner in which time is expressed is clearly an important aspect of any mathematical expression of a process, but it is at least equalled in importance by another aspect: the form of the equational representation itself. The task of finding an appropriate equation or function to express a given process is often a difficult one, and requires comment, as well.

Finding an expression. - There is, first of all, no single, well-defined procedure for generating an equation to describe a given line in a graphic representation of a process. Accordingly, an investigator must often depend primarily on his knowledge of the particular process as a guide. There are, however, certain general approaches to generating equations or representations of processes, at least one of which has a high probability of success, though occasionally at some expense of effort. In discussing these approaches, it will be convenient to refer at times to the line in a graphic

representation of a process not as a "line," but as a "signal," a term frequently used to refer to a variable which changes over time.

The first general approach perhaps depends most heavily on the investigator's knowledge of the process he is studying. Here the attempt is to find a representation for the given process in the form of an algebraic expression, a very simple example of which is finding the equation of a straight line. More generally, it is possible to find a polynomial of degree n which will pass through any n points on a graph, and to fit this polynomial as closely as possible to the line or signal by the method of least squares (see Gabor, 1946, p. 430).¹⁰ In many cases, however, a somewhat simpler function may adequately represent a given signal, e.g., a step function, exponential function, logarithmic function, sinusoidal function, etc. In addition, certain signals such as rectangular and triangular waves have fairly well known representations, and it is sometimes feasible to represent these signals or others by an average or root-mean-square value. Representations such as these are discussed in more detail in algebra, analytic geometry, and calculus texts, although somewhat shorter discussions of a number of these can also be found in Koenig (1967, pp. 20-25, 30-33), and in Milsum (1966, Ch. 3).

In numerous cases, however, it is not possible to find an algebraic expression like those above which will adequately represent the given line or signal. In these cases, a second general approach

¹⁰In their general forms, a straight line would be expressed as $v = at + b$, while a polynomial of degree 3 would be $v = at^3 + bt^2 + ct + d$.

will almost always succeed in producing a viable representation, though sometimes with an expense of effort. This approach is to find a "Fourier series" representation for the signal; more specifically ". . . any function [or signal] defined over a finite interval of time $t_1 < t < t_2$ can be represented by means of an infinite series of sinusoidal functions of time known as the Fourier series (Koenig, 1967, p. 25)." The degree of accuracy in representing a particular signal is determined by the number of terms in the series which are considered. Obviously an infinite number of terms is not needed in any practical application, and generally a fairly small number is sufficient. The scope and application of Fourier series representations has been extensively studied, as in Bracewell (1965), and many others. Of particular interest, here, are the briefer discussions of this representation both in terms of effort reducing approaches and the use of the discrete form (Bergland, 1969; Hamming, 1962, Ch. 6), and in the context of system analysis (Koenig, 1967, pp. 25-30) and of telecommunication (Cherry, 1957, pp. 128-143).

The third general approach to finding a mathematical expression for a given process is in many ways related to the use of Fourier series representations. This approach would have particular application in cases where the signal to be represented had statistical or random characteristics, a situation not uncommon in dealing with living, and especially human systems (see Milsum, 1966, Ch. 14). In many cases, statistical signals could be treated using Fourier series techniques, but frequently the special techniques and functions which have been devised for representing such signals may be more useful

(see Milsum, 1966, pp. 370-390).

These three general approaches to generating equations or functions to represent given signals or lines constitute the primary means by which an investigator might find a specific equational form in which to express a process he is studying. Again, the task is often difficult, and lacks a unified, well-defined procedure. Note, too, that while each of the three approaches may produce an expression for a given process, the models which result will make certain assumptions about the characteristics of the events under study. As always, the scholar must identify these assumptions and be sure they are justified in the particular situation (see page 102).

This discussion of the general problem finding a mathematical expression for a process, together with the discussion of the expression of time as either discrete or continuous, constitute the examination of certain aspects of the mathematical expression of a process. This examination, together with the consideration of the mathematical treatment of the concepts of structure_m, function, and history, as well as the study of the mathematical definition of process, comprise the discussion of the mathematical aspects of constitutive definition. There are, of course, other aspects and terms which might have been considered; however, in the context of use as potential tools in theory building in communication, the various aspects and terms which have been chosen appear to be the most useful.

Note, too, that were this paper not concerned solely with the concept of process, there would be a number of other terms which might be considered. That is, if the paper were concerned with the concept

of system, a great deal more might be added on the mathematical (and verbal) formulation and treatment of systems. Such discussions may be found in Bertalanffy (1965, Chs. 3, 5, 6), Hall (1968, pp. 81-92), Koenig (1967, and more briefly, 1965, pp. 41-45), and Milsum (1966). Despite the possible utility of such information for the study of human communication, it cannot be considered here, since to do so would be to change radically the level of discussion, and to obfuscate the goal of seeking the means of explicating the concept of process.

In review, this section has considered a number of linkages between the concept of process and a set of mathematical terms which may have a place in future theories of communication. The discussion of linkages has encompassed not only an examination of the mathematical definition of the concept of process and the mathematical treatment of certain descriptive terms, but also a discussion of the mathematical aspects of the ties between "process" and three related concepts, as well as a consideration of the mathematical expression of processes. In short, the discussion has covered a number of mathematical aspects of constitutive definition. It is appropriate therefore to summarize briefly the discussion of both the verbal and mathematical aspects of constitutive definition, in that these aspects lead to a statement of the necessary and sufficient conditions for the use of the term "process."

3.3.4 Necessary and Sufficient Conditions for Use of the Term "Process"

It has been the burden of sections 3.2 and 3.3 to examine a number of links between the concept of process and various verbal and

mathematical terms which might be utilized in future theories of communication. Linkages to verbal terms have been considered because of the central place of such terms in theory in the study of human communication. Linkages to mathematical terms have been included both because of the potential importance which these terms have, and because of the perspective such terms can offer if they can be employed in constructing theory. The mathematical formulation and treatment of "process" provides, in addition, a number of useful insights into the more usual verbal formulation and treatment of the concept.

The discussion of linkages between the concept and both verbal and mathematical terms has been an attempt, again, to suggest a set of potentially useful tools for constructing constitutive definitions of the concept of process. There has been no attempt to build a unique constitutive definition, though, because such a task can be carried out only in the context of a specific theoretical framework. Rather, the attempt here has been to suggest and discuss various approaches to a constitutive definition, i.e., to suggest linkages between the concept of process and a set of verbal and mathematical terms which might be useful in constructing theory. Clearly, other approaches, or linkages to other terms, could have been included if space had not dictated a choice. The information and terms which have been chosen are those which are particularly consistent, general and above all useful, when judged as potential tools in theory building related to human communication.

Because the attempt here has been one of suggesting potential linkages or tools for use in forming constitutive definitions, rather

than one of constructing specific definitions, it is not appropriate to judge these linkages by the normal criteria for a viable, formal constitutive definition. Such criteria are generally those of clarity, simplicity, consistency, fertility, and above all, utility of linkages (Berlo, 1967, pp. 3-5). The linkages suggested here are seen, though, as particularly capable of meeting such criteria if they are used in a specific theoretical framework to constitutively define the concept of process.

The approaches to a constitutive definition of the concept of process which have been suggested in this Chapter have two broad consequences. First of all, they lead to a statement of the necessary and sufficient conditions for the use or application of the term "process." Secondly, they carry a number of important implications for the form of theory which deals with communication events. This second consequence will be the topic of the next section, and the first will serve to summarize the consideration of the verbal and mathematical aspects of constitutive definition.

Specifically, we shall adopt Kaplan's approach to the necessary and sufficient conditions for the use of a term, as expressed in his statement that "The definition formulates the conditions which are both necessary and sufficient for the applicability of the term defined (1964, p. 72)." Hence, in verbal terms, the necessary and sufficient conditions for the use of the term "process" are, that it apply to "All change over time of matter-energy or information, within a bounded interval of time." Likewise, in mathematical terms, the necessary and sufficient conditions for the use of the term

"process" are, that it apply to "A function of the general form $v = f(t)$, defined over an interval of time, $t_1 \leq t \leq t_n$."

3.4 Implications for the Form of Theory

To this point, Chapter 3 has been concerned with a number of suggested approaches to constitutive definition of the concept of process. More specifically, it has considered both the verbal and the mathematical aspects of such definition, and in so doing has suggested a number of verbal and mathematical terms which have potential utility as tools in theory building in communication. As any craftsman is aware, the nature of the tools one works with determines in part what can be built. So too with theoretical tools: the nature of the terms a scholar works with defines to some degree the form or type of theory which he can construct. It is therefore appropriate to examine the implications which the potentially useful terms noted above have for the form of theory which deals with communication events.

It should be noted that an examination of the forms which theory may take is a formidable task in any discipline, especially in that of human communication. Accordingly, we shall restrict the discussion by identifying certain bounds--bounds which need to be made explicit at the outset. In particular, the concern here will be entirely one of outlining certain key implications for theory, particularly theory dealing with human communication. That is, the discussion will focus primarily on indicated modifications to theoretical forms, rather than on a study of present forms, and will be more concerned with broad classes of theories than with specific details or instances (except as examples). The concern here will also be entirely with theory

itself--the many and close relationships between theory and research will be considered in Chapter 4. In addition, in keeping with Chapter 1, the terms "theory" and "model" will be treated as virtually interchangeable, following Rudner's view of a model as ". . . an alternative interpretation of the same calculus of which the theory itself is an interpretation (1966, p. 24)." While some would reserve "model" for more specific "interpretations," and "theory" for more general ones (Lowry, 1968, pp. 55-56), such a distinction is not considered useful in this discussion given the current level of advancement of human communication theory.

In addition to these bounds on the discussion of implications for theory, it should be noted again that the concern here is with theoretical forms only as they incorporate the concept of process, as distinct from other concepts such as interaction, emergence, or system (see page 40). It should likewise be noted again that the considerations below will not necessarily apply to all theory building within the discipline of communication, since not all such theory need incorporate the concept of process (see page 71). For those bodies of theory which do involve process, the implications noted here, as well as the modifications to theoretical forms which they indicate, should be of some importance. The various theoretical forms suggested below are therefore presented not as replacements for present forms of theory, but rather as highly useful additions to such theory (see page 75).

General implications and comments. -- Given these bounds for the discussion, it is possible to ask what it is in the "nature" of

the many terms suggested earlier that bears implications for the form or type of theory used in the study of human communication. Again, each of the terms noted above is linked to the concept of process. If those terms, and the concept of process itself, are to be applied in theory dealing with communication events, then that theory must be of a form or type capable of expressing the relationship between the key properties of the events and the dimension of time. More specifically, a theory (or model) must be capable of expressing the functional relationship of properties or variables in events to the property or variable of time. This primary implication brings with it a number of more specific implications for the form of theory dealing with communication events; however, several points about the primary implication need to be mentioned first.

The "functional relationship" between the properties of events and time is of course a "function" in the sense of a mapping, or of a rule of relationship or correspondence between values. The medium through which this relationship is expressed is not a basic concern, here, so that the function may be presented in verbal, logical, or mathematical terms, by means of graphs or physical devices, etc. Likewise, it is not a basic concern whether the properties or variables (including time) are considered as discrete or continuous, or whether they are classed as independent, dependent, or intervening (although time is in all cases an independent variable). Note, too, that it is not necessary for all of the properties or variables of a class of events to have a direct functional relationship to time in a theory which deals with those events as processes. That is, it is entirely

possible that certain relevant properties or variables incorporated in a theory will (1) have no inherent relationship to time, or (2) be linked to time only indirectly, i.e., by means of a functional relationship to another property or variable which is itself linked directly to time. Finally, it is important to note that the concern here is with properties or variables of events only as they are related to time, rather than to one another (except for (2) above). Clearly the relationship of variables to one another is a key aspect of any theoretical formulation. However, to consider such relationships here would be to shift the focus of this paper from a concern with concept of process only, to a concern with concepts like interaction and emergence, as well. The latter concepts do require study with regard to the form of theory dealing with communication events, but obviously cannot be examined in the space available here.

Once again, the primary implication which the suggested approaches to a constitutive definition have for the form of theory dealing with communication events is that such theory must express functional relationships between the key properties or variables of events and time. Taking into account the points just mentioned, it is possible to trace a number of more specific implications for the form of theory. As an aid in doing so, it will be helpful to distinguish among three general forms or types of theory: the iconic, the analogic, and the symbolic (after Clarke, 1968, p. 33).

An iconic theory or model is a ". . . coded isomorphic record of observations (Clarke, 1968, p. 445)." Such theories or models are primarily descriptions of events in the sense that the events are

documented in some medium (e.g., verbal, graphic, physical, etc.)¹¹

Iconic theories or models for events may be formulated over a wide range of levels of abstraction, as for example the use of Who's Afraid of Virginia Woolf to describe or model interaction systems (Watzlawick, et al., 1967, Ch. 5) versus Lasswell's "Who says what in which channel to whom with what effect? (1948, p. 37)." Because the description of events is basic in any science, iconic theories or models are widespread, especially in the discipline of communication. Such description has limitations, however, one of the primary being the difficulty or impossibility of making predictions from these theories or models (Lowry, 1968, p. 54). In addition, in the context of the concern here, it is evident that there may be considerable difficulty in expressing in an iconic theory or model a functional relationship between key properties or variables and time.

Such difficulties are often much less severe in the case of an analogic theory or model, defined here as "a representation of events employing a substitution of congruent structures."¹² A "congruent" structure is isomorphic to a structure in the events under study, so that there is no basic distinction between iconic and analogic theories

¹¹Certain authors dislike the terminology "descriptive theory" or "descriptive model" (Brodbeck, 1959, p. 379). In general, the same viewpoint is reflected in this paper, although an exception is made at this point for the sake of continuity in the presentation.

¹²The term "analogic" and its definition are slight departures from Clarke (1968, p. 33) for the sake of clarity in this particular presentation. The basic principle is nevertheless the same. A similar comment applies to the term "symbolic" and its definition, below. Note, too, that Clarke's distinction of iconic, analogic, and symbolic theory is drawn from Ackoff, et al. (1962).

regarding their degree of isomorphism. Rather, the distinction lies in the use in analogic theories of verbal, graphic, physical, or logical structures (and relationships) which are distinct entities in themselves, but which have direct, well-defined correspondences or congruencies to the structures (and relationships) present in the events. For the most part, analogic theories or models appear to be formulated on higher levels of abstraction than are many iconic models. They are also considerably fewer in number, particularly in the discipline of communication: the work of Katzer (1970) and of Stanfield, et al. (1965, pp. 25-50) being examples of completed models, and that of Borden (1970) of a model under development. While not always easy, it is nevertheless possible using analogic models such as these not only to make predictions from the model, but also to express a functional relationship between key variables and time.

In addition to iconic and analogic forms, it is possible to distinguish a third class of symbolic theories or models, defined here as "representations of events employing logical or mathematical notations and systems." Like iconic and analogic theories, symbolic theories must also maintain an isomorphism with the events represented. However, the specific logical or mathematical notations which form the medium of expression need not be direct analogs of particular structures (and relationships) in the events under study. In part because of the medium in which symbolic theories are expressed, they are usually formulated on higher levels of abstraction than are either iconic or analogic theories. Symbolic theories or models are also infrequent in the discipline of communication, appearing normally only as lower

level theories or models within the framework of other theories, e.g., the mathematical equations found in the work of Stanfield, et al. (1965, pp. 25-50), noted above. The work of Jaffe and Feldstein (1970) on dialogue is a notable exception, however. Despite their relatively infrequent appearance to date, symbolic theories or models are potentially the easiest of all from which to draw predictions and in which to express a functional relationship between key variables and time.

The distinctions which have been made above between iconic, analogic, and symbolic theories or models quite obviously do not define three mutually exclusive classes. Rather, the three general forms or types of theory represent three points along what is essentially a continuum. That is, there are some theories or models which fall between the different classes, and perhaps a few which would be difficult to classify at all. The distinctions have been made not for the purpose of categorizing theories, but for the purpose of tracing the more specific implications which the suggested approaches to constitutive definition have for the form of theory which deals with communication events.

Specific implications, comparisons, and comments. According to the primary implication, again, a theory dealing with communication events must be of a form which is capable of expressing a functional relationship between key properties or variables of the events and time. Of the three forms of theory considered above, iconic theory is certainly less well suited to this task than are analogic and symbolic theory, despite the fact that it encompasses much of the present theory

in the discipline of communication. One implication, therefore, is that if communication scholars desire to build theories and models which deal with communication events as processes, they will have to devote somewhat greater attention to the analogic and symbolic forms of theory. Note that this evaluation does not indicate any necessary deficiency in current theory, but instead implies a need to expand the scope of theoretical formulations in the discipline to include the other two forms of theory. A more detailed examination and comparison of analogic and symbolic theories or models should indicate more clearly what is implied by the need for added attention to the two forms. In particular, it will be helpful to consider and compare the two forms with respect to their inclusion of a time variable, their relationship to computers, and their function and use as theories.

As they were defined above, analogic and symbolic theories or models did not necessarily incorporate a functional relationship between properties or variables in events and time. In fact, no restriction whatsoever was placed on the nature of the function. The primary implication notes, however, that a functional relationship to time must be included in a theory or model which deals with communication events. Accordingly, it will be useful in the present context to redefine "analogic" and "symbolic" theories or models to take the dimension of time into account.

An analogic theory or model which includes a time relationship is one which specifies, for each set of conditions in a given universe, a single set of congruent structures which operate on variables in a specific time sequence. That is, for any one set of conditions,

there is only a single set of congruent structures operating in a specific sequence. On the other hand, a symbolic theory or model which includes a time relationship is one which, for all sets of conditions in a given universe, expresses each key variable as a logical or mathematical function of the variable time. Hence, for any one set of conditions and any one point in time, there is only a single set of values of the variables (see discussion of functions of time, section 3.3.1).

The two definitions reveal that for one set of conditions and one point in time in an event, the two forms of models would yield the same results, though they would "produce" those results by different means. The definitions reveal, too, a difference in the nature of the functional relationships to time. That is, analogic theories express time by specifying sequences of operations in time, whereas symbolic theories express time by specifying direct notational relationships to time. Nevertheless, both approaches qualify as functional relationships to time in the sense of a mapping of properties or variables onto time.

