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ABSTRACT

A theory of group interaction with a focus on the trajectories of relevant variables as they change over time is developed in this paper. The four major components of the group interaction process (communication, conflict, involvement, and centralization) are presented and conceptually defined, and the nature of their interdependence is discussed. For the major components, the paper defines a set of actual values, a set of expectancies, and a set of discrepancies. Based on these variables, it then presents a set of difference equations, a set of differential equations, and a computer simulation as three forms of the model of the group interaction process. It suggests a time series study for collecting the necessary data to test the model. Appropriate methods of analyzing the data and testing the model are also discussed. (FL)

A DYNAMIC MODEL OF GROUP INTERACTION

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A DYNAMIC MODEL OF GROUP INTERACTION

The purpose of this paper is threefold, to (a) present a model of the group interaction process in three forms: a set of difference equations, a set of differential equations, and computer simulation model, (b) propose a study for collecting the necessary data to test the model, and (c) present the appropriate methods of analysis for the tests of the model.

Homans (1950) lays out three steps toward a theory of group interaction:

> First, group behavior will be analyzed into a number of mutually dependent elements. Second, the group will be studied as an organic whole, or social system, surviving in an environment. Third, the relations of the elements to one another will be found to bring about the evolution of the system with the passage of time. (p. 6)

This paper will develop a theory of group interaction following Homans with a focus on the trajectories of relevant variables as they change over time.

It is not a new suggestion that group interaction should be studied as a time-dependent process. Tuckman (1965), in his review of developmental processes in groups, observed that "the question of change in process over time has been relatively neglected" (p. 384). Hawes and Foley (1976) note that "it takes talk and time to make decisions, . . . using talk appropriate for making decisions means using talk which functions differently at different points in time" (p. 237). Other researchers have observed group interaction variables as a function of time, beginning with the work of Jaffe and Feldstein (1970) concerning rhythms of dialogue, followed by Chapple (1971) studying the coordination of interaction tempos, and most recently Cappella (1979, 1980) developing models of talk/silence sequences. Rausch (1965) indicated that one would not try to explain or describe chess by recording only the frequency of moves of each piece on a chess board. Similarly, one would not expect to find out much about dyadic interaction merely by correlating the frequency of interpersonal choices (Wolf, 1970). Other studies of group interaction utilizing dynamic conceptualizations are those by Doreian (1979) and Fink and Huber (1977).

While time-dependent conceptualizations for studying group interaction are available, research which takes this approach is less common. Bales and Strodtbeck (1951) performed one of the first time-dependent studies of group interaction and found qualitatively different phases in group interaction. More recently, some researchers have used Markov analysis on discrete data to take into account the dynamic process of group interaction (Bartos, 1967; Ellis & Fisher, 1975; Hawes & Foley, 1976; Donohue, Hawes, & Mabee, 1979). Because of the limited research which explicitly incorporates time and uses continuous variables, this paper presents a dynamic model of group interaction utilizing continuous variables and proposes a time series study with accompanying analyses to be used for the test of the model.

The next section describes the model of group interaction by defining the variables of interest and describing their interdependence.

DESCRIPTION OF THE MODEL

This section will present and conceptually define four major components of the group interaction process. They are communication, centralization, involvement, and conflict. Similar variables can be found in other models of the group process (Festinger, 1950; Homans, 1950). Three related measures will be used for each of these four variables. They are (a) the observed amount of the variable, (b) the expected value of the variable, and (c) the discrepancy between the expected and actual amount of the variable. Actual amounts and expectancies are obtained directly and the discrepancies are computed from the observed amounts.

System Components

The following are the conceptual definitions for each variable along with relevant research dealing with similar variables. Because the focus of our theory is the group process, i.e., the group is the system under investigation, the unit of analysis for each of the variables will be the group (see Operationalization of Variables for further discussion).

Communication. Volume or amount of interaction has often been used in understanding interaction processes (Jackson, 1960; Schachter, 1960; Doreian, 1979). The amount of communication is indicative of the level of activity in the group (Homan, 1950) and is used as such in our model. For our model of group interaction, amount of communication is defined as the amount of messages which are sent in a group. Messages exchanged in the group may be verbal or non-verbal.

Involvement. Literature focusing on the dynamics of group interaction often uses the concept of cohesiveness as the active involvement of group members in perpetuating the group interaction (Jackson, 1960; Pepitone & Reichling, 1960). Spontaneous involvement has been discussed directly by Goffman (1957), and also in related work on the sociology of interaction and alienation (Emerson, 1970). Amount of involvement in the model is defined as the extent to which group members actively attend to the group's interaction. A group with a high level of involvement is one in which group members are not self-conscious or distracted, but actively participate in the group interaction.