It is important to note that in the redefinitions above, analogic and symbolic theories bear some interesting similarities to computer programs (whether digital or analog), especially when the latter are defined as "procedures which specify, for each set of conditions in a given universe, a single set of operations on variables." Despite this similarity, it is crucial to note that analogic and symbolic theories are in no way restricted to implementation through computer programs. To consider such a restriction as necessary or

implied is to neglect the broad range of highly useful flowcharts, algorithms, games, manual and machine simulations, etc., which meet the definitions for analogic or symbolic theories, but which in no way involve the use of a computer. In cases where a computer does prove to be a useful tool, it should be noted that the program itself is the theory or model under study, and that a similar situation prevails if a flowchart or game is used as a theory. Scholars have not been at all inclined to view programs, flowcharts, etc., as theories in the past, but it is becoming much clearer that they should perhaps begin to do so (Gullahorn, 1965, pp. 445-446; Uhr, 1966, p. 367).

Irrespective of the particular manner of implementation, analogic and symbolic theories do have considerable potential for use. In particular, both forms will serve the four purposes which Deutsch has noted for a theory or model: (1) providing a conceptual framework for organizing data, (2) generating hypotheses, (3) providing actual predictions, and (4) providing information relevant to measurement techniques (1952, pp. 360-361). The means by which hypotheses are generated and predictions are made from analogic theories clearly will be distinct and perhaps less straightforward than the means employed with symbolic theories. That is, both forms serve the same overall purposes, but do so by somewhat different approaches, each approach having inherent advantages and disadvantages. Because both analogic and symbolic theories or models are potentially important in the discipline of communication, the advantages and disadvantages in using the two forms have been compared briefly in Table 5, below.

Table 5. A Comparison of Analogic and Symbolic Forms of Theory

Analogic Theory	Symbolic Theory
Relatively complex--many statements often needed.	Relatively simple--few statements often sufficient.
Requires low sophistication in expression of relationships and variables.	Requires high sophistication in expression of relationships and variables.
Minor changes generally easy to make.	Minor changes often difficult or impossible.
Derivation of hypotheses may be difficult.	Derivation of hypotheses often straightforward.
Non-analytic solutions generally needed (see Carroll, 1968, pp. 53-60; Lowry, 1968, pp. 58-59).	Analytic solutions often possible. Non-analytic solutions usually straightforward.
Manipulative tools only sketchily developed and often unavailable.	Powerful manipulative tools well developed and available.
Not often a relevant consideration	Certain tools restricted in application to classes of expressions (e.g., linear) or of behaviors (e.g., stochastic as Osgood, <u>et al.</u> , 1965, p. 230).
Investigator may become "immersed" in minute details.	Investigator may become "immersed" in mathematical elegance.

A careful study of the advantages and disadvantages presented in Table 5 reveals an important point regarding the use of analogic versus symbolic theories or models in the discipline of communication. That is, despite their desirability in terms of ease in deriving hypotheses or availability of powerful tools, symbolic theories or

models for the most part require too high a level of abstraction and sophistication in expression to find wide application at present. Instead, it appears that the current state of theory relevant to human communication is such that analogic theories or models are the most useful and applicable form. The insights which may be gained from symbolic theories related to communication are by no means to be ignored, as Krippendorff has stressed (1969a, pp. 129-131) and as will be evident in Chapter 4. However, the largely untapped potential of analogic theory demands that it be more fully explored and developed in building and advancing theory which deals with communication events as processes (see Katzer, 1970, and Scheflen, 1968).

In summary.— As indicated in part by this examination of certain aspects of analogic and symbolic theory, there are a number of relatively specific implications regarding the form of theory used in the study of human communication. These implications stem from the more general implication that a theory or model which deals with communication events as processes must include a functional relationship of key properties or variables to time. This primary implication, once again, results from the particular nature of the terms introduced earlier in the chapter in suggesting approaches to the constitutive definition of the concept of process. In short, those terms and suggested approaches were ones appropriate for dealing with the dimension of time in events, and more specifically, with the change over time or process which is seen here as an integral aspect of human communication events.

Quite clearly, it has not been possible in a chapter of this length to discuss all possible details either of the verbal and mathematical aspects of constitutive definition, or of the implications which these approaches have for the form of theory. Recognizing this, the procedure in both cases has been to specifically limit the range of the discussion. That is, in considering the verbal and mathematical aspects of constitutive definition, terms were chosen and discussed only if they had potential utility as tools in theory building related to communication. On the other hand, the approach to limiting the discussion of implications for the form of theory was to identify in advance the bounds within which the discussion would be placed. Both of these techniques will prove useful in Chapter 4, as well.

Chapter 3, then, has endeavored to provide approaches to a constitutive definition of the concept of process, as well as to consider some of the implications which these approaches have for theory. But constitutive definition of a concept is but one step in the explication. Operational definition is needed also, and approaches to this step in explication will occupy the next chapter.

CHAPTER 4

APPROACHES TO AN OPERATIONAL DEFINITION

As in the previous chapter, the concern here is also with the concept of process or of change over time--a concept seen earlier to be important and useful in the conduct of research and theory building related to human communication. This importance and utility has led to the task of explicating the concept for use as a tool in research and theory. With the first major step in that explication complete (Chapter 3), there remains the second step of providing approaches to an operational definition of the concept of process. Chapter 4 will be devoted to this step, as well as to an examination of the implications which these approaches have for research and analysis techniques. Chapter 4 will lead to a consideration both of examples of research in Chapter 5, and of broader implications in Chapter 6.

4.1 Nature of the Definition

As mentioned in Chapter 1, an operational definition of a concept specifies a procedure, under specific conditions, whose performance by an investigator will identify (i.e., measure or generate) in nature a situation which is the referent of the concept (see page 9ff and Berlo, 1967, pp. 2-3, 11). As noted in the same discussion, a formal operational definition can be formed only within the context of a specific observational or experimental framework. However,

because there is no attempt herein to design or carry out a specific experiment or plan of observation, the present situation is not one in which a unique operationalization can be formed. Accordingly, the attempt in this paper will be to identify the general principles for operationalizing the concept of process. In other words, the attempt will be to suggest approaches to an operational definition by providing a set of criteria which a particular operationalization must meet if it is to produce data which adequately characterize a given form of change over time or process. These suggested approaches not only provide the tools for forming operational definitions in specific observational and experimental situations, but also hold a number of important implications for research and analysis techniques.

Because the concept of process has received relatively small attention in the study of human communication, it will be again necessary in suggesting approaches to an operational definition to draw on information from a number of different sources. Of particular importance will be the information provided in Chapter 3, and especially in section 3.3. In addition, disciplines such as biology, cybernetics, mathematics, system theory and analysis, and several others will serve as important sources of information. The choice of information from these various disciplines will be eclectic, but will be in all situations a choice based on the criteria of consistency, generality, simplicity, and primarily, utility. The judgments on these different criteria, and especially on utility, will be made in the context of potential use of the information as a tool in research related to human communication.

Note again that there will be no attempt in this chapter to construct a unique operational definition. Rather, a set of potentially useful approaches to such a definition will be suggested and discussed. In doing so, it will be helpful to divide the remainder of this chapter into three parts. In particular, since the general principles for operationalizing the concept of process are of key importance, the second section will focus on them, as well as on a consideration of the necessary and sufficient conditions for the description of a process. These general principles carry a number of important implications for research techniques, especially for design and measurement, so that the third section will focus on these particular implications. In addition, because research techniques are closely associated with analysis techniques, it will be appropriate to devote the fourth section to briefly examining implications for the analysis of research information. In the normal context of observational or experimental research one would not normally consider research technique apart from analysis technique (cf. Kirk, 1968, p. 11). However, presentational economy makes such a separation useful here, and perhaps justifiable given the absence of a single, specific research framework.

4.2 General Principles of Operational Definition

Again, the first task is to suggest a set of approaches to an operational definition of the concept of process. More specifically, the task will be to develop a set of general principles for operationalizing the concept, i.e., a set of criteria or requirements which a research design must meet if it is to produce data which adequately

characterize (or identify) a given form of change over time or process. The development of such a set of criteria will involve the use of information from a number of different sources, and in several cases a detailed review of such information would require extensive discussion or derivation. As space is limited, such highly detailed discussions or derivations will occasionally be bypassed, with special attention given to appropriate references. In considering the general principles of operational definition of the concept of process it will be useful to divide the discussion into two parts. First, a consideration of the relationship between measurement at discrete points in time and the form of variation which can be characterized, and second, a statement of the necessary and sufficient conditions for the description of a process.

4.2.1 Discrete Measurement and Forms of Variation

In developing the criteria which a research design must meet to produce data characterizing a process, it will be necessary to depend heavily both on the concept of a path or form of variation, and on the graphic approach to representing such a path.¹ It will be necessary, in addition, to restrict attention to the case of a single variable changing over time within a bounded interval, recognizing that what is said for the single variable case may be extended directly to the multiple variable case (see pages 87ff and 104ff). Finally, it is important to note again that in order to record or characterize a given

¹These concepts were introduced in Chapter 2, pages 33 and 37, respectively, and have been used several times since, most notably in section 3.3.

form of variation, it is necessary to measure both the value of the variable under study, and the point in time at which that value is recorded (see page 33). In other words, the time of the observation must be recorded along with the value of the variable.

In an ideal situation, the process or change over time being studied would be indexed at all points in time by continuous measurement of the variable. Such continuous measurement within a bounded interval provides data which characterize the full form of the variation in that interval, i.e., no consideration need be given to the adequacy of the data in characterizing the process. Continuous measurement is an ideal, however, and is not always necessary nor always possible. In a more normal situation, the approach is to measure or sample the variable at a number of discrete points in time (usually regularly spaced) during the interval. This latter form of measurement raises the question to be considered here: Does the data produced by the discrete measurement adequately characterize the form of variation? The question may be broken down into three parts: How frequently must measurements be made? What is the minimum number of measurements? How long must measurement continue?

Frequency of measurement.-- That it is possible for a set of measurements taken at discrete points in time to completely characterize a continuous path or form of variation (a signal) in a bounded interval has been known for many years.² The reason that the finite

²Complete characterization means that the data provide the same information as continuous measurement. That is, even though the data are finite, they allow reconstruction of the full form of the variation

number of data produced by discrete measurement can fully characterize the "infinite" number of data in a continuous signal is that only some of the data in the continuous signal are independent of one another (Cherry, 1957, p. 141). It is therefore necessary to establish what data are independent, or in other words, to determine how frequently measurements must be made on a given signal or form of variation. In this particular context, such a determination can be made most readily by considering both the technique of Fourier analysis and the Sampling Theorem.

Fourier analysis has been introduced earlier (page 122), and is a mathematically valid technique for "decomposing" any signal or form of variation within a bounded interval of time into a number of component signals, each of which is sinusoidal. In theory, an exact decomposition might require an infinite number of such components, but if one is willing to accept a small margin of error, the number becomes finite and often small. The advantage in decomposing a "complex" signal into component signals is that each component, because it is sinusoidal, can be characterized by only two data (G. A. Miller, 1951, pp. 29-30). An example of a complex signal and its three component signals, as might be determined by Fourier analysis, is presented in Figure 1, page 146. The sinusoidal components form the complex signal when added algebraically, and a similar relationship would hold between any other form of variation and its components. For the purpose of

over the interval. Note that the term "signal" will again be used here as synonymous with "form of variation," as in section 3.3.3.

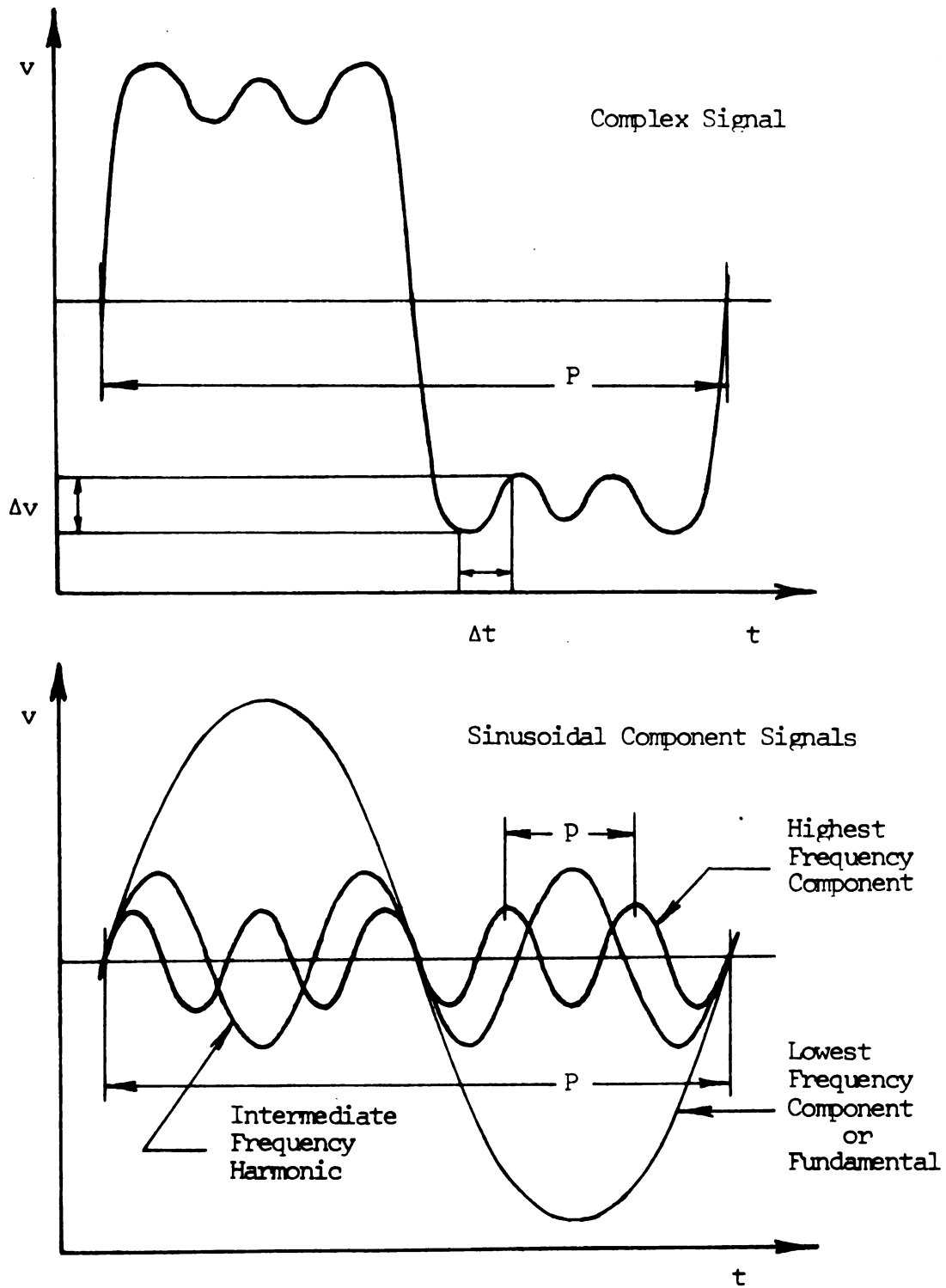


Figure 1. A Complex Signal and Its Components
(After Koenig, 1967, pp. 25-30)

determining how frequently measurement must be made on a complex signal, it is the component with the highest frequency which is of primary interest.³

The high frequency component has a characteristic frequency, f , in cycles per second, as well as a particular period, p , in seconds, which is the time required for a single cycle (note $p = 1/f$). The Sampling Theorem reveals that discrete measurements spaced at intervals less than or equal to one-half of the period p are sufficient to completely characterize the complex signal. In other words, it is the period, p , of the high frequency component of a particular signal or form of variation which determines how frequently the signal as a whole must be measured. Measurement which is spaced at intervals (Δt) where $\Delta t \leq p/2$ produces data which characterize the signal over the bounded interval and which allow its reconstruction through Fourier techniques (see Cherry, 1957, pp. 141-143; Gabor, 1946, p. 430; G. A. Miller, 1951, p. 30; Pierce, 1961, pp. 272-273; and Shannon, 1963, pp. 53-54). Measurement at intervals where $\Delta t > p/2$ can provide an approximation of the signal under study, but cannot completely characterize it or allow its reconstruction in all detail.

This particular criterion regarding the frequency of measurement is the primary criterion relating measurement at discrete points in time and the form of variation which can be characterized by that

³Further information on Fourier analysis, together with detailed derivations may be found in: Bergland (1969, pp. 41-52), Bracewell (1965), Cherry (1957, pp. 128-143), Gabor (1946, p. 430), Hamming (1962, Ch. 6), Koenig (1967, pp. 25-30), and Pierce (1961, pp. 30-34).

measurement (see page 34). It should be noted though, that it is not always necessary to identify the high frequency component and hence the measurement interval, Δt , through Fourier analysis. That is, one can frequently determine a maximum frequency or "bandwidth" for a given form of variation, or can identify a minimum response or reaction time, etc. Both of these approaches would provide similar information, and will be considered again, below. The Fourier analysis approach has been used above because of its broad generality and power. Note too, that in the absence of information on highest frequencies, it is possible to use the same criterion to identify the forms of variation which can be adequately characterized by a given measurement interval, Δt . This point will also be considered, below, but it is necessary first to complete the present task.

Minimum number of measurements.-- In addition to considering how frequently measurements must be taken on a given signal or form of variation, it is useful to determine the minimum number of measurements which might be required to characterize a form of variation. To do so, it will be helpful to exclude from consideration the case where the path or form of variation is known to be linear. In this case, one measurement is sufficient if the slope is known (cf. page 35n) and two are sufficient if the slope is unknown (cf. page 37n).⁴ Given this exclusion, the simplest possible measurement situation is that in which one attempts to characterize a sinusoidal signal.

⁴Note, however, that three measurements are not sufficient to determine whether the variation is linear. Linearity is, instead, an independent determination.

That is, because any other form of variation can be analyzed into a set of sinusoidal components, the sinusoidal signal is the basic or simplest form. In considering the number of measurements needed to characterize such a signal, it will be helpful to focus again on the high frequency component of a particular signal because of its centrality in measurement considerations. More specifically, it will be assumed below that the frequency, f , of this component is known.

Given this particular assumption, it can be shown (as in Appendix B), that one measurement is insufficient to characterize a sinusoidal signal in any case. Two measurements, however, may well be sufficient to characterize such a signal (cf. page 37n). However, should the measured values be equal, two measurements are not sufficient, and it is necessary to obtain three measurements spaced at intervals of Δt , where $\Delta t < p/2$. Three measurements spaced at $\Delta t < p/2$ are sufficient, in all cases under the assumed conditions, to characterize a sinusoidal signal (see Appendix B).

The minimum numbers of measurements mentioned above are derived from an examination of the equation for a sinusoidal signal and especially of the number of unknown variables in that equation for which information must be provided. The frequency of a sinusoidal signal is one of the variables in the general equation for such a signal, but is assumed to be known in the derivation used here. Note that if the frequency is not known, a new unknown variable is introduced--one which makes three measurements an absolute minimum number, and which in all cases requires that the measured values be unequal in order to characterize a sinusoidal signal (see Appendix B).

Length of measurement period.-- Again, the above analysis indicates that three measurements spaced at $\Delta t < p/2$ are sufficient to characterize a sinusoidal signal of known frequency. It is therefore evident that if the signal under study is a complex form of variation having several sinusoidal components, it cannot be completely characterized by three measurements. Other measurements are necessary to provide information to characterize the other components. Since the frequency of measurement is fixed at $\Delta t \leq p/2$, it becomes useful to determine how long measurement must continue to characterize a complex form of variation in a bounded interval. Such a determination can be made by considering, once again, both Fourier analysis and the Sampling Theorem.

As noted in the discussion of frequency of measurement, discrete measurements spaced at intervals, Δt , where $\Delta t \leq p/2$, are sufficient to completely characterize a complex signal in a bounded interval. If the bounded interval has a total time span, T , then the number of measurements needed to characterize it is $T/\Delta t = T/p/2 = 2T/p = 2fT$, since $f = 1/p$. Not surprisingly, the quantity $2fT$ is also the number of independent data in any continuous signal of duration T (see Cherry, 1957, pp. 141-142; Shannon, 1963, pp. 53-54).

Thus, in order to completely characterize a complex signal in a bounded interval, measurement must continue until $2fT$ data collected (cf. Pierce, 1961, p. 272). In practice, with measurements spaced at or just under the interval $\Delta t = p/2$, measurement would have to continue for the entire interval, T . However, if the complex signal repeats itself regularly in the bounded interval under study,

somewhat fewer measurements may suffice. In this case, measurement which continued over a sub-interval equal to the period, P , of the lowest or fundamental frequency component would be sufficient to completely characterize the complex signal (see Figure 1, page 146; G. A. Miller, 1951, p. 30). While these latter two criteria are perhaps slightly less general than that above, they will be used here as a matter of convenience.

A number of other details could be added to the above discussions of the frequency of measurement, the minimum number of measurements, and the length of the measurement period; however, the intent here is not to reproduce detailed information available from other sources. Rather, the intent is to develop and explain a set of criteria for determining whether the data produced by the discrete measurement of a signal adequately characterize that signal. The various criteria considered are useful in such determinations, but have a somewhat broader use in the present context. That is, the criteria suggested above are also the criteria which a research design must meet if it is to produce data which adequately characterize a given form of change over time or process. These criteria can be most conveniently summarized by assembling them into a set of conditions for the description of a process.

4.2.2 Necessary and Sufficient Conditions for Description of a Process

An examination of the criteria discussed above reveals that the necessary and sufficient conditions for the description or measurement of a signal, of a form of variation or change over time, or of a process, are these:

- (1) Measurement of the value of the variable(s) under study, and of the points in time at which such measurements are taken.
- (2) Measurement at at least 3 points in time where:
 - (a) the measurement interval, Δt , is $\Delta t < p/2$, and p is the period of the highest frequency sinusoidal component of the signal, or:
 - (b) the measured values, v_n , are unequal, $v_1 \neq v_2 \neq v_3$, and the frequency of the highest frequency sinusoidal component is unknown.
- (3) Measurement over the bounded interval, T , or over a sub-interval, P , where P is the period of the lowest frequency sinusoidal component of the signal.

Fulfillment of these necessary and sufficient conditions by an observation procedure or research design assures that that procedure or design will produce data which adequately describe, measure, or characterize a given form of variation or process in a bounded interval. The conditions also constitute a set of general principles for operationalizing the concept of process, in the sense that a research design which meets these conditions would be an operationalization of the concept of process. That is, such a design would specify a procedure, under specific conditions, whose performance would identify (or measure) a situation which is the referent of the concept (see page 9).

It has been the burden of section 4.2, then, to develop this set of general principles for operationalizing the concept of process. Again, because the present situation is not one in which a unique operational definition can be constructed, the attempt has been to suggest a set of potentially useful approaches to such a definition. These suggested approaches are, in effect, a set of tools which may be used to construct specific operational definitions of the concept of process. As noted earlier, the various approaches or principles have

been developed using information from a number of different sources--information chosen on the basis of its consistency, generality, simplicity, and particularly its utility when judged as a potential tool in research related to human communication.

Because the attempt here has been one of suggesting approaches or principles for use in forming operational definitions, rather than one of constructing specific definitions, it is not appropriate to judge these principles by the normal criteria for a viable, formal operational definition. Such criteria are generally those of formal clarity, significance, correspondence to the concept, independence, and above all, utility (G. R. Miller, 1967, pp. 14-24). However, the suggested approaches or principles are seen as capable of producing definitions which meet these criteria, should they be applied in specific research situations to operationalize the concept of process.

The approaches to an operational definition considered above clearly have a number of important implications for research and analysis techniques in the study of human communication. Specifically, the principles for operationalizing the concept of process have several very direct implications for research techniques, i.e., for research design and for measurement. Section 4.3 will examine these direct implications, and in so doing will attempt to tie the rather abstract necessary and sufficient conditions noted above to the more concrete considerations of actual research.

Note, too, that the information produced in an actual research situation usually undergoes some form of analysis, normally by means of an analysis technique which is closely associated with the

particular research technique employed. As a consequence, the principles for operationalizing the concept of process have a number of indirect implications for analysis techniques. Section 4.4 will examine these somewhat less direct implications, but in so doing will create a distinction between research and analysis which is not normally made (cf. Kirk, 1968, p. 11). As noted earlier, it is the absence in this paper of a single, specific research situation which makes such a distinction necessary.

4.3 Implications for Research Techniques

To this point, Chapter 4 has been concerned with a set of suggested approaches to the operational definition of the concept of process. In particular, it has considered certain general principles for operationalizing the concept and has provided a set of criteria, in the form of necessary and sufficient conditions, which a particular operationalization must meet. These approaches, and more specifically the criteria or conditions, have a number of direct implications for research techniques, not only for research design, but also for measurement. It is appropriate to examine these implications for research techniques, particularly as those techniques relate to the study of human communication events.

An examination of the techniques of research design and of measurement is clearly a lengthy and involved task in any discipline, that of communication being no exception. The present limitations of space dictate a somewhat restricted or bounded discussion, and it will be helpful to identify those bounds in advance (see section 3.4).

More specifically, the concern here will be entirely one of outlining key implications for techniques of design and measurement, especially as these techniques relate to research on human communication. In other words, the discussion will focus primarily on indicated modifications in research techniques, rather than on a review of existing techniques. In addition, the concern will be more with general modifications and broader classes of techniques than with specific changes or tools (except as examples). As a result, in some instances where detailed information might otherwise be useful, it will be necessary to suggest outside references as more complete sources. A similar situation will hold in the separate discussion of analysis techniques in section 4.4.

In keeping with Chapter 2, both observational and experimental research will be considered relevant in the discussion below (see pages 33, 70; cf. Sidman, 1960, p. 237). That is, while certain research techniques lend themselves more readily to observational research than to experimental research, or vice versa, such a distinction will not be a primary concern in the discussion of those techniques. In addition to these bounds, it should be emphasized again that the concern here is with research techniques only as they relate to the concept of process, not as they relate to other concepts such as interaction, emergence, or system (see page 40). Likewise, it is important to note again that the discussion below will not necessarily apply to all research conducted in the discipline of communication, since not all such research need incorporate the concept of process (see page 71). However, for research which does involve process, the implications and

modifications suggested here should be of some importance. The research techniques discussed below are presented therefore not as replacements for present techniques, but as potentially useful additions to such techniques (see page 75).

Acknowledging these bounds for the discussion, it appears appropriate to divide what follows into three parts. First, an examination of the direct implications for research design of each of the necessary and sufficient conditions. Second, a brief examination of several potentially useful "process designs." And third, a consideration of certain implications for the measurement of variables other than time.

4.3.1 Direct Implications for Research Design

As is clear from the discussion in section 4.2, a research design which is to adequately measure a form of variation or process must fulfill the necessary and sufficient conditions noted on page 152. Designs which meet the conditions are said to be operationalizations of the concept of process and will produce data which completely characterize the form of variation under study. Because the necessary and sufficient conditions are the criteria separating "adequate" from "inadequate" designs, they quite clearly hold direct implications for the development of research designs. Because each of the three conditions holds distinct implications, it will be appropriate to examine each of them in order. In doing so, it will also be possible to express in more concrete form the various considerations to be made in constructing process designs, i.e., designs capable of producing data which characterize a form of variation or process (see pages 38-40, 56-58).

Variable value and time.-- The first of the three conditions for the description of a process notes that it is necessary to obtain "Measurement of the value of the variables(s) under study, and of the points in time at which such measurements are taken (page 152)." While this first condition describes a fundamental operation in the description of any process, it is perhaps the easiest of the three conditions to fulfill. Its implications for research design are therefore somewhat less far-reaching than those of the other conditions.

Very briefly, the first condition identifies an additional type of measurement which must be made in conjunction with the measurements taken on the variable(s) of interest. The additional measurement indexes the times at which the other measurements are made, and requires both the operational definition of an "observation point," and the measurement of the time of this point from some reference point (see pages 33-34, 56). Time is capable of ratio measurement, and the reference point may be either an arbitrary zero point, or the point of the first measurement. These considerations apply both to the measurement of variables at discrete points in time, and to measurement over all points in time (i.e., continuous measurement), although in the latter case the concept of a discrete observation point loses its meaning. Note, again, that measurement at discrete points in time approaches continuous measurement as the interval Δt approaches zero (see section 3.3.3).

The actual implementation of the measurement of time with respect to the measurement of other variables depends heavily on the nature of the specific research situation. In general, though,

problems may arise in defining an "observation point" if the procedure for measuring the variable(s) under study requires a large amount of time in comparison to the interval Δt . The specific research situation would indicate what type of operational definition is most appropriate, as in the choice, for example, of defining the observation point as the beginning, middle, or end of the measurement period. Other problems may arise, as well, if the measurement procedure interferes with the presentation of an important stimulus. Consideration will be given to this problem in section 4.3.2, below, since the solution may require the use of a particular type of research design.

Measurement interval and resolution.— The second of the three conditions for the description of a process is somewhat more complex than the first. It notes, in the first place (a), that measurements must be made at at least three points in time where "the measurement interval, Δt , is $\Delta t < p/2$, and p is the period of the highest frequency sinusoidal component of the signal (page 152)." This aspect of the condition is by no means easy to fulfill, and carries a number of important implications for human communication research. The first aspect of the condition implies, in general, the need for certain new considerations in developing adequate research designs. That is, in constructing a design to measure a process, it is necessary to consider certain specific characteristics of the form of variation in order to determine the appropriate span between observation points. Such considerations are not often made in human communication research, at present, and it will be helpful to examine

briefly what they involve.

As the first aspect (a) of the condition is stated, it requires an a priori knowledge of the frequency or period of the highest frequency sinusoidal component of the signal under study. Such information can be obtained in advance only by depending on similar, earlier studies which indicate the expected form of the variation. If the form is known in general (as in learning curves), or specifically (as in previous recordings), it may be possible by means of Fourier analysis to determine directly the highest frequency component, its period, and hence the appropriate measurement interval (see page 122).

However, it is not always necessary, or more importantly, always possible, to obtain information on the highest frequency component as suggested above. In such cases it may be possible, as an alternative, to determine a "minimum response time" for the particular event(s) or individual(s) under study. If such a response time is the minimum time required to initiate some change in state, then that time interval may well be a suitable measurement interval, Δt . More generally, it may be possible to determine a maximum frequency by determining the "bandwidth" of the signal under study. As the term is employed, here, the "bandwidth" of a complex signal is the frequency of the highest frequency sinusoidal component of the signal (Cherry, 1957, p. 303). In some cases, this maximum frequency can be determined without knowing (or anticipating) the general or specific form of the variation, as above. That is, determinations of maximum "channel" or "input/output" rates or capacities, whether for machines or for individuals, may provide information on bandwidths (cf. Shannon, 1963, pp.

66-68, 79-81; Pierce, 1961, pp. 36-38). If such a rate or capacity can be found, it will provide the necessary information to determine the appropriate measurement interval. In more concrete terms, if one can answer the question "How fast can this state (e.g., an attitude) possibly change?" he can determine how frequently to measure it in order to record its variation.

Despite the existence of these alternatives for determining the appropriate measurement interval, situations will still exist in which it is extremely difficult or even impossible to obtain the necessary information on Δt . In such cases, the second condition remains basically unfulfilled, as considered above, though it is by no means irrelevant. Specifically, the condition notes, in the second place (b), that measurements can be made at at least three points in time where "the measured values, v_n , are unequal, $v_1 \neq v_2 \neq v_3$, and the frequency of the highest frequency sinusoidal component is unknown (page 152)." Note that this second aspect of the condition is not a substitute for the first in providing the necessary information to develop adequate research designs. Nevertheless, this aspect is important and implies, in general, the need for additional new considerations in developing research designs.

That is, in constructing a research design in the absence of information on the appropriate measurement interval, it is necessary to consider what may be termed a design's "resolution capability" or "resolving power" in measuring a process. In other words, the second aspect (b) of the condition indicates that if a design includes at least three measurement points, it is possible to determine the fre-

quency of the highest frequency component which the design is capable of measuring. Note that whether or not the design actually does measure such a component depends on the presence of three unequal values of v_n . However, a design would be capable of resolving or measuring component frequencies up to a maximum of $f = 1/p = 1/(2 \cdot \Delta t)$, where Δt is the smallest measurement interval in the design.

Considerations of the resolution capability of a particular design do not often appear in research on human communication at present, even though the resolving power of a design may place a constraint on the analysis of the data produced by the design, and on the semantic interpretation of the resulting evidence (see page 34). In addition, Sidman (1960, pp. 287-289) has suggested that in certain research situations there may well be optimum resolutions which need to be carefully examined and determined. Note that a design's resolution capability need not be considered if continuous measurement is involved, just as it is unnecessary to consider or determine the appropriate measurement interval. The reason is that the second condition is "automatically" fulfilled by continuous measurement. Should the measurement be discrete, however, the first aspect (a) focusses attention on the measurement interval, while the second aspect (b) requires consideration of resolution capability, particularly if the appropriate measurement interval cannot be found.

Length of measurement period.-- The third of the three conditions for the description of a process notes that the measurement must continue ". . . over the bounded interval, T, or over a sub-interval, P, where P is the period of the lowest frequency sinusoidal

component of the signal (page 152)." This third condition is fairly straightforward, but is not always easy to fulfill. As such, it also holds important implications for research design.

In brief, the third condition indicates that adequate measurement of a form of variation or process within a bounded interval requires that the measurement continue throughout that interval. Exceptions to this requirement do exist, but only if the variation is such that it repeats itself over the period of the fundamental and within the bounded interval under study. As in the second condition, it is possible to take advantage of this exception only if there is a priori knowledge about the frequency or period of the fundamental. Such information can be obtained through Fourier analysis of general or specific forms of variation; however, in this case there are few, if any, alternatives to the Fourier method.

The third condition implies the need for yet another consideration in research design—one which is, in effect, the opposite of resolving power and might be termed a design's "inclusiveness." That is, whatever the length of the measurement period in a design (whether T or P), the design is only capable of including or measuring component frequencies with periods shorter than or equal to T or P, whichever is shorter. Hence, the lowest frequency which can be identified by a design is $F = 1/T$ or $1/P$, whichever is higher.

Considerations of a particular design's "inclusiveness" are occasionally included in human communication research, at present, often in terms of a comment on a design's weakness in measuring a "long term trend." Such considerations constitute an important constraint

both on the analysis of research data and on the semantic interpretation of evidence, and should not be overlooked. Note that unlike the case above, the third condition applies equally to discrete and to continuous measurement of a process.

The third condition, then, like the other two which comprise the necessary and sufficient conditions for describing a process, holds certain distinct and direct implications for developing research designs. As a group, these implications lead to a number of fairly concrete considerations for constructing designs capable of producing data which characterize a process. But the considerations above remain at a fairly general level, and it will be helpful in studying the overall implications for research design to examine briefly several specific designs.

4.3.2 Some Specific Process Designs

In particular, it will be helpful to review several designs mentioned earlier, as well as to introduce one "new" design, all of which are potentially useful as "process designs" in research on human communication. Each of the designs below is capable of operationalizing the concept of process, though clearly whether it does so or not in a given research situation depends entirely on whether or not it fulfills the necessary and sufficient conditions. If the conditions are fulfilled, then the data which the design produces will characterize the process under study.

Note that the discussion below is not intended to be exhaustive in indicating the strengths and weaknesses of the various designs. Many of the critical strong and weak points of each design have been

examined at length by Campbell and Stanley (1963), and it is clear that many problems with specific designs arise from (or are solved by) particular conditions of use. The discussion below is intended rather to review a number of potentially useful designs in view of the considerations above. Clearly, of all the research designs considered by Campbell and Stanley (1963), and summarized earlier in Table 2, page 57 (and in Appendix A), only those which include three or more observation points are capable of meeting the necessary and sufficient conditions. A brief review of each of the designs in the third column of Table 2 is therefore in order, as only these can function as "process designs."