Conflict. Conflict has also received much attention in the literature on interaction. It has been addressed as "confronting utterances" (Wolf, 1970), competition or disagreement (Donohue et al., 1979), expressed disagreement or disfavor (Ellis & Fisher, 1975), or as a choice between two behaviors that is internal to the individual (Bartos, 1967). To integrate these definitions, the amount of conflict is defined as the amount of opposing forces exhibited by group members. These forces may be directed at individual group members, subgroups of members, or the group as a whole. If conflict becomes too great and unresolved, the group will disband. The absence of conflict is manifested in pressures toward uniformity and consensus (Festinger, 1950; Asch, 1960; Mills, 1960).

Centralization. Democratic or authoritarian atmospheres, group centered or leader centered environments, and laissez-faire or directive groups are similar in conception to centralization in describing the structure of group interaction (Golembiewski, 1962; Lewin & Lippitt, 1965). Centralization incorporates an aspect of group structure into the model as a continuous variable. The amount of centralization is defined as the extent to which messages in the group are sent by or directed towards one individual. The maximum amount of centralization occurs when all messages are either sent by or directed toward one individual in the group. A minimum level of centralization occurs when message generation and receipt is equally distributed among all group members.

Theoretical Model of Interdependence

Group interaction is viewed as a dynamic process in which the interdependent components of the process operate to maintain the system. This section will present a dynamic model of group interaction based on six relationships among the four variables presented above. Six propositions will be presented that describe the causal relationships between the variable amounts for any small group. The propositions are illustrated in Figure 1.

Figure 1 about here

Proposition 1: An increase in the amount of involvement (η_2) causes an increase in the amount of communication (η_1).

The more that group members actively attend to the group interaction, the more likely it is that messages will be sent. While research linking involvement and amount of communication per se is not readily available, it is hypothesized that group members who are actively participating in a group will send more messages. Homans (1950) links the idea of some activity level in the group interaction with the group coming together as a unified group. Festinger (1960) comments that communication becomes easier the more one interacts with others. Researchers who study developmental processes in groups have implied that as members become more involved in the group, more interaction may occur (Tuckman, 1965; Hawes & Foley, 1975).

<u>Proposition 2</u>: An increase in the amount of communication (η_1) causes an increase in the amount of involvement (η_2).

More communication overall tends to increase the involvement of the group members. The quantity of messages occurring in a group will influence the degree to which people participate in the group. Jackson (1960) found that attraction to membership in a group depends on the volume of interaction of group members. Anderson and Triplett (1977) used a computer simulation to test Festinger's hypothesis and found that group cohesiveness created an increased pressure to communicate. Although most of the literature focuses on cohesiveness as opposed to involvement, there exists a body of literature linking group levels of activity (communication output) with acting as a member of the group (Homans, 1950; Jackson, 1960; Golembiewski, 1962).

<u>Proposition 3</u>. An increase in the amount of communication (η_1) causes an increase in the amount of conflict (η_3).

As more messages are sent in a group, there will be a subsequently higher level of conflict. This occurs because individuals generate messages in an attempt to manage their environment and satisfy personal goals (Miller & Steinberg, 1975). This most often results in some amount of conflict however small. Simmel (1955) states that it is impossible to have conflict without interaction. Doreian (1979), using data on the interaction between two countries as a two-person group, showed that the more the communication between these two countries, the greater the potential and actual conflict.

Proposition 4: An increase in the amount of conflict (η_3) causes an increase in the amount of involvement (η_2) up to a critical point; after which an increase in the amount of conflict (η_3) causes a decrease in the amount of involvement (η_2).

Small amounts of conflict motivate group members to resolve the conflict through increased participation. When prolonged conflict becomes taxing or begins to appear unresolvable, group members may reduce their participation and attentiveness for some period of time by focusing their attention away from the interaction. This is a reaction to a frustrating or difficult situation. From the study done by Asch (1960), one could conclude that conflict leads in general to greater involvement in groups as group members increase their active attempts to persuade the deviant members. Pepitone and Reichling (1960) state that hostility in groups may have a cathartic effect, thus creating a more cohesive group following the conflict. Most generally, an individual's response to conflict in a group will be curvilinear over time relative to their degree of active involvement in the group. This relationship may be mathematically reexpressed for analysis to be compatible with the linear relationships presented in the rest of the model.

Proposition 5: An increase in the amount of conflict (η_3) causes a decrease in the amount of centralization (η_4).

When a situation of conflict exists, there is a diffusion of control evident in the structure of messages sent. In the extreme, there would be a movement away from focusing on some central figure. Lewin and Lippitt (1965) note that when a high state of tension exists in an autocratic group, the group structure tends to become less stable. Alinsky (1971) views conflict as a precursor to structural change. A group with minimal amount of conflict can function satisfactorily with just a few persons handling most of the messages. When large amounts of opposing messages are aired, this indicates that the status quo is not working, and the group will go through a decentralized period where ideas emanate from a variety of persons in the group.