Three of the process designs listed in column three of Table 2 (page 57) share a common characteristic: they are direct extensions of difference designs (column two) in attempts to index a time dimension. Specifically, the pretest-posttest with control and time extension design (Hovland's design) is an extension of the basic "pretest-posttest with control group" design (4); the separate-sample pretest-posttest with time extension design (12b) expands upon a similarly named difference design (12); and the 'multiple-wave' panel design (B) is an extension of the "two-wave panel" design (A).⁵ The first two of these three process designs, i.e., Hovland's design and the separate-sample design, both have the somewhat unfortunate characteristic of requiring one (or more) groups of subjects for each additional observation point desired. Such a characteristic multiplies the sample size, effort, and cost in using these designs for more than three

⁵A brief comparison of these designs in their schematic forms (Appendix A) will make the nature of the extensions considerably more evident. The numbers in parentheses refer to Appendix A.

observations, although the high precision and control in the Hovland design may be worth the expense. The multiple-wave panel design, on the other hand, requires no additional groups (if used in its simple form), but carries and compounds the many disadvantages of panel designs noted by Campbell and Stanley (1963, pp. 67-68).

The other two process designs listed in column three of Table 2 (page 57) are distinct in that they are not extensions of simpler designs, but instead are designs created especially to index a time dimension. The two designs are the time series design (7) and the multiple time series design (14), and are sufficiently similar to be treated together. These two time series designs require no additional groups for additional observation points, and are especially flexible with respect to the number and spacing of such points. In fact, as the measurement interval in these designs becomes smaller, the measurement involved approaches continuous measurement. These strengths, and others, nevertheless may be offset by certain weaknesses, as Campbell and Stanley (1963, pp. 37-43, 55-57) have noted, among which is the potential problem of repeated measures. This latter problem is not often encountered in research in areas such as interaction analysis, however, a point which accounts in part for the many successful uses of the time series designs in such research (see pages 62-64).

The five process designs reviewed above are ones which have been mentioned earlier (section 2.3.2) as potentially useful designs in research on human communication, but they do not exhaust the possibilities for process designs. That is, the fact that three of the five designs above are extensions of simpler designs suggests that

other process designs might be generated by using difference or even point designs as bases. To exemplify such possibilities, it will be helpful to present a single "new" process design, and to examine its strengths and weaknesses, though again not in the same detail as the Campbell and Stanley analyses (1963).

This new design draws in part on the pretest-posttest with control and time extension design (Hovland), and on certain counter-balanced designs (11). For lack of a more imaginative name it will be termed the separated group delayed posttest design. Using the same code employed by Campbell and Stanley (1963, p. 6; Appendix A) for presenting designs, this new design may be presented schematically as follows:

		t_1	t_2	t_3	t_4	t_5
Group A	R X_a	0 X_b				0
Group B	R X_a		0 X_b			0
Group C	R X_a			0 X_b		0
Group D	R X_a				0 X_b	0

Very briefly, the R represents the randomization of subjects into separate groups, the X_a and X_b represent the exposure of a group to stimulus variable(s) or event(s), and the 0 represents some form of observation or measurement. In this design, the posttest observation is delayed for a different time span with each separate group, thus giving rise to the name. Note that a pretest is possible in the design if desired.

As presented above, the separated group delayed posttest design would perhaps not be automatically classed with the other process

designs. However, if the four groups can be assumed homogeneous due to randomization, the design can be seen to produce data which are equivalent to the following "design":

		t_1	t_2	t_3	t_4
Group Y_a	X_a	0	0	0	0
Group Y_b	X_b	0	0	0	0

Quite clearly this latter equivalent design is a process design. Note that the "Group Y_a " observations are a composite of the observations on Groups A, B, C, and D. Similarly, the "Group Y_b " observations are composed of the observations on the same four Groups, but following a different stimulus. All of the observations on Group Y_b actually occur at time t_5 , but involve intervals which are the same as those separating times t_1 through t_4 .

Referring to this presentation, it is possible to examine some of the strengths and weaknesses of this new design. It is apparent, first of all, that the design requires as many separate groups as there are delayed posttests, so that additional observation points do increase the sample size, effort, and cost. However, this disadvantage may well offset by the design's ability to accommodate situations in which the measurement period is lengthy, or in which the measurement procedure seriously interrupts or otherwise interferes with the presentation of the stimulus variable or event. For example, the design would permit a complex measurement instrument to be applied to a continuous stimulus (e.g., a speech), in effect without interrupting that stimulus.

The separated group delayed posttest design may be subject, in the second place, to weaknesses with respect to history, maturation, and multiple treatment interference, as Campbell and Stanley have defined these terms (1963, pp. 5-6). On the other hand, the design has the advantage of not involving the problems of repeated measures, as do the time series designs, even though it produces similar data. The design offers, as well, a considerable flexibility in the use of its two stimulus exposures. That is, the design would allow similar testing on two different treatments, or would allow a wide range of possibilities for incorporating controls in an experiment.

The separated group delayed posttest design clearly has certain weaknesses and specific strengths, as do the other process designs. It is presented here both as a potentially useful design in research on human communication, and as an example of the possibilities in developing new designs capable of operationalizing the concept of process. Other designs could have been suggested, and more details could have been added than have been included above, were the intent here to present an exhaustive study of process designs and their use. While designs above are capable of operationalizing the concept of process, whether they in fact do so in a given research situation is separate matter. That is, the designs must still meet the necessary and sufficient conditions for describing a process (page 152) in order to produce data which characterize the process under study. In general, then, the necessary and sufficient conditions for describing a process carry the additional implication that if research on human communication is to adequately deal with the concept of process, it will be

necessary both to use existing process designs and to develop new ones.

As is perhaps evident in the above review of process designs, the choice of any one research design depends, at least in part, on the choice of the measurement technique to be employed. For example, choosing a time series design may bring the problems of repeated measurement, while the nature or complexity of a measurement technique may dictate the choice of a design such as the separated group delayed posttest design. The result of this interaction between research design and measurement technique is that the necessary and sufficient conditions also have certain implications for measurement of variables other than time--implications which need to be examined as part of the broader task of studying implications for research techniques.

4.3.3 Implications for Measurement

As the term "process" is used here, it refers to a "change over time of matter-energy or information, within a bounded interval of time." Measurement of the variable of time has been considered already in section 4.3.1, so that the focus here is entirely on the measurement of other types of variables, i.e., those representing the states of matter-energy or information under study. Again, the concern here is with measurement in its interaction with research design, rather than with measurement per se, recognizing that changes in measurement may well open new possibilities in the choice of designs. Note, too, that because the details of a measurement technique are always closely tied to a specific research situation, it will be necessary in what follows to consider only general aspects of measurement.

In other words, the intent here is not to review the many different forms which measurement may take, ranging from psychophysical to verbal, nor to consider the problems raised by levels of measurement, whether nominal, ordinal, interval, or ratio. Rather, the concern will be with those broader aspects of measurement which require further development or which must be considered in choosing research designs. In particular, it will be helpful to examine the need both for development of unobtrusive measures and for consideration of individual or group measurement, as well as the need for attention to two other, somewhat briefer points.

One of the problems often encountered in communication research is that of the effect which the measurement instrument or procedure has on the research stimulus, on the subject(s), or on both. Such effects may well be compounded in certain process designs by the presence of repeated observation or measurement of some event, and may well be disruptive enough to prevent the use of those designs. While alternate designs may be applicable in some cases, an important additional possibility is the use of some form of "unobtrusive" or "nonreactive" measurement.

The different forms of and problems in using unobtrusive measures have been discussed at length by Webb, et al. (1966), and cannot be detailed here. In general, such measures may involve the use of "archival" records, or of simple or "contrived" observation, the latter class including "hardware" such as the audio-video taping equipment which has contributed to the recent advances in interaction analysis (Ekman, et al. (1969); Frahm (1970); Harrison (1969b); cf.

Starkweather (1969)). While the measurement techniques discussed by Webb, et al., are not always widely applicable, the importance in finding or developing an unobtrusive measure for a given research situation is that it may permit the use of a previously unsuitable though desirable research design.

As a specific example, the availability of an unobtrusive measure for a key variable might allow the use of a straightforward time series design in a particular situation, in place of the more complex and expensive separated group delayed posttest design. More generally, development in the area of unobtrusive measures would appear useful in broadening the application of existing process designs, as well as in encouraging new designs. One must always be on guard against the lure of "gadgets" and of "fads" in measurement, but at the same time it is clear that developments in measurement techniques (e.g., the semantic differential) have occasionally brought valuable changes in both the methods and the content of human communication research.

In addition to the possible use or development of unobtrusive measures as a factor affecting the choice of research designs, it may be useful in certain communication research situations to consider specifically the question of whether individual or group measurement is to be employed. That is, is the measurement instrument or technique to be one which is applied to subjects as isolated individuals or to subjects assembled in some form of group?⁶

⁶Note that the concern here is with the "situation" in which

At first glance, such a question may well seem trivial, since the answer would appear to be "determined" by the purposes underlying the research, by the availability of subjects, by the nature of the variable(s) under study, by cost, etc. Indeed, such factors do often dictate the use of, say, group measurement over individual measurement, but it is also the case that such a decision is sometimes made by default, owing to tradition or to the availability of a particular instrument or technique, for example. Particularly in the latter case, it becomes important to consider whether individual or group measurement is to be employed because of the strong tie between these forms of measurement and research designs. That is, of the process designs considered earlier in section 4.3.2, only the time series designs and the multiple wave panel design appear readily adaptable to both forms of measurement--the other three designs are strongly associated with group measurement.

Rather than implicitly accept such restrictions on the choice of a research design as may be imposed by tradition or by an available form of measurement, it appears important for the investigator to consider of whether the "opposite" form of measurement might be used. Specifically, if an investigator can recognize the need for and can develop a group measurement technique where an individual technique had previously been used, he may well find that he has a larger range of process designs to draw on. On the other hand, development of an

the instrument or technique is applied, not with the treatment of the resulting data; i.e., data gathered from isolated individuals might well be "grouped," while that gathered in a group might be analyzed on an "individual" basis.

individual measurement technique to replace a group technique might allow, in a particular situation, more effective use of a time series design. In general, it would appear useful to consider specifically the question of whether individual or group measurement is to be employed, since doing so may broaden considerably the range of applicable process designs.

Along with these considerations of the "form" of measurement and of unobtrusive measures, there are two other somewhat briefer points which need attention and which should be mentioned in reviewing implications for measurement. The first of these concerns both the nature of variables other than time and their operational definition. More specifically, the use of process designs which meet the necessary and sufficient conditions discussed earlier will have certain effects on the types of variables studied in research situations. Increased frequency of measurement, for example, may make it difficult to employ some variables which would be quite suitable in point or difference designs (e.g., Noble's m measure). New variables will have to be developed, both to replace older ones and to utilize the added potentials of increased measurement frequency. Such new variables will require operational definitions, as do all variables (Berlo, 1967, p. 11), and in view of the possible complexity of some variables which might be measured in a process design, it is important to note that there are other modes of operational definition besides the usual verbal statement of procedures. In particular, analog or digital computer programs are also statements of procedures, but with the particular advantages of being able to define a wide range of variables, at

many levels of complexity, and with extreme uniformity.

The second of the two briefer points concerns the problems of repeated measurement. In particular, the use of process designs in research will result in sets of observations which will not always satisfy the assumption of independence of observations required by most statistical techniques. Note that while this point borders on the concerns of section 4.4 with analysis techniques, it deserves mention here due to its intimate relationship to measurement.

Specifically, in the case where the measurement occurs over a total interval, T , and where the highest frequency sinusoidal component has a known frequency, f , it is evident that $2fT$ data are independent (see section 4.2.1). While such information will be of help in certain situations, it is clear that many uses of process designs will require a fuller consideration of the means for dealing with measurements or data which are related in some degree. While it is quite clear that the problems of repeated measurement have received a fair amount of attention, as in Harris (1967) among others, it is also clear that more work remains to be done (Campbell, 1963, pp. 45-46).

These two somewhat briefer points concerning variables and repeated measurement could be considerably expanded, were the concern here with the problems of measurement per se. The concern is, however, entirely with measurement in its interaction with research design, and these two brief points are mentioned because they require at least some consideration in using a process design. Of key importance in using, and especially in choosing a process design are the two broader factors of possible use of unobtrusive measures and of consideration of

individual or group measurement. Again, changes in either of these two aspects of measurement may well open new possibilities in the choice of designs. Because of this interaction between research design and measurement technique, the necessary and sufficient conditions for describing a process also carry implications for the measurement of variables other than time. In general, those implications are that if research on human communication is to utilize research designs which meet the specified conditions, it will be necessary to consider several broader aspects of measurement which might normally be overlooked.

In summary.-- This examination of the implications for measurement is only one portion of the study of implications attempted in this section (4.3). That is, the review of implications for measurement, in combination with the consideration of specific process designs and the examination of direct implications for research design, as a group comprise the review of implications for research techniques. Because many of these implications are relatively specific, it may be helpful to formulate a somewhat more general implication to serve as a summary of the above. Namely, if research on human communication is to deal adequately with the concept of process it must use and develop process designs, considering carefully both the ways in which the designs meet the necessary and sufficient conditions, and the nature of the measurement which is employed.

If research can be conducted in the manner of this general implication, it will provide data which adequately characterize a process under study. Such data are clearly necessary if one is to

eventually make semantic interpretations of communication research in terms of the concept of process (see page 35ff). However, while the implications for research techniques discussed here do indicate what is required of a research design which operationalizes the concept of process, the implications also make clear that such research is not necessarily easy. That is, in certain situations it may require far too much effort to add even a third observation point to a difference design, or to employ a process design in a manner which satisfies the necessary and sufficient conditions. In such cases the conditions may provide helpful information on the limits of the design in characterizing a process, but they are also likely to indicate that despite its desirability, a semantic interpretation in terms of "process" is plainly not justified by the data.

It has not been possible in a section of this length to be exhaustive in considering the implications for research techniques, even as those techniques may apply to research on human communication. Recognizing this, the approach has been to examine the techniques of research design and of measurement within certain bounds which were identified in advance. A similar approach will be followed in section 4.4, as well. That is, while section 4.3 has considered the implications which the approaches to an operational definition have for research techniques, it is evident that such techniques comprise only one of the aspects of any research situation. Analysis techniques are also a vital aspect of research, for as Coombs has noted: "The method of collecting data determines what information they contain, but the method of analysis defines this information . . . (1953, p. 495)."

4.4 Implication for Analysis Techniques

To this point, Chapter 4 has been concerned both with a set of suggested approaches to the operational definition of the concept of process, and with the implications which these approaches carry for research techniques. More specifically, the chapter has provided a set of necessary and sufficient conditions for describing a process, and has considered the implications which these conditions have for research design and measurement. These approaches, and more specifically the criteria or conditions, have additional implications which extend beyond those for research techniques. In particular, the approaches hold a number of indirect implications for analysis techniques--implications which it is appropriate to examine, especially as the techniques relate to the study of human communication events.

It is important to emphasize, at the outset, that the implications for analysis techniques do not stem directly from the necessary and sufficient conditions, as in the case for research techniques. That is, a brief examination of the conditions presented earlier (page 152) will reveal that they describe the "framework" within which the measurement of a process is to take place. As a result, the conditions provide information which is directly relevant to research design and to measurement. The resulting process designs, when applied, produce data having a special characteristic which results from the method of collection; namely, the data contain information on the time dimension of an event. Although many different forms of analysis may be performed on such data, we shall be concerned here only with those forms which take the time dimension into account.

Consequently, while the necessary and sufficient conditions have direct implications for research techniques, they have only indirect implications for analysis techniques, since the latter in effect derive from the former.

In addition, it is worthwhile noting again that the consideration of analysis techniques has been purposely separated from the discussion of research techniques. Such a distinction would not normally be made, given that the method of analysis is often chosen and considered in conjunction with the research design (cf. Kirk, 1968, p. 11). In the absence of a single, specific research situation, however, such a distinction appears necessary (see sections 4.1 and 4.2).

An examination of the analysis techniques applicable in any discipline is a lengthy and complex task, especially in the discipline of communication. The present limits of space, in addition, dictate a highly restricted or bounded discussion, and it is important to identify those bounds in advance (see sections 3.4 and 4.3). In general, the concern here will be to outline briefly the implications for analysis techniques, especially as these techniques relate to research on human communication. In particular, because the implications are indirect, the discussion will focus primarily on useful additions to analysis techniques, rather than on a review of current techniques. Also, because the details of using any particular analytic technique are tied both to the purpose of the research and to the specifics of the individual research situation, the concern will be with general approaches to analysis and with broad classes of

techniques. In cases where detailed information does appear useful, special attention will be given to suggesting appropriate outside references as more complete sources.

Again, in keeping with Chapter 2, both observational and experimental research will be considered relevant in what follows (see pages 33, 70; cf. Sidman, 1960, p. 237). That is, while certain analysis techniques lend themselves primarily to one form of research or the other, such a distinction will not be of concern below in discussing the techniques. In addition to these bounds, it must be emphasized again that the concern here is with analysis techniques only as they relate to the concept of process, not as they may relate to other concepts such as interaction, emergence, or system (see page 40). Consequently, while many different analyses may be performed on one set of data, and while many of the techniques below have broader applications, the only analyses and applications considered here will be ones relevant to the time dimension in the data, i.e., to the process involved in the event(s) under study. It is important to note again, too, that the discussion here will not necessarily apply to all research conducted in the discipline of communication, as not all such research need incorporate the concept of process (see page 71). The analysis techniques suggested below are accordingly not presented as replacements for current techniques, but as additions with potential utility in research which deals with human communication events as processes (see page 75).

Taking into account these bounds on the discussion, it appears useful to divide this section into three parts. First, an examination

of certain basic distinctions and considerations useful in discussing analysis techniques. Second, an outline of analysis techniques which serve primarily in "reducing" data. And third, an outline of techniques which function primarily in "testing" situations.

4.4.1 Basic Distinctions and Considerations

As noted above, the necessary and sufficient conditions for describing a process hold both direct implications for research techniques and indirect implications for analysis techniques. That is, a research design which is to measure adequately a process or form of variation must fulfill the necessary and sufficient conditions, so that the conditions have a direct effect on the research design and on certain related aspects of measurement. Designs which do fulfill the conditions are said to operationalize the concept of process, and will produce data which completely characterize the variation under study. The distinguishing feature of such data, for the present discussion, is the association of a time measurement with each observation or measurement on the variable under study, and clearly any analysis of this data with regard to the concept of process must take this time dimension into consideration. The necessary and sufficient conditions therefore have an effect on analysis techniques, albeit indirect, resulting from the nature of the data produced by the research technique.

In discussing these effects on analysis techniques, it is helpful, first of all, to distinguish two classes of techniques which serve different, though often closely related functions in the analysis

of research information. One class of techniques serves the primary function of "reducing" data to a more manageable form, in effect by generating some smaller amount of information or data which symbolizes or represents the larger body of original information. Such "reduced data" are frequently the input to another class of analytic techniques which serves the primary function of "testing" data or information, whether in testing predictions or in testing the performance of a model. More specifically, the techniques for generating various descriptive statistics are examples of analytic techniques which serve to reduce data, while the techniques for making significance tests are key examples of techniques for testing data. It is evident that the functions of reducing and testing data or information are not totally disjoint, since a descriptive statistic may be the input to a significance test. Nevertheless, the distinction can be useful, in this case as an aid in organizing the discussion of analysis techniques.

It will be helpful, secondly, to note in brief several other considerations which affect the discussion. In particular, it is important to emphasize again that the concern here is primarily with the case of a single variable changing over time within a bounded interval (see section 4.2.1), i.e., with a single path or form of variation (see pages 33 and 37). That is, the analysis techniques considered below will be viewed primarily as they apply to the single variable case, although in some cases they may be extended directly to the multiple variable case (see pages 87ff and 104ff). There will be no direct concern with the multiple variable situation, since to

do so would require an examination of individual analysis techniques somewhat beyond the scope of the present discussion.

It is important to note, too, that the concern here is only with variables as they are related to time, not as they are related to one another. Inter-variable relationships are clearly important in much research, but to consider them here would be to change the focus of the paper from a concern with process only, to a concern with interaction and emergence. It should be recognized, in addition, that any one variable which changes over time may be, in and of itself, a measurement taken on a single individual or a composite of measurements taken on a group (e.g., a mean value). While this distinction is an important one in many research situations (Sidman, 1960, pp. 46-54), it will not enter into the present discussion of analysis techniques.

Finally, it will be helpful to consider briefly the place in the discussion of three different factors which enter into the choice of a particular analysis technique. First, there will be no concern here with whether a variable is classed as independent, dependent, or intervening, although it is clear that time is in all cases an independent variable. Second, there will be no consideration of the distinction between discrete and continuous measurement of time, or of other variables, as it may affect analysis techniques. Discrete measurement is the primary mode of measurement assumed in the techniques considered, however, and it should be noted that it is always possible to adequately translate continuous measurement into discrete measurements (section 4.2.1) if a technique suitable for continuous measurement does not exist. Third, there will be no concern below with the level of

measurement of time, or of other variables, as it affects the applicability of various analysis techniques. Clearly, the available level of measurement is an important factor in the choice of an analysis technique, as are the other two factors; however, an examination of individual techniques taking level of measurement into account would move far beyond the scope of this discussion.⁶

4.4.2 Reduction Techniques

In view of the considerations, above, it is possible to turn to an outline of several analysis techniques which serve the primary function of reducing data to more manageable forms. Again, such reduction is accomplished by generating some smaller set or more convenient form of data or information which represents or symbolizes the larger body of original data. The reduction may be one of number, as in generating the mean of fifty values, or possibly one of form, as in producing a graph of the same fifty values. In either case, the reduced data may be an end in itself, or it may be the input to another analysis technique, such as the testing techniques outlined in section 4.4.3.

As indicated earlier in the consideration of the bounds of the present discussion, the attempt here is not to review current reduction techniques, but rather to outline useful additions to such techniques. Accordingly, it is assumed in what follows that the more common reduction techniques are known, as for example the techniques for

⁶Many of the techniques discussed do have several forms which permit them to be applied with different levels of measurement. Time, of course, is capable of ratio measurement.

determining measures of central tendency and of dispersion, for constructing graphs, histograms, and frequency distributions, etc. Such techniques are fundamental ones, and are considered in most statistical texts, as in McNemar (1962, Chs. 2-4) and in Quenouille (1952, Chs. 1 and 2), among others. Of special interest here are certain reduction techniques which may be generally less well known, and which are particularly useful in reducing data that contain a time dimension. Five such "new" techniques are presented in Table 6, page 186, namely: pattern recognition, constraint analysis, signal analysis, stochastic processes, and trend surface analysis.

These five "techniques" are not single, specific techniques, but rather broad classes of techniques, both as suggested in the earlier consideration of the bounds of the discussion, and as evidenced by the general descriptions included in Table 6. Clearly, this presentation of techniques is not intended as a comprehensive or exhaustive summary, but rather as a general outline, introduction, and guide. In particular, because Table 6 is to serve as a guide, special attention has been given to references, both in including notes suggesting the usefulness of each reference, and in selecting sources which provide basic information or which themselves function as references. Again, it has not been possible to be exhaustive.

Comments.-- Each of the classes of techniques presented in Table 6 has a distinct purpose or "output," even though all are potentially useful approaches to reducing data which contain a time dimension. The attempt has been, by means of the general descriptions, to indicate the nature of the various purposes or outputs so that the Table can

Table 6. Reduction Techniques for Analysis of Data from Process Designs

Technique and General Description ^a	References and Notes
<u>Pattern Recognition</u> Techniques for either identifying new patterns or seeking specified patterns in data. Patterns may exist in time or space, with temporal patterns (and data) of special interest here. Actually a broad area containing many techniques, some specifically adapted to certain types or classes of patterns and data.	General information: Uhr (1966, entire vol.) Comprehensive bibliography: Mason (1970) Discussion of techniques: Kanal (1968), Watanabe (1969) Note that journals such as the <u>IEEE Transactions on Systems Science and Cybernetics</u> or on <u>Computers</u> , as well as the <u>Journal of the Pattern Recognition Society</u> are also valuable sources of information.
<u>Constraint Analysis</u> Techniques, often closely related to pattern recognition techniques, for determining the bounds or constraints present in a given set of data. Again, the data may be temporal, spatial, etc., although temporal data, often termed "protocols" are of special interest here. Individual techniques vary, but are apt to be more generally applicable than many pattern recognition techniques.	General information with special reference to human communication: Krippendorff (1969b, pp. 24-32) General information: Ashby (1964) Potentially relevant sources on special aspects: Ashby (1963), Klir (1967), Shannon and McCarthy (1956)
<u>Signal Analysis</u> Techniques for deriving symbolic (mathematical) representations of temporal data or signals. Actually a broad area containing many different techniques.	General information: Gabor (1946), Koenig (1967, pp. 20-33), Milsum (1966, Ch. 3) Specific information on Fourier analysis: Bergland (1969), Bracewell (1965), Hamming (1966, Ch. 6) Basic information on statistical signals: Milsum (1966, Ch. 14)
<u>Stochastic Processes</u> Techniques for deriving a specific class of symbolic representations of data. Data are often temporal, and the representation differs from those above in that it describes the sequence or succession of individual data points.	General information: Bartlett (1966), Fararo (1969), Parzen (1962), Snell (1965) Detailed information, especially with respect to spectral theory: Hannan (1960, Chs. 1-3), cf. Milsum (1966, Ch. 14) Detailed information with respect to multiple time series: Quenouille (1957, Chs. 1-6)
<u>Trend Surface Analysis</u> Techniques for deriving a symbolic representation of a trend or movement in a set of data or form of variation. Data are often spatial, but may be temporal. Actually a broad collection of techniques and may include regression analysis.	General information: Chorley and Haggett (1968), Clarke (1968, pp. 480-490), King (1969, pp. 152-154)

^aNo ranking or ordering of techniques is implied. The ordering is generally alphabetical, except for variations brought by relationships or similarities among the techniques.

serve as an initial guide to selecting an appropriate reduction technique. The question of "Which specific technique do I use," cannot be answered here except in general, both because it is clearly beyond the present scope and purpose to provide a sufficiently detailed outline of specific techniques, and because the answer to such a question depends heavily on factors such as the available level of measurement, as well as on the purpose of the research.

The classes of techniques presented in Table 6 are not to be considered mutually exclusive. In many cases the classes border or overlap one another in that they share basic tools or methods, so that they are perhaps best described as general emphases or directions in reduction techniques. In addition, all of these general techniques may involve the use of analog or digital computer programs. There is of course no binding necessity that a specific technique be implemented in a computer program, although complexity often makes it highly expedient.

One further comment on Table 6 regards the absence of the class of techniques generally termed "system analysis." These techniques have been omitted, here, in that they apply to situations where an analysis (both reduction and testing) of system data is required. System data are considerably more complex than the data considered herein because they contain information not only on processes in events but also on structure_m or structure_i (cf. Koenig, 1967, Chs. 1-4). As such, system analysis techniques encompass many of the techniques in Table 6, most notably signal analysis, and include other techniques as well. Because the concern here is entirely with analysis techniques

applicable to the study of events as processes, rather than as systems, the techniques of system analysis per se have been omitted.

The general techniques considered in Table 6, then, represent a set of "new" analysis techniques which are useful in reducing data which contain a time dimension. The object of such data reduction is primarily to provide a more manageable form for the data, while taking the time dimension into account, although the reduction may also provide an input to a testing technique, as considered below. Because of their ability to deal with a time dimension in data, the reduction techniques considered are all potentially useful techniques in the analysis of data produced by process designs. As a result, although the implication of the necessary and sufficient conditions is somewhat indirect, it can be seen that if research on human communication is to deal adequately with the concept of process, it must use and develop reduction techniques such as those presented in Table 6.

4.4.3 Testing Techniques

As suggested at several points above, reduction techniques fulfill only one of two functions of analysis techniques. It is important, therefore, to outline several techniques which serve the other primary function of testing data or information. Such testing may, again, be either a test of predictions or a test of the performance of a model. Note that in both cases it may be difficult to separate the testing technique from the reduction technique, since many statistical tests in effect combine testing and reduction, and since tests of a model's performance may require that large quantities of data be reduced. In

addition, it is clear that many testing techniques require some form of reduced data as their "input." The distinction between testing techniques and reduction techniques is a useful one, nevertheless, if for no other reason than as an organizing device in discussion.

Within the general area of testing techniques, itself, it may be difficult at times to separate a test of prediction from a test of the performance of a model. Very briefly, prediction testing may be thought of in the present context as a situation in which a set of observed data containing a time dimension is to be compared to a set of predicted data. The data appear in these situations as a sequence of values in a time dimension, and it is specifically the variation over time in the observed and in the predicted data which is to be compared or tested. In a very general sense, then, prediction testing may be viewed as a problem of "curve matching" in an attempt to answer the question: "Is the predicted curve or data a 'reasonable' fit to the observed curve or data?"

Performance testing, on the other hand, may be viewed as a situation in which a model, in this case one incorporating the concept of process, is manipulated to determine the characteristics of its "operation." The manipulation may take the form of a mathematical analysis or of an actual "run" or use of the model under specified conditions. The characteristics sought may be various mathematical relationships or the actual "outputs" or results of the model. However, it is at this point that the distinction between performance testing and prediction testing breaks down, for obviously one extremely valuable means of performance testing is to form a prediction from the

model, gather data, and test that prediction. Granting this exception, the distinction between the two types of testing will still prove useful as an aid in the discussion.

As indicated earlier, the intent here is not to review current testing techniques, but to outline useful additions to those techniques. As a result, it is assumed in what follows that the more common testing techniques are known, as for example the techniques considered by McNemar (1962, Chs. 5-16, 18), Ouenouille (1952, Chs. 3-10, 12), and Siegel (1956). It will likewise be assumed that the problems of testing predictions on change using difference designs are known, as considered by Bohrnstedt (1968) and Lord (1967), for example. Of particular interest here are those reduction techniques which may be generally less well known, and which are particularly useful either in testing predictions where process designs have been used or in testing models in which the time dimension is central. Table 7, page 191, presents five such techniques for prediction testing and two techniques for performance testing.

These various "techniques" are not specific, individual techniques, but rather somewhat broader groupings of techniques, both as suggested earlier and as indicated by the general descriptions in Table 7. This particular presentation of sets of techniques is not to be considered comprehensive or exhaustive, but is intended instead to be an outline or guide. As in Table 6, particular attention has been given here both to suggesting sources which provide basic information or which serve as references themselves, and to including notes indicating the usefulness of each source. Nonetheless, it is impossible

Table 7. Testing Techniques for Analysis of Data from Process Designs

Technique and General Description	References and Notes
Prediction Testing^a	
Analysis of Variance: Analyses and tests of "change" or "time-curve" information by partitioning of variance.	Univariate procedures: Gaito and Wiley (1967) Multivariate procedures: Bock (1967)
Trend Analysis: Analyses and tests of the shape of the relation between two variables. Closely related to analysis of variance procedures.	General information: McNemar (1962, Ch. 17) Nonparametric trend analysis: Ferguson (1965) Related discussion with special reference to measurement: Sidman (1960, Ch. 10)
Goodness of Fit: Analyses and tests of the "fit" between two series of data (often the predicted and the observed).	General information: Carroll (1968, pp. 71-72), Jaffe (1970, pp. 83-84) Theoretical discussion: Hannan (1960, pp. 93-104)
Time Series Analysis: (a) Analyses and tests of serial correlation (autocorrelation), correlation, partial correlation, and regression between time series.	General information: Campbell (1967, pp. 224-229), Holtzman (1967), Quenouille (1952, Ch. 11) Detailed information: Bartlett (1966, Ch. 9), Quenouille (1957, Ch. 7)
(b) Analyses and tests with regard to stochastic processes.	Detailed information: Bartlett (1966, Ch. 8), Hannan (1960, Chs. 4-5)
Sequential Analyses: Analyses and tests where the number of observations required by the statistical procedure is not determined in advance.	General and detailed information: Wald (1947)
Performance Testing^a	
Sensitivity Testing: A general approach to testing models in which parameters or relationships are systematically varied over successive "runs" of the model. The resulting differences in outcomes are compared to determine the sensitivity or "strength" of the model. Techniques are basically non-analytic.	General information: Carroll (1968, pp. 73-74), Lowry (1968, p. 62)
Response Analysis: A collection of mathematical techniques for manipulating models to examine characteristics of their operation. Includes analyses of stability or controllability as well as examination of outputs given specified inputs. Techniques are basically analytic.	General information: Carroll (1968, pp. 53-60) Detailed information: Koenig (1967, Chs. 5-7), Milsum (1966, Chs. 6-9, 11)

^aNo ranking or ordering of techniques is implied. The ordering is generally alphabetical, except for variations brought by relationships or similarities among the techniques.

to be exhaustive.

Comments.-- Each of the groupings of prediction testing techniques presented in Table 7 has a slightly different purpose or result, as well as a somewhat distinct "input," even though all are potentially useful in testing predictions where the time dimension must be considered. The two classes of performance testing techniques likewise have different purposes and results, and may also have somewhat different forms of models as their "inputs." The general descriptions provided for both the prediction and the performance testing techniques attempt to outline these special purposes, results, and inputs, so that Table 7 can function as a guide to testing techniques. However, it must remain a general guide to such techniques, since the information which would be necessary in a guide to specific techniques is beyond the scope and purpose of the present paper.

One factor which does enter into the selection of specific prediction testing techniques should be mentioned briefly, though. That is, each grouping of techniques has certain requirements and makes certain assumptions regarding the data or information under study. A specific technique may require, for example, a particular level of measurement, or may assume that the data or observations are independent. Such requirements and assumptions must be checked before a specific prediction testing technique is chosen and applied, and it may be helpful to note one important point in this regard. That is, the often troublesome assumption of independence may be checked using the technique of serial correlation or autocorrelation, as mentioned in Table 7 in conjunction with the time series analysis techniques,

and as discussed by Quenouille (1952, pp. 165-167) and others.

As was the case for reduction techniques in Table 6, the various groupings of testing techniques presented in Table 7 are not mutually exclusive classes. In many cases the prediction testing techniques share common methods and information, and much the same is true for the performance testing techniques. In addition, both prediction and performance testing techniques may involve the use of analog or digital computer programs. The high degree of complexity which may be involved in some performance tests make such tools particularly applicable, there, though they by no means lack importance in prediction testing.

The groupings of techniques presented in Table 7, then, represent a set of analysis techniques which are useful in prediction testing and in performance testing where the time dimension is a central concern. The object of prediction testing is, again, to compare an observed event with a predicted event, in this case taking the time dimension into account. Because of their ability to deal with a time dimension, the prediction testing techniques considered above are all potentially useful in the analysis of data produced by process designs. The object of performance testing, on the other hand, is to determine certain important characteristics of the use or operation of a given model, especially a model in which time is a key dimension. The performance testing techniques described in Table 7 are capable of dealing with such models, and hence are potentially useful in analyzing models which consider communication events as processes. This consideration of the two classes of testing techniques reveals an additional indirect implication

of the necessary and sufficient conditions; namely, that if research on human communication is to make proper use of the concept of process, it must use and develop testing techniques such as those considered in Table 7.

In summary.-- The above examination of testing techniques is only one aspect of the study of analysis techniques in this section (4.4). The earlier discussion of reduction techniques is an equally important aspect, and although these two classes of techniques have been distinguished here, as considered earlier (section 4.4.1), it is clear that the two functions of testing and of reducing data or information are not disjoint. Indeed, the distinction has been made here entirely for ease of presentation, for the functions of reduction and testing normally are and should be considered as one in any research situation. Quite clearly, too, it has not been possible to be exhaustive in considering analysis techniques in a section of this length. Recognizing this, the attempt has been to make clear the limits of the discussion both by specific comments, and by placing the discussion within a set of bounds identified at the outset.