Proposition 6: An increase in the amount of centralization (η_4) causes a decrease in the amount of communication (η_1).

The more formal or informal limitations there are on how messages can be sent in a group, the less communication occurs. Research using a variety of network configurations yields conflicting information concerning the relationship between number of messages and the centralization of the network. It is believed that these differences in results were due to the type of task (Shaw, 1971). It should be noted that greater centralization means that certain paths are not open to message exchange, and hence there are fewer extraneous messages sent. Borgatta and Bales (1965) examined group differentiation (similar to centralization) and found that more differentiated groups had higher rates of interaction.

Causal loops. The three major causal loops in the model will now be discussed. The first is the relationship between communication and involvement. This relationship is a self-perpetuating one, such that the more involved one is in a group, the more one communicates and vice versa. If this were the only consideration in determining the value of these variables, one would expect the system to eventually explode. This may not be the case due to the influence of the other two loops in the model.

The second loop consists of involvement, communication, and conflict. The more involved a group becomes, the more they communicate, and the more likely conflict becomes. Conflict can then lead to either increased or decreased involvement, depending on its degree. The third loop consists of communication, centralization, and conflict. An increase in centralization will lead to a decrease in communication with a subsequent decrease in conflict. If unmediated by the other relationships in the model, one would expect the group to become so centralized as to cease functioning as a group.

The relationship between conflict and involvement is key to the stability of the group interaction process. The impact of all other variables is influenced by this relationship. A cursory look at the relationship between conflict and centralization might reveal that a rise in conflict is only followed by a subsequent decrease in the centralization of the group. This occurs since an increase in conflict leads to a decrease in centralization and an increase in communication until the group becomes so decentralized that it disbands. This situation may not occur, however, due to the intervening effect of the relationship between conflict and involvement. Because there exists a critical point above which conflict leads to a decrease in involvement rather than an increase, the direction of the subsequent relations change. When the relationship between conflict and involvement becomes negative, communication decreases, conflict decreases, and centralization increases, thus restoring the system.

SPECIFICATION OF THE MODEL

This section specifies the group interaction process and presents the model in three different forms: (a) a set of simultaneous difference equations for direct estimation of parameters; (b) a set of differential equations to represent the rates of change of the variables over time, and (c) a computer simulation that tests the logic of the model, facilitates experimentation with the model, and generates research hypotheses. Before presenting the three forms of the model, it is first necessary to define two additional sets of variables, expected amounts and discrepancies.

Expected Amounts

Given that individuals often appear to learn over time what to expect from social situations, it seems reasonable to propose that it is not the absolute amount of some variable that affects the individual, but rather the difference between what is expected and what is perceived. For example, most people would expect some amount of conflict to exist in a task group. If the perceived amount of conflict is greater than we expect, it would not be the perceived amount that makes an impact per se, but rather the differences between our expectations and our actual experience.

Our model posits that group members will act to make the actual amounts of the variables at time t approach the expected amounts. Expected amounts will be taken from the t-2 observed amounts for each variable. The expected amounts of communication, involvement, conflict, and centralization will change as the interaction proceeds since they are based on the past actual amounts (t-2) of the relevant variable.

Discrepancies

It has been proposed above that it is the difference or discrepancy between expected and actual amounts of a particular variable that affects its future value as opposed to the actual magnitude of the variable (Doreian & Hummon, 1976; Anderson & Triplett, 1977; Doreian, 1979). Because we propose that a discrepancy affects the future value of its respective observed variable rather than having an instantaneous impact, it is necessary to take the expected amount at t-2 and actual amount at t-1 to compute a discrepancy (t-2 minus t-1 values) which will affect the observed amount at time t.

The next section presents the first form of the model as a set of simultaneous difference equations for estimating the parameters of the model.

Difference Equation Form of the Model

By combining the previously stated bivariate propositions where appropriate, the group interaction process may first be modeled as a set of stochastic multivariate difference (structural) equations which are amenable to linear estimation procedures. The multivariate equations are interdependent and, thus, model the system of interdependent variables.