The study of analysis techniques in this section has been prompted by the examination of research techniques in the previous section, both sections being considerations of certain implications of the necessary and sufficient conditions. Again, while the implications of the conditions for research techniques are direct, those for analysis techniques are relatively indirect, since analysis techniques must take into account the characteristics of the data produced by research techniques. Because of this indirectness, it may prove

helpful to state a fairly general implication for analysis techniques as a whole. That is, if human communication research is to deal adequately with the concept of process, it must use and develop techniques capable of reducing and testing the special data which are produced by process designs.

If the analysis of research information can be performed as suggested by this general implication, it will provide evidence which characterizes the process under study. Such evidence is a necessity if one is to move to the step of making semantic interpretations of communication research in terms of the concept of process (see page 35ff). Note again, that while there are many different forms of analysis which may be performed on a given set of data, the concern here has been only with analyses which take the time dimension in a given set of data into account. The implication above makes clear that even if the data in a particular situation do adequately characterize the process under study, an analysis which does not consider the time dimension is plainly not capable of semantic interpretation in terms of "process."

Taking a somewhat larger perspective than this concern solely with analysis techniques, then, it should be evident that a comment like that above on the distinction between reduction and testing techniques may also be applied to the distinction between research techniques and analysis techniques. That is, although research and analysis have been discussed separately here, as mentioned earlier in the Chapter (sections 4.1 and 4.2), it is clear that these two aspects of research are not disjoint, either. The distinction between research and analysis

has been made primarily as an aid in the discussion, because the absence of a single, specific research situation makes it difficult to consider research and analysis techniques in conjunction. In the context of an actual research situation, these two important aspects should be and normally are considered together because of their close association.

This examination of research techniques and of analysis techniques has had the purpose of indicating the implications for each which result from the necessary and sufficient conditions for describing a process. In a considerably more general form, the implication of those conditions is that research which deals with communication events as processes must use research techniques and analysis techniques which take the dimension of time into account. This general implication results both from the necessary and sufficient conditions, and, in a somewhat broader sense, from the principles and criteria introduced in suggesting approaches to the operational definition of the concept of process. Once again, those criteria and suggested approaches were ones appropriate for dealing with the dimension of time in events, and more specifically, with the change over time or process which is seen here as an integral part of human communication events.

It has not been possible in a chapter of this length to consider all of the details either of the principles and criteria for operational definition, or of the implications which they hold for research and analysis techniques. Consequently, the procedure in both cases has been to specifically limit the range of the discussion. In particular, in considering the principles of operational definition,

information and derivations were included only if they had potential utility as tools in research related to human communication. The approach to limiting the discussions of implications, on the other hand, was to identify in advance the bounds within which the discussion would take place.

An overview.-- Chapter 4 has attempted to provide approaches to the operational definition of the concept of process, and to consider some of the implications which these approaches have for research techniques and analysis techniques. Again, while research and analysis have been considered separately here, they are not distinct in that research is seen as leading to analysis. Similarly, research and analysis are not distinct from theory, either, for there clearly exists a "cycle" from theory to research to analysis and back to theory. Consequently, the implications for research and analysis considered in Chapter 4 may be grouped with the implications for theory examined in Chapter 3 to form a somewhat larger set, i.e., the implications which explicating the concept of process hold for theory and research on human communication.

This essential unity of the implications for research, analysis, and theory suggests that comments similar to those above on the distinctions made among various techniques may also be applied to the distinction between constitutive definition and operational definition. That is, while constitutive definition has been considered apart from operational definition in this paper, it is clear that these two aspects of the explication of a concept are not totally separate. Here, too, a distinction has been made as an aid in organizing the

overall discussion, even though it is evident that in the larger context of theory building and research, these two important aspects must be considered together.

In fact, a concept can be said to have been explicated if and only if it has been provided with both a constitutive definition and an operational definition (see page 9; cf. Berlo, 1967, pp. 2-4). Again, such definitions are normally constructed and applied only within the context of a specific theoretical or research framework. Because there is no attempt in this paper to build a specific theory or to carry out specific research, the procedure has been to suggest a set of potentially useful approaches to both constitutive and operational definition of the concept of process. These suggested approaches not only provide a set of tools for explicating the concept of process in specific theoretical and research frameworks, but also carry the implications for theory, research, and analysis which have been mentioned above.

Chapters 3 and 4, then, have attempted to provide approaches to the explication of the concept of process or of change over time, a concept which was indicated in Chapter 2 as an important and useful one in the conduct of research and theory building related to human communication (cf. pages 73 and 74). This attempt to provide approaches constitutes the major emphasis of this paper--an emphasis described earlier as a search for the means of explicating the concept of process, a concept which is seen as a useful tool in the further conduct of theory building in the discipline of communication (see pages 8 and 9).

The attempt of these second two chapters to develop and consider approaches to explication can be materially aided by considering examples of research which takes the concept of process into account. Accordingly, Chapter 5 will be devoted to a brief review of several specific bodies of research relevant to the study of human communication. The attempt will be to provide a set of concrete referents for the use of many of the approaches discussed in Chapters 3 and 4. Following these examples, it will be appropriate in Chapter 6 to examine certain broader implications of the explication of the concept of process, as well as several aspects of its place in research and theory related to human communication.

CHAPTER 5

EXAMPLES

Having seen in Chapters 1 and 2 that the concept of process is an important and useful one in the conduct of theory building and research on communication, and having considered approaches to the concept's explication (both constitutively and operationally) in Chapters 3 and 4, it will be helpful in Chapter 5 to consider several examples of research relevant to human communication which take the concept of process into account. Such an examination of specific examples of current research will be useful both in providing a somewhat less abstract consideration of many of the approaches than has been possible to now, and in answering several general questions regarding the nature of research which deals with communication events as processes. In particular, questions like: How widely applicable are the approaches considered in Chapters 3 and 4? What is the form of research which makes use of these approaches, i.e., what does it "look" like? What kind of results will such research produce, and how will that information differ from the results of other research? Chapter 5 will attempt both specific and general answers to such questions, and will open the way to a consideration of conclusions and implications in Chapter 6.

5.1 Comments on the Examples

It should be noted again that the purpose of this paper is not to consider or develop a specific theoretic or research framework (i.e., to build theory or to test hypotheses), but rather to consider the means of explicating the concept of process (see pages 9 and 10). Given this important point, together with the fact that examples of research utilizing the suggested approaches have been presented in the communication literature, it appears more appropriate to consider several such examples with respect to the above questions than it does to design a single, specific experiment.

Because there are a number of examples of research which might be considered in this context, it is necessary to choose from among them. The limits of space dictate a consideration of no more than three examples in any detail, although a number of other possible examples will be mentioned briefly. The three examples which are presented have been chosen on the basis of two criteria. First, the examples must be relevant to the study of human communication and should be representative of larger bodies of research. Second, the examples as a group should show variation over the following six dimensions to assure a breadth of coverage:

- (1) Content area of the research, within the scope of human communication research.
- (2) Type of research design, though it is clear that the research must employ a process design (see sections, 2.1.3, 2.3.1, 2.3.2, and 4.3.2).
- (3) Focus on observational or experimental research. Again, both forms of research are considered relevant in this paper (see pages 33n, 69-70, and sections 4.3 and 4.4).
- (4) Type of measurement technique, given that research design and measurement technique are

- linked to one another (see section 4.3.3).
- (5) Type of analysis technique. The techniques mentioned for each example will be those which deal with the time dimension, although others may have been employed (see section 4.4).
- (6) Focus on individual or group behavior. A potentially relevant consideration in the use of process designs (see section 6.2).

No particular ranking is implied in the ordering of these various dimensions. Again, variation on these six dimensions and relevance to the study of human communication are the criteria on which the examples of research below have been chosen.

Two further comments should be made before mentioning the three examples, specifically, and considering their variation on the above dimensions. It will be evident in the discussions in section 5.2.1 that the examples chosen have both strengths and weaknesses with respect to the approaches considered in Chapters 3 and 4. In particular, it is clear that for the most part, the research considered does not derive from theory which deals with communication events as processes, as such theory has been described in section 3.4. That is, it is evident in some cases that the concept of process per se was not a primary concern of the researchers in either their theory or their research and analysis techniques, even though the research does operationalize the concept. In addition, it is also clear that among the examples chosen (and especially among those not reviewed), certain research designs may fall short of meeting all of the criteria suggested on page 152 for the adequate description of a process. Such research may therefore only approximate full operationalization, again usually because the concept of process was not a primary concern of the

investigator. These various problems will be considered below, but specifically do not make a particular example inappropriate for consideration here, in that the example still may reveal important characteristics of research on events as processes and can produce information which is obtainable by no other means.

It should be noted once again that the concern here is solely with the concept of process. Other concepts such as interaction, emergence, and system eventually must be considered and operationalized in research, as well, in order to reach a fuller understanding of human communication (see page 40). However, space dictates a focus below entirely on those aspects of research which relate to the concept of process.

Given these comments, it is possible to turn to a consideration of the three examples. Very briefly, those chosen for consideration are: (1) research by Brown and Bellugi (1964) on language development in young children, (2) studies by Harrison (1969b) using his Verbal-Nonverbal Interaction Analysis technique, and (3) a study by Insko (1964) on primacy-recency effects as a function of timing of arguments and measures. (Note that there is no ranking implied here--the order is alphabetical). Before considering each of these examples of research in detail in the next section, it will be useful to summarize their aims and to compare their characteristics. These two functions are fulfilled by Table 8, page 204, which presents both a brief summary of each research example and compares them on the basis of the six dimensions noted above. Table 8 will be an important reference in the discussion of each example.

Table 8. Summary and Comparison of Research Examples

Investigators, Content Area ^a , and Summary of Research	Brown and Bellugi (1964) A study in child language develop- ment, esp. acqui- sition of syntax from 18 to 36 months.	Harrison (1969b) Studies of inter- personal inter- action, esp. the use of verbal and nonverbal chan- nels of commun- ication.	Insko (1964) A study of pri- macy vs. recen- cy effects as a function of the timing of mea- sures and argu- ments.
Type of Research Design ^a	Time Series (7) (Longitudinal)	Time Series (7)	Modified form of separated group delayed posttest design (section 4.3.2).
Observational or Experimental Research ^a	Observational	Observational	Experimental
Type of Measurement Technique ^a	Individual: "Unobtrusive" recording and transcription.	Group: Unobtrusive recording with sampling.	Group: Verbal recall by subject.
Type of Analysis Technique ^a	Reduction to categories and graphs; Des- criptive sta- tistics.	Reduction to categories and graphs; Descriptive statistics.	Descriptive statistics; t- tests, trend analysis.
Focus on Individual or Group Behavior ^a	Individual behavior with comparisons.	Dyadic behavior.	Individual behaviors measured; Group responses used in analysis.
Notes	Analysis techs. included are only those for this report. Other work uses addition- al techs.	Analysis techs. do not include those dealing with inter- action ma- trices (which remove the time dimen- sion).	Analysis techs. included are only those used for analysis of temporal effects.

^aThese dimensions are described more fully in section 5.1.

5.2 The Examples, Individually and In Sum

The procedure for presenting the examples in this section will be first to present the three, as individual entities, along with certain other potentially relevant examples, and second to consider the examples as a group with respect to the general questions mentioned at the outset.

5.2.1 Individual Examples

In each case below, the plan in presenting an example will be to begin with a summary of the aims, methods, and results of the research. Only a brief sketch will be provided, as in each case a more detailed report is available and because the primary interest is not to reproduce an existing report but to relate the research to the present concerns. Next, the example will be considered as it incorporates the concept of process. In particular, it will be examined with respect to the principles and criteria discussed in Chapter 4. This step will suggest both strong and weak points in the research, as well as certain advantages and problems.

Brown and Bellugi (1964).-- In their article entitled "Three Processes in the Child's Acquisition of Syntax" (1964), Brown and Bellugi report on one aspect of an extended research project on language development in children. In this particular article, the authors investigate the acquisition of syntax in children between the ages of 18 and 36 months, or approximately the time span during which an average or normal child moves from the point of basic, two-word utterances to the construction of complete, simple sentences. This particular study is one out of a number which are based on observational

research conducted by Brown over a several year period.

In particular, the data for these studies were gathered longitudinally from two children (called Adam and Eve). Brown describes the data gathering and analysis as follows:

Every second week we visited each child for at least 2 hours and made a tape recording of everything said by the child as well as of everything said to the child. The mother was always present and most of the speech to the child is hers. Both mother and child became very much accustomed to our presence and learned to continue their usual routine with us as the observers.

One of us always made a written transcription, on the scene, of the speech of mother and child with notes about important actions and objects of attention. From this transcription and the tape a final transcription was made, and these transcriptions constitute the primary data of the study. For many purposes we require a "distributional analysis" of the speech of the child. To this end the child's utterances in a given transcription were cross-classified and relisted under such headings as: "A + noun"; "Noun + verb"; "Verbs in the past"; "Utterances containing the pronoun it," and so forth. The categorized utterances expose the syntactic regularities of the child's speech. (1964, p. 133)

Brown's description, together with the characteristics noted in Table 8, page 204, reveal the basic outline of the research.

The analysis of any such complex, developmental process requires that particular features be chosen for attention. In the study cited here, the authors focus on three aspects which they term "Imitation and Reduction" on the part of the child, "Imitation with Expansion" on the part of a parent, and "Induction of the Latent Structure" by the child. These three aspects of the child's syntax acquisition cannot be considered at length, but Brown's concluding remarks with regard to them are rather instructive:

We have described three processes involved in the child's acquisition of syntax. It is clear that the

last of these, the induction of latent structure, is by far the most complex. It looks as if this last process will put a serious strain on any learning theory thus far conceived by psychology. The very intricate simultaneous differentiation and integration that constitutes the evolution of the noun phrase is more reminiscent of the biological development of an embryo than it is of the acquisition of a conditioned reflex. (1964, pp. 160-161)

The research reported by Brown and Bellugi incorporates the concept of process in its measurement of the developing behavior at frequent, equal intervals over an extended period of concern (basically a time series design). Whether the two week measurement interval is the appropriate interval for the form of variation under study depends on the particular aspect of language development being considered. Two weeks does appear to be suitable in this case, and it would be easy to check such an assumption, as suggested earlier, although this does not appear to have been done in this case. Note especially that the method of collecting and recording data in this research is essentially one of "capturing" the event under study so that it may be subjected later to a wide range of analyses at many levels of complexity.

Those analyses which take into account the dimension of time may yield especially useful evidence on the development of language, as Brown's semantic interpretation above suggests. Such evidence not only raises questions about the nature of language learning, but also is needed to distinguish among those theories of development and of structure which currently exist. Note too, that while Brown and Bellugi are concerned primarily with how the child acquires syntax, their research indicates how heavily that acquisition depends on the

communicative interaction between parent and child.¹

Harrison (1969b).-- In his paper entitled "Verbal-Nonverbal Interaction Analysis: The Substructure of an Interview" (1969b), Harrison reports on the development of a technique for measuring and describing certain aspects of the communicative interaction of two individuals. In particular, the technique indexes the presence or absence of communication in both the verbal and nonverbal bands, and has been used to examine, for example, the interaction between doctors and patients.

Data collection using the Verbal-Nonverbal Interaction Analysis technique (VNVIA) is basically a two-step process in which an on-going interaction of some form is first recorded (by audio-video taping), and later sampled at three second intervals. The sampling is performed by coders whose output is an indication of whether or not the verbal and nonverbal bands are being used at each sampling point by each participant. The analysis of the interaction is performed by entering the data into a matrix which is so constructed that the relative presence or absence of entries in its various sectors indicates characteristics of the interaction such as monologue, changes between communicators, etc. Entering the data into the analysis matrix thus provides a characterization of the interaction period as a whole, although at the same step it removes the time dimension from the data.

¹Brown and Bellugi's work is representative of other longitudinal studies of language development by such investigators as: Bellugi and Brown (1964), Erwin (1964), Erwin and Miller (1963), Lenneberg (1966), and Templin (1966).

The research which has been conducted to the present has been observational in nature, as indicated in the summary in Table 8, but there is nothing to prevent the technique from being used in experimental contexts, as well. In a related study by Frahm and Harrison (1969), the authors have used the interaction matrices from successful and unsuccessful doctor-patient interviews in a test of several hypotheses on the differences between such interviews. The authors conclude their study with these comments:

While it is tempting to generalize from this data, it must be remembered that the amount of data available to us at this time is very limited. Essentially what is now needed most is an exhaustive test of the analysis. What this paper suggests is that VNVIA can be a viable tool for quantifying human interaction. It provides an objective look at the structure of an interaction and can help to isolate interaction typologies which will lead to greater insights into the problems of human dyadic interaction. (1969, pp. 11-12)

In a somewhat more general vein, Harrison concludes his report with several comments about the value of the VNVIA technique:

Verbal-Nonverbal Interaction Analysis gives us a new picture of the interview, or of dyadic interaction generally. It provides a content-free 'x-ray' of the substructure of the interaction, highlighting the skeleton of verbal-nonverbal interplay. Like an x-ray, it doesn't show us many things that we might also find interesting; but it does provide a new research tool--and possibly some theoretic insights. (1969b, p. 18)

The research reported by Harrison incorporates the concept of process in its measurement of the on-going interaction at frequent intervals throughout the period under study (basically a time series design). The adequacy of the three second measurement interval does not appear to have been examined in the manner considered earlier (section 4.3.1), although a recent study by Frahm (1970) has shown

the sampling scheme to be reliable. Also, as in the case of the Brown and Bellugi study, the VNVIA procedure of recording data for later examination is one which permits a type of in-depth sampling and analysis which would not be possible otherwise.

To the present, the analyses which have been employed on the sampled data have been, for the most part, analyses which have not considered the time dimension and which have therefore not incorporated the concept of process. Here again, however, Frahm (1970) has made preliminary analyses which do consider time, and it appears likely that further analyses of this sort could produce quite valuable information on the development of an interaction. Questions about the various ways or patterns by which a given interaction matrix might be produced, for example, are ones which can only be answered by considering an interaction event as a process.²

Insko (1964).-- In his article "Primacy versus Recency in Persuasion as a Function of the Timing of Arguments and Measures" (1964), Insko reports the results of experimental research which examined certain predictions made by Miller and Campbell (1959) regarding the persuasive impact of a communication as related to its retention. Insko's work differs from the work previously done by Miller and Campbell both in his choice of a measure of retention and in his use of a wider range of intervals between communications and

²The VNVIA technique is representative of a number of other interaction analysis techniques, particularly Flanders (1967), but also Chapple (1948), Ekman (1957), and Schefflen (1966). One important set of studies very similar to those using VNVIA, but which do consider the time dimension in analysis, are those reported in a

measures.

It is this latter innovation concerning the timing of measures which is of interest here. Insko describes his work in the following way:

In an after-only design 4 independent variables were manipulated to test Miller and Campbell's theory of primacy versus recency in persuasion: time between communications (none, 2 days, 1 week, or 2 weeks), time between the second communication and the measures of opinion and retention (none, 2 days, or 1 week), order of communications (pro-con or con-pro), and order of measures (opinion-recall or recall-opinion). There were 2 dependent variables: opinion (measured on a rating scale) and retention (measured through recall). Confirming Miller and Campbell, the longer the time interval between 2 communications the greater the recency effect in both opinion and recall immediately after the second communication; and the longer the time elapsed from the second communication until measurement the less the recency effect. Contrary to Miller and Campbell's prediction, delayed measurement did not tend to produce primacy in the case of the groups in which the second communication followed immediately upon the first. The theoretically predicted shape of the recency function over time was only roughly supported. A correlational analysis of the relation between opinion and retention called into question the assumption that opinion is a direct function of retention of message content. (1964, p. 381)

This abstract, together with the characteristics noted in Table 8, provide a brief outline of Insko's research.

Because of the complexity of the overall research design, Insko's analysis of the results is also rather complex and cannot be extensively considered here. The analysis does pay particular attention to comparisons of the predicted and observed shapes of the "retention curves," in this case through the use of trend analysis

recent book by Jaffe and Feldstein (1970). A review of interaction analysis techniques was presented earlier in section 2.3.2.

(see Table 7, page 191). Insko summarizes this particular aspect of the research as follows:

The predictions concerning the shapes of the opinion and recall functions over time are only roughly supported. Many of the curves either are linear or have significant linear components when they should be quadratic. It should be noted, however, that the number of cases at any one data point is fairly small (each point plots the difference between two groups of 14 subjects each), and that the time intervals may not have covered a sufficient range to show the true shape of the curves. (1964, p. 390)

This particular experiment incorporates the concept of process in its use of a process design. As noted in Table 8, the design was a modified form of the separated group delayed posttest design (see section 4.3.2). Although too complicated to discuss at length, the design involved the same principle of employing differing time spans between stimulus and measurement for different groups, then combining those results to obtain, in effect, a sequence of measurements over time. In this particular experiment, the measurement intervals are not all equal, since measurements effectively occurred with no delay, and 2, 7, 14, and 21 days delay. The adequacy of these intervals was not examined in the manner considered here (section 4.3.1), and Insko indicates a possible problem in this regard in the second quote.

Although Insko does not say so in his report, it appears that his choice of design was dictated at least in part by the problems which repeated measurement would have produced in the research--one of the main reasons for favoring the separated group delayed posttest design. Such a design, and the corresponding analysis, both of which take the time dimension into account, are by no means easy to employ. On the other hand, given a prediction involving changes in effects of

communication over time, it is clear that no other form of research would be appropriate. Such research seems especially valuable when one considers a recent remark by Insko (1970) on subsequent research which has shown that, contrary to Miller and Campbell's assumptions, subjects are not "passive" with respect to the stimulus materials between presentation and measurement--instead, they actively consider it during this time span (cf. Chronkite, 1969, p. 128).³

Other research.-- In addition to this more detailed discussion of three examples of research which incorporate the concept of process, it will be helpful to mention very briefly certain other examples of research which also incorporate the concept. Several of these examples might have been used in the discussion above, but were bypassed for one reason or another, often because the direct relevance to communication (as defined here) was somewhat unclear.

One area of research which incorporates the concept of process is that done on the "extralinguistic" aspects of language behavior, as for example, on the relationships between changes in pitch, in various non-fluencies, in speech rate, etc., and the expression of emotional states. Such work generally examines verbal output over time as an indicator of other behaviors, and may be observational or experimental. The designs involved and the relationships studied in such research have been discussed at greater length earlier in this paper (see page 65).

³Insko's work is representative of other work which has examined attitude or opinion effects over time, as for example Hovland, Janis, and Kelley (1953, Ch. 8).

A second research area of some importance is that concerned with human arousal, particularly as arousal relates to changes in an individual's environment such as conflict, surprise, etc. The work of Berlyne (1960, 1965) is especially important in this respect, and is a primary example. Such research generally uses some measure of arousal, such as EEG or GSR activity, which is obtained continuously or by small-interval sampling during the on-going behavior. Other recent, and not unrelated work by Greenberg and Graham (1970) has examined changes in EEG activity during the learning of speech and non-speech stimuli. Greenberg's work is of special interest, here, because of its use of Fourier analysis techniques in analysing the EEG record (see page 122; cf. Table 7, page 191; and see related work by Oppenheim, 1970, and Smith, 1967).

Finally, other work which might have been considered in this context is that by Lazarsfeld (1944) using a multiple-wave panel design, that by psychologists such as Barker (1968) and Wright (1967) working in "ecological psychology," and that by Kivlin, et al. (1968), in the area of diffusion. The latter study is of interest in that it represents a somewhat different content area in communication; however, it has been bypassed here both because it is an isolated case, not representative of the larger class of diffusion studies, and because its approximation of the criteria noted on page 152 appears at best minimal.

5.2.2 The Examples In Sum

The aim of this Chapter, then, has been to examine briefly several examples of research relevant to human communication which

takes the concept of process into account in ways similar to those suggested in this paper. The attempt has been to provide both a somewhat less abstract discussion than has previously been possible, and an answer to several general questions on the nature of research which incorporates the concept of process. The examples above have provided fairly specific answers to those questions, and it will be helpful to examine them once again from a more general point of view.

First of all, it is apparent from the examples that the approaches considered in Chapters 3 and 4 are applicable over a fairly wide range. The processes which may undergo study may be slowly changing language development, attitude, or diffusion processes, rapidly changing human interactions, or extremely fast-moving EEG activity. The events involved may be verbal and/or nonverbal. The measurement techniques may range from psychophysical to "paper and pencil." In short, the suggested approaches appear to apply in a number of content areas of research, and with a number of different kinds of activity and forms of measurement.

Secondly, it is evident that the form of any research which incorporates the concept of process is determined in large measure by the necessary and sufficient conditions for describing a process (see page 152, and section 4.3). Research which studies events as processes must utilize some form of process design, those which have mentioned (section 4.3.2) being only a few of the possibilities. If the results of the research are eventually to undergo semantic interpretation in terms of the concept of process, it is apparent, too, that the analysis techniques employed must be capable of dealing with the dimension of

time in events (section 4.4).

Third, and finally, the results provided by research which has at all steps taken the concept of process into account are evidence and semantic interpretation on how events change over time. Other evidence and interpretation may result from a given set of data, but those relevant to the concept of process or of change over time can come only from "process research." Interpretations in terms of "process" may include, for example, those on the growth or history, on the behavior or function, and on the statics or structure_m of a system or event. Information on structure_m can be obtained, in many cases, from other forms of research, but information on function and history (as these terms are defined here) can come only from research like that described in this paper. That such information is of value in human communication research is, hopefully, an understatement (cf. Krippendorff, 1969b). Again, information on how communication events change over time is not the only type of information which is of value, but in cases where it is useful, the approaches suggested in this paper for the explication of the concept of process should be of some help.

Having examined the three general questions, again, in light of the examples of research presented in this Chapter, it is appropriate to draw together the various aspects of the paper and to seek an overview. To this end, Chapter 6 will briefly review what has been accomplished, and will consider the broader implications and overall place of the concept of process in the study of human communication.

CHAPTER 6

CONCLUSIONS AND IMPLICATIONS

In a general sense, the Introduction and Chapters 1 and 2 indicated that the concept of process was an important and useful one in the conduct of theory building and research in the discipline of communication. Chapters 3 and 4 fulfilled the major goal of the paper in presenting approaches to the explication of the concept, thereby making it more available as a tool in theory building. Both chapters examined certain implications of the approaches to explication, as well. Chapter 5 presented examples of the use of the approaches, so that it is appropriate in Chapter 6 to conclude with an overview and a consideration of broader implications. We shall do so by attempting to answer, in effect, the general questions: Where did we go? and Where does the paper lead us?

6.1 A Review

One means of considering the general question "Where did we go?" is to reconstruct the basic argument of the paper and to trace its development. At the outset, the paper identified three main concerns, in particular, with time as a key dimension in events, with the scientist's approach to such events through theory building, and with the universe of discourse identified by the concept "communication." All three of these concerns are unified in the study of the concept of

process as it relates to the discipline of communication, thereby making the major emphasis of the paper one of seeking, as a step in theory building in communication, the means of explicating the concept of process (section 1.1).

The definition of communication as "a process of transmission of structure among the parts of a system which are identifiable in time and space" (section 1.2) appears both general and useful in the context of this paper, even though the paper emphasizes human communication (section 1.3). The concept of process is a significant aspect of this definition, and if distinguished from a number of related concepts, may be defined as "All change over time of matter-energy or information" (section 2.1). The concept is an important one not only because of its relationship to research designs (point, difference, and process designs; section 2.1.3), but also because of its particular utility both in solving general problems in research and as a key concept in new concerns in human communication research (section 2.2).

However, despite this importance and utility, an examination of the current place of the concept of process in research reveals that its operationalization and use have been small. In other words, although the concept is regarded as important and appears particularly useful in human communication research, it has not been widely applied in such research. An explication of the concept appears needed to correct this situation and to make the concept more available as a tool in the conduct of research and theory building in the discipline (section 2.3).

The first step in explicating the concept of process is to provide a constitutive definition. However, because no specific theory is involved, it is necessary to provide not a specific definition but a set of approaches to constitutive definition (section 3.1). Such approaches may involve either verbal terms (section 3.2) or mathematical terms (section 3.3), so that the necessary and sufficient conditions for using the term "process" must be formulated with both aspects in view (section 3.3.4). In addition, because theory is formed using verbal and mathematical tools, the approaches to constitutive definition have a number of implications for the form of theory which deals with communication events as processes (section 3.4).¹

The explication of a concept is not complete without the second step of providing an operational definition. Here too, the absence of a specific research situation requires the development of a set of approaches to operational definition (section 4.1). Examination of these approaches or general principles for operationally defining the concept of process results directly in a set of necessary and sufficient conditions for describing a process (section 4.2). These conditions have several rather direct implications for research techniques (i.e., design and measurement; section 4.3), as well certain indirect implications for analysis techniques (i.e., reduction and testing; section 4.4).

¹It is impossible to be more specific about these implications in the space of this chapter; see the section indicated for more information. The same is true for the implications noted in the next two paragraphs.

In a general sense, then, Chapters 3 and 4 perform the task set out by Chapter 1 and 2, namely, that of seeking, as a step in theory building in communication, the means of explicating the concept of process. One of the results of seeking approaches to the constitutive and the operational definition of "process" is a set of potentially useful tools for dealing with the concept in specific theoretical and research frameworks (as exemplified in Chapter 5). This latter result stems directly from the result already mentioned, i.e. the set of implications for theory building and research related to human communication. Rather than reiterate here the many specific implications which have been noted previously, it will be helpful in review to formulate a single, much broader implication. That is, if theory building and research on human communication are to deal with events as processes, it will be necessary to use and to develop not only appropriate forms of theory, but also research and analysis techniques capable of dealing with the dimension of time. This broader implication, together with certain others which stem from it, comprise the concern of this chapter.

6.2 Implications and Place of "Process" in the Study of Human Communication

The implication considered above is one very general answer to the question: "Where does the paper lead us?" A number of other more specific answers are of considerable importance, as well, and an examination of several of them should not only indicate certain additional implications of the concept of process, but also make clearer its place in the conduct of theory building and research related to human

communication. The discussion will provide an opportunity, as well, to consider once more the various limits on the scope of this paper.

In particular, it has been noted at several points in the paper that what is said here may not apply to all theory and research related to human communication, as it is evident that many studies do not require the consideration or use of the concept of process. Indeed, it is quite clear that much valuable work has been done which has not incorporated the concept. On the other hand, it should be equally clear that theory and research which does consider and utilize the concept of process is valuable and vital, even though it is only occasionally formulated or performed. That is, although studies which incorporate the concept have been recognized as necessary in the discipline of human communication (see sections 2.1.1 and 2.3.3), neither theory nor research in the forms considered here has been especially evident (see sections 3.4, 4.3, 4.4). It is only as such theory and research begin to appear that a potentially large and important class of information will become available, i.e., information on how communication behaviors develop, evolve, and interact during an event, or in short, on how they change over time.

Many of the tools needed to perform studies such as those suggested above are currently available, as noted in Chapters 3 and 4. Such tools have not been actually applied here (except for the examples in Chapter 5), because there is no attempt in this paper to build theory or to conduct research. As mentioned earlier, these tools are not presented as replacements for existing theoretic and research tools, but rather as potentially useful additions to them. Note particularly

that the present availability of a number of tools for dealing with the concept of process in specific theory-research frameworks should not be taken as an indication that those tools are complete. Indeed, much the opposite is true, for the existing tools are in many cases only starting points which require further development. The nature of such development has been indicated with regard to theory, research, and analysis (sections 3.4, 4.3, 4.4),² and it is clear that scholars in the discipline of communication will have to share in this development (both in the challenges and in the headaches) if they wish a continued ability to interpret the results of their studies in terms of the concept of process (cf. Krippendorff, 1969b, p. 35).

If scholars do make use of the existing tools and begin the development of new tools, the body of research which develops will not exist as an entity distinct from present research, but instead will be an extension of it. That is, research which operationalizes the concept of process can be seen as an extension of present research in the same respect that a process design can be seen as an extension of a difference design through the addition of another observation point (see section 2.1.3). In this sense, research which operationalizes "process" is a refinement of current research, capable of collecting new or additional information. It is also possible, of course, to take the "opposite" point of view which sees current

²In slightly more specific terms, development is needed in analogic (and symbolic) forms of theory, in research techniques involving both design and measurement, and in analysis techniques for reducing and testing research information. Any further indication of needed development is beyond the scope of this chapter; see sections 3.4, 4.3, and 4.4, for further information.

research as comprised of the special "point" and "difference" cases of a more general "process" research framework. But the question of whether or not this view is appropriate is one which can only be answered as the concept of process is increasingly operationalized in communication research.

Increased operationalization of the concept of process will present researchers in human communication with at least one problem which they have not often confronted in the past (Sidman, 1960, p. 54). Specifically, they will have to consider in more depth the question of whether to focus their research on individual behavior or on group behavior. At first glance, such a decision may appear trivial, being "merely" a matter of choosing whether to consider individual values or some composite value such as a mean. However, the choice of research focus is not this simple, particularly when one is involved in the study events as processes, and especially if those events are complex. That is, Sidman (1960, pp. 46-54) has pointed out that a behavioral process for a group may have no counterpart in the same behavioral process for an individual, and that in some cases, ". . . individual and group curves simply cannot provide the same information, even if their forms are identical (p. 53)."

A focus on individual behavior in research will thus be likely to supply information which differs in important ways from the information obtained if group behavior is the primary focus. The decision on which of these two foci to choose is closely tied to the purpose for which the research is being conducted, but the matter is even more complex. That is, the decision is affected, as well, both by

considerations of generality and variability (Berlo, 1967, pp. 13-15; Sidman, 1960, Chs. 5, 6), and by considerations regarding measurement (see sections 4.3.3, 4.4.1). The need to make a decision on the individual or group focus in research has been encountered in the past in studies of human interaction and of language development, and promises to be a decision which is increasingly necessary as the concept of process continues to be operationalized in research.

In view of the emphasis which has been placed on the concept of process in the paper as a whole, it is important to note again that this concept is not the only one of importance in research and theory related to human communication. The concept has been purposely narrowed from its broader usage, and the additional concepts which were introduced in so doing must not be overlooked. In particular, interaction and emergence are also important concepts in the study of human communication,³ and in many respects need explication in a manner similar to that employed here. The concept of process was chosen from among these concepts and others entirely because the limits of space dictated a choice of the single most important and useful concept. Indeed, it is clear that a fuller understanding of human communication events will come only as these various concepts begin to be considered together in research.

³This choice of additional concepts is not meant to disparage the importance of the other concepts introduced in sections 1.2 and 2.1. However, interaction and emergence are perhaps the most important of the various concepts, with respect to the conduct of theory building and research relevant to communication (see page 40).

This recognition of the necessity of incorporating and operationalizing a number of different concepts in the conduct of theory building and research can be seen, too, in Krippendorff's recent and important comments on communication research (1969b). An examination of Krippendorff's requirements for what he terms "elementary communication data" reveals that not only must the concepts of process, interaction, and emergence be incorporated in theory and operationalized in research, but the concept of system must be considered, as well (1969b, pp. 23-33; cf. pages 16-18).⁴ Indeed, unless these concepts and others are incorporated in theory and especially in research, Krippendorff has noted the resulting data will probably not produce evidence that is capable of semantic interpretation in terms of the concept of communication (1969b, pp. 2-8, 34-36).