The difference equation model is illustrated in Figure 2. This model is a single-indicator theoretical model which meets the necessary conditions for overidentification (Nambooderi, Carter, & Blalock, 1975, p. 504). The difference equations for Figure 2 are (Jöreskog & Sörbom, 1978):

$$\eta_{1_t} = \beta_{10} - \beta_{11}\eta^*_{1_{t-1}} - \beta_{12}\eta_{2_t} - \beta_{14}\eta_{4_t} + \zeta_{1_t} \quad (1)$$

$$\eta_{2_t} = \beta_{20} - \beta_{21}\eta_{1_t} - \beta_{22}\eta^*_{2_{t-1}} - \beta_{23}\eta_{3_t} + \zeta_{2_t} \quad (2)$$

$$\eta_{3_t} = \beta_{30} - \beta_{31}\eta_{1_t} - \beta_{33}\eta^*_{3_{t-1}} + \zeta_{3_t} \quad (3)$$

$$\eta_{4_t} = \beta_{40} - \beta_{43}\eta_{3_t} - \beta_{44}\eta^*_{4_{t-1}} + \zeta_{4_t} \quad (4)$$

where β_{i0} is the intercept, β_{ij} is the partial slope, ζ_i is the error of prediction, $\eta^*_{i_{t-1}}$ is the discrepancy between expected ($\eta_{i_{t-2}}$) and actual ($\eta_{i_{t-1}}$) amounts, and t is time. The model does not assume zero covariances among the errors of prediction at time t.

Figure 2 about here

Differential Equation Form of the Model

The differential equations are the rates of change for the group interaction process, i.e., how fast the state variables are increasing or decreasing in amount. To express the difference equations as differential equations, the difference equations must be transformed to find the partial slopes (a_{ij}) in the differential equations.[1] The set of first order differential equations for the interaction process are:

$$\frac{d\eta_1}{dt} = a_{10} + a_{11}\eta_1^* + a_{12}\eta_2 + a_{14}\eta_4 + u_1 \qquad (5)$$

$$\frac{d\eta_2}{dt} = a_{20} + a_{21}\eta_1 + a_{22}\eta_2^* + a_{23}\eta_3 + u_2 \qquad (6)$$

$$\frac{d\eta_3}{dt} = a_{30} + a_{31}\eta_1 + a_{33}\eta_3^* + u_3 \qquad (7)$$

$$\frac{d\eta_4}{dt} = a_{40} + a_{43}\eta_3 + a_{44}\eta_4^* + u_4 \qquad (8)$$

where a_{i0} is the intercept, a_{ij} is the partial slope, η_i^* is the discrepancy, and u is the error of prediction or white noise.

Computer Simulation Form of the Model

Computer simulation is often undertaken: (a) to develop and test the logic of a theory (Frijada, 1967; Hermann, 1967), (b) as an alternative to a complex, nonlinear mathematical model to derive analytical or mathematical solutions (Forrester, 1968; Bråten, 1970; Larsson & Lundin, 1970; Cohen, 1974), and (c) to generate hypotheses based on experiments with the model (Anderson & Triplett, 1977). Before presenting the computer simulation form of the model, the modeling method employed will be described briefly.

System dynamics was chosen as the modeling method because it views the system as a series of interconnected feedback loops consisting of decisions, resulting actions, and information feedbacks reporting on the actions, i.e., as in information feedback control systems (Forrester, 1968; Goodman, 1968). It is particularly applicable to systems that change through time and have feedback loops. As can be seen in Figure 1, there are three feedback loops in the model of the group interaction process. System dynamics also consists of a flow diagram which illustrates the system processes and provides useful detail. The flow diagram illustrates the levels, rates, and information feedback loops of the process.

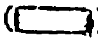
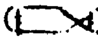
The flow diagram (Figure 3) shows each feedback loop as a substructure of levels () and rates () which are interconnected to produce the feedback loops. In turn, these create the group interaction process. The level (or state) variables describe the condition of the system at any point in time and are equivalent to η_{i_t} in the difference equation. The levels accumulate or integrate the net difference between inflow and outflow rates. The rate variables, which are equivalent to $d\eta_i/dt$ in the differential equations, indicate how fast the levels are changing and determine the slope (change per unit time) of the level variables. The auxiliary variables (), which represent the expected amounts and discrepancies, lie in the information channels between the rate and level variables and are algebraic subdivisions of the rates. The flow of variables is symbolized by a solid line and an arrow while an information flow is represented by a dotted line and an arrow. When a flow's origin or destination is external to the system, it is shown as originating from an infinite source () or going to an infinite sink ().

Figure 3 about here

Figure 3 represents the process of group interaction as specified in the propositions and the difference and differential equations. The amount of communication, involvement, conflict, and centralization are represented as levels of the system with respective rates which regulate the increase or decrease in the amount of the levels. The rates of communication, involvement, conflict, and centralization have been divided into two parts: (a) a discrepancy which is the difference between the expected (value at t-2) and actual (at t-1) amounts and (b) a constant fraction per time unit (FPT_i) which is a measure of how quickly the group responds to a discrepancy (represented by D_i). FPT_i is the fraction of the discrepancy acted on per time unit.

TEST OF THE MODEL

The previous sections have focused on the authors' conceptualization of group interaction as a dynamic