Such a situation means that to be adequate, research on human communication must become a considerably more sophisticated endeavor than it is at present, not only in operationalizing the concept of process as considered in this paper, but also in operationalizing the related concepts which cannot be considered here. At the same time, theory too must become more sophisticated if it is to be useful in adequately explaining, predicting, and/or controlling events (see page 6). Theory must incorporate the concept of process, together with the related concepts, and in this respect is likely to become somewhat

⁴Again, these four concepts are not the only ones which must be considered in dealing with communication events, as is clear in sections 1.2 and 2.1. However, for the present discussion these four are the most important.

more "complex" than it is at present--a potentiality which has already been recognized (Carroll, 1968, pp. 2-10; Jenkins, 1970). There is no implicit assumption here that complex behavior, e.g., human communication, requires complex theory, but it is interesting to note by way of analogy that the theory of relativity, often held as a paragon of economy in explanation and prediction, is actually an exceedingly complex and intricate structure.

This potential complexity in theory and research, the new problems to be encountered and considered in conducting studies, and the difficulties in dealing with the concept of process itself, all point to one end: there is no panacea in studies of human communication. This paper has attempted to isolate one form of information which appears vital, yet is lacking in such studies, i.e., information on communication events as processes, and has sought to provide a basis for theory and research which will provide that information. In so doing it has uncovered many more problems than it has solved, perhaps because the suggested approaches will change not only the ways in which communication events are studied, but also the very content of those studies.

The potential changes should prove highly beneficial to the study of human communication, however, both in improving explanation and prediction of what happens over time when humans communicate, and in opening a door to two areas of theory and research which scholars have seen as important in communication, but also as unuseable until now, namely, system theory and analysis (Carroll, 1968; Harrison, 1967a; cf. Buckley, 1967, p. 39) and cybernetics (Krippendorff,

1969a, pp. 117-118, 129-132). In general, then, the concept of process has an important place in human communication research, and it is apparent why "Most scholars engaged in the study of human communication will agree with Berlo (1960) in choosing the phrase, 'the process of communication,' to describe the focal point of their discipline."

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APPENDICES

APPENDIX A

Schematic Presentation of Experimental Designs

In their brief booklet on experimental design, Campbell and Stanley (1963) present a series of "pre-," "true," and "quasi-" experimental designs, each design having a unique schematic or graphic representation. Because these designs are referred to at several points in this paper, they are presented here for convenience. Campbell and Stanley explain their code as follows:

In presenting the experimental designs, a uniform code and graphic presentation will be employed to epitomize most, if not all, of their distinctive features. An X will represent the exposure of a group to an experimental variable or event, the effects of which are to be measured; O will refer to some process of observation or measurement; the Xs and Os in a given row are applied to the same specific persons. The left-to-right dimension indicates the temporal order, and Xs and Os vertical to one another are simultaneous. To make certain important distinctions, as between Designs 2 and 6, or between Designs 4 and 10, a symbol R, indicating random assignment to separate treatment groups, is necessary. This randomization is conceived to be a process occurring at a specific time, and is the all-purpose procedure for achieving pretreatment equality of groups, within known statistical limits. Along with this goes another graphic convention, in that parallel rows unseparated by dashes represent comparison groups equated by randomization, while those separated by a dashed line represent comparison groups not equated by random assignment. A symbol for matching as a process for the pretreatment equating of comparison groups has not been used, because the value of this process has been greatly oversold and it is more often a source of mistaken inference than a help to valid inference. . . . A symbol M for materials has been used in a specific way in Design 9 [to indicate equivalent materials] (1963, p. 6).

Each of the following presentations includes the number given to the design in the Campbell and Stanley volume, a brief descriptive title for the design, a page reference to Campbell and Stanley (1963), and the

schematic for the design.

(1) One-Shot Case Study (p. 6):

X	0
---	---

(2) One-Group Pretest-Posttest (p. 7):

0	X	0
---	---	---

(3) Static Group Comparison (p. 12):

X	0

	0

(4) Pretest-Posttest with Control Group (p. 13):

R	0	X	0
---	---	---	---

R	0		0
---	---	--	---

(5) Solomon Four Group (p. 24):

R	0	X	0
---	---	---	---

R	0		0
---	---	--	---

R		X	0
---	--	---	---

R			0
---	--	--	---

(6) Posttest-Only with Control Group (p. 25):

R		X	0
---	--	---	---

R			0
---	--	--	---

(Hovland, et al.) Pretest-Posttest with Control Group and Time Extension
(pp. 31-32):

R	0	X	0
---	---	---	---

R	0		0
---	---	--	---

R	0	X		0
---	---	---	--	---

R	0			0
---	---	--	--	---

(7) Time-Series (p. 37):

0 0 0 0 X 0 0 0 0

(8) Equivalent Time Samples (p. 43):

$X_1 0$ $X_0 0$ $X_1 0$ $X_0 0$

Note that X_0 stands here for the absence of experimental stimuli.

(9) Equivalent Materials (p. 46):

$M_a X_1 0$ $M_b X_0 0$ $M_c X_1 0$ $M_d X_0 0$ etc.

"The M s indicate specific materials, the M_a , M_c , etc., being in sampling terms, equal to the sample M_b , M_d , etc. (p. 46)." Note that here, as in Design (8), a basic pattern of $X_1 0$ $X_0 0$ is repeated with the same group.

(10) Nonequivalent Control Group (p. 47):

0	X	0

0		0

(11) Counterbalanced (including Latin Square) (pp. 50-51):

	t_1	t_2	t_3	t_4
Group A	$X_1 0$	$X_2 0$	$X_3 0$	$X_4 0$
Group B	$X_2 0$	$X_4 0$	$X_1 0$	$X_3 0$
Group C	$X_3 0$	$X_1 0$	$X_4 0$	$X_2 0$
Group D	$X_4 0$	$X_3 0$	$X_2 0$	$X_1 0$

(12) Separate-Sample Pretest-Posttest (p. 53):

R	0	(X)
R		X 0

Note that the parentheses indicate an optional X. The following variations in the basic design are also mentioned:

(a) Time Extension (p. 40, 53):

R	O	(X)		
R		X	O	

R			O	(X)
R				X O

(b) Time Extension (p. 40, 53):

R	O		(X)
R		O	(X)
R			X O

(c) Retested Group (p. 40, 54):

R	O	X	O
R		X	O

(13) Separate-Sample Pretest-Posttest with Control Group (p. 55):

R	O	(X)	
R		X	O

R	O		
R			O

(14) Multiple Time-Series (p. 55):

O	O	O	O	X	O	O	O	O

O	O	O	O		O	O	O	O

(15) Institutional Cycle--Patched-up (p. 56, 57):

Group A		X	O	

Group B ₁	R	O	X	O
Group B ₂	R		X	O

Group C				O X

Note that the X, here, occurs in a cycle. The schematic given here is a specific example of a patched-up design. See pp. 57-61 for further information.

(16) Regression-Discontinuity Analysis (p. 61):

$$\begin{array}{ccc} (0) & X & 0 \\ - & - & - \\ (0) & & 0 \end{array}$$

Note that no schematic is presented by Campbell and Stanley for this particular "design." The above is the present author's schematic, the parentheses indicating an optional or unrelated observation.

The following schematics are added to the above list for completeness. They follow the notation used above, but are not necessarily taken from Campbell and Stanley (1963).

(A) Two-Wave Panel Design (Campbell, 1963, p. 67, 68):

(a)

(b)

$$\left(\begin{array}{c} 0 \\ - \\ 0 \end{array} \right) - \left(\begin{array}{c} X \\ -? \\ 0 \end{array} \right) - - - \left(\begin{array}{c} 0 \\ - \\ 0 \end{array} \right) - \left(\begin{array}{c} X \\ ? \\ 0 \end{array} \right) - \left(\begin{array}{c} 0 \\ - \\ 0 \end{array} \right)$$

(Unacceptable)

(Better)

"Here the spanning parentheses indicate occurrence of the 0 or X on the same interview; the question mark, ambiguity of classification into X and no-X groups (Campbell, 1963, p. 67)."

(B) "Multiple-Wave" Panel Design (Lazarsfeld, 1938, 1948):

$$\left(\begin{array}{c} 0 \\ - \\ 0 \end{array} \right) - \left(\begin{array}{c} X_a \\ ? \\ 0 \end{array} \right) - \left(\begin{array}{c} 0 \\ - \\ 0 \end{array} \right) - \left(\begin{array}{c} X_b \\ -? \\ 0 \end{array} \right) - \left(\begin{array}{c} 0 \\ - \\ 0 \end{array} \right) - \left(\begin{array}{c} X_c \\ ? \\ 0 \end{array} \right) - \left(\begin{array}{c} 0 \\ - \\ 0 \end{array} \right)$$

The above schematic is the present author's representation of one possible application of a "multiple wave" panel design. The X_a , etc., indicate a continuing event, such as an election campaign, while the question marks indicate ambiguity in classification or lack of control over exposure. Many other variations are possible for other types of events, and for purposes of gaining precision (Lazarsfeld, 1938, 1944, 1948; Zeisel, 1957, pp. 215-254).

APPENDIX B

Derivation of Minimum Number of Measurements

As indicated in section 4.2, the problem considered here is that of determining the minimum number of measurements required to completely characterize a sinusoidal signal. As discussed, it will be assumed that the frequency, f , of this signal is known, thereby making the period, p , of the signal, $p = 1/f$. The sinusoidal signal to be considered will be the general case presented graphically in Figure B-1, below:

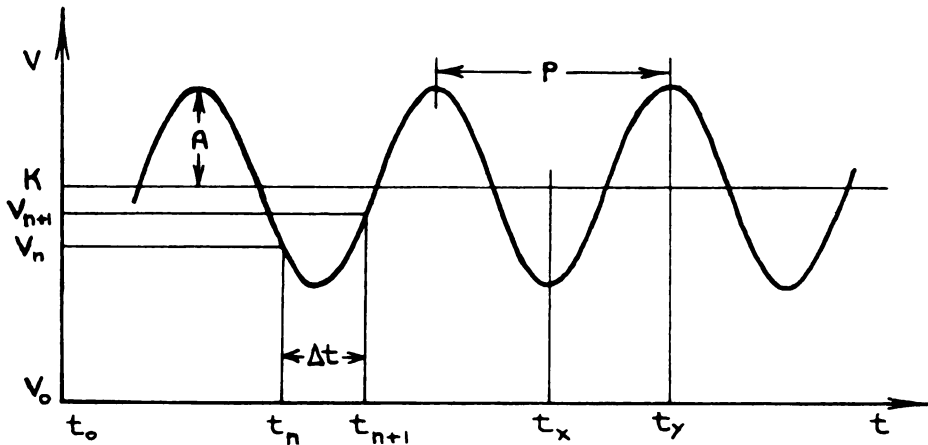


Figure B-1. General Sinusoidal Signal

In this case, a value, v_n , is obtained at a measurement point, t_n , where the value v is measured from an arbitrary reference, v_0 , and time is measured from a reference point, t_0 . Successive measurements are separated by an interval of Δt , so that $t_{n+1} = t_n + \Delta t$.

The concern here will be, of course, with intervals of Δt where $\Delta t \leq p/2$, as considered in section 4.2. The general equation for the value, v_n , is (cf. Milsum, 1966, pp. 150-151):

$$v = K + A \cos \omega t_n \quad (1)$$

where A is the amplitude of the sinusoidal signal measured from its mean, and ω is known, given that $\omega = 2\pi f$ and the frequency, f , is known. The term $A \cos \omega t_n$, therefore, describes the variation of the sinusoidal signal about its mean, which in this case is a constant value, K .

Note that the quantity ωt_n in equation (1) is an angle expressed in radian measure. Hence, if t_n is initially zero, the quantity ωt_n will be an angle of zero. If t_n is $p/2$ or one-half of a cycle of the sinusoidal signal, the quantity ωt_n will be an angle of π since $\omega t_n = 2\pi f \cdot t_n = 2\pi f \cdot p/2 = 2\pi f \cdot 1/2 \cdot 1/f = \pi$. Similarly, if t_n is p or one full cycle, then the quantity ωt_n will be an angle of 2π . In short, it is possible to consider a time interval of Δt , where $\Delta t = p/2$, in terms of an angle of π , and it will be convenient to do so at points below.

Note, also, that in the derivation below, the quantities v and t will always be known, since measurement of a signal or form of variation is considered here to involve both determination of the variable value and determination of the time at which that measurement is taken. Examination of equation (1) will show, then, that the only terms to be determined are K and A , since all other terms are known. Determination of these terms results in complete characterization of the sinusoidal signal. The general procedure will be, then, to determine whether or not equation (1) can be solved, and under what conditions, given one,

two, or three measurement points.¹

One measurement point.-- Given a value v_1 obtained at a time t_1 , the result of substituting in equation (1) would be:

$$v_1 = K + A \cos \omega t_1 .$$

Clearly, the above equation is one equation in two unknowns (K and A), and cannot be solved under any conditions. Hence, one measurement point will not completely characterize a sinusoidal signal.

Two measurement points.-- Given values v_1 and v_2 obtained at times t_1 and t_2 , it is possible to write two equations using equation (1) above:

$$\begin{aligned} v_1 &= K + A \cos \omega t_1 , \text{ and} \\ v_2 &= K + A \cos \omega t_2 . \end{aligned} \quad (2)$$

This pair of equations may be solved for K and A . Solving for A , first, it is possible to rewrite the above as:

$$\begin{aligned} K &= v_1 - A \cos \omega t_1 , \text{ and} \\ K &= v_2 - A \cos \omega t_2 , \end{aligned}$$

hence:

$$v_1 - A \cos \omega t_1 = v_2 - A \cos \omega t_2$$

and:

$$A \cos \omega t_1 - A \cos \omega t_2 = v_1 - v_2$$

or:

$$A = \frac{v_1 - v_2}{\cos \omega t_1 - \cos \omega t_2} \quad (3)$$

¹Appreciation is expressed to John J. Forsyth for guidance in this approach.

Solving for K, second, by substituting equation (3) into one of the initial pair of equations:

$$v_1 = K + \left(\frac{v_1 - v_2}{\cos \omega t_1 - \cos \omega t_2} \right) \cos \omega t_1$$

or:

$$K = v_1 - \left(\frac{v_1 - v_2}{\cos \omega t_1 - \cos \omega t_2} \right) \cos \omega t_1 \quad (4)$$

Note that equations (3) and (4) are general forms applying to situations where $t_2 = t_1 + \Delta t$ and $\Delta t \leq p/2$, i.e., $\Delta t \leq \pi$. If $\Delta t = \pi$, certain simplifications are possible, since $\cos \omega t_2 = \cos \omega(t_1 + \Delta t) = \cos \omega(t_1 + \pi) = -\cos \omega t_1$.

An examination of equations (3) and (4) shows, of course, that all values on the right side of the equal sign are known values, as would be expected in any solution of two equations in two unknowns. It is the curious property of measurements on sinusoidal signals, however, that a pair of measurements taken at an interval whose midpoint is t_x or t_y in Figure B-1 will yield equal values for v_1 and v_2 . Such a situation may occur regardless of whether the interval is $\Delta t = p/2$ or $\Delta t < p/2$. Note the following crucial point: if the values v_1 and v_2 are equal, equations (3) and (4) above break down, i.e., if $v_1 = v_2$, it is not possible to solve the pair of equations (2) considered above! Hence, two measurement points are sufficient to completely characterize a sinusoidal signal, but only if the measured values are not equal. If $v_1 = v_2$, it is necessary to obtain a third value, v_3 , which is not equal to the other two. Such a value, $v_1 = v_2 \neq v_3$ will permit a solution to the pair of equations above. A third value

requires, however, a third measurement point.

Three measurement points.-- The reason underlying the breakdown of equations (3) and (4) when $v_1 = v_2$ can be seen by examining again the initial pair of equations (2). That is, v_1 may equal v_2 only if the points t_1 and t_2 are symmetrical around the a point like t_x or t_y in Figure B-1. In such cases, the cosine terms in equations (2) are identical, and since the values v_1 and v_2 are equal, the result is two identical equations in two unknowns--a situation which has no solution. The need, then, is to obtain a third measurement, v_3 , at time t_3 which will not yield an equation identical to those in (2).

Note, however, that if $v_1 = v_2$ and t_1 and t_2 are separated by an interval of $\Delta t = p/2$, all successive measurements spaced at $\Delta t = p/2$ will yield the same value of v! That is, such a measurement scheme would be "locked in" to measurement of the mean of the sinusoidal signal, as can be seen by examining Figure B-1. Such a situation would not provide information leading to the solution of equations (2), for the reasons noted immediately above; hence, it would not be possible to characterize the sinusoidal signal in this case, even with three measurement points.

On the other hand, if $v_1 = v_2$ and t_1 and t_2 are separated by an interval of $\Delta t < p/2$, then a third measurement at time t_3 could not yield a value v_3 identical to v_1 and v_2 . That is, measurement at an interval of $\Delta t < p/2$ could not be "locked in" to producing identical values. Such a situation would produce at most two identical values in any three measurements, or in this case, $v_1 = v_2 \neq v_3$. The presence of at least two distinct values of v would allow solution of equations

(2), and consequently would characterize the sinusoidal signal.

Reviewing the above discussion, then, it may be seen that, given the frequency of a sinusoidal signal, three measurements of that signal spaced at intervals of $\Delta t < p/2$ are sufficient in all cases to completely characterize that signal.

Further considerations.-- As noted, the assumption above has been that the frequency of the sinusoidal signal under investigation is known. If this assumption is removed, then it is clear that three measurement points is an absolute minimum number. That is, equation (1) would be revised under these conditions to the following:

$$v_n = K + A \cos 2\pi f t_n$$

where K , A , and f are unknown. Such a situation of three unknowns clearly requires at least three measurements which provide three different values of v_n in order that a solution be found.

As in the case of three measurement points above, it may be impossible, because of the measurement scheme and the interval Δt to obtain three different values of v_n . Unlike the case above, however, such situations are numerous and are not as easily specified, so that it is more difficult to determine, for example, the conditions under which four (or more) measurements might be sufficient to completely characterize a sinusoidal signal. Since such a determination moves beyond the scope of the present discussion of the minimum number of measurements required, given the frequency value, it will be more expedient to turn to another type of sufficient condition. That is, when the frequency of a sinusoidal signal is unknown, three measurements of that signal are sufficient in all cases to completely

characterize that signal if $v_1 \neq v_2 \neq v_3$.

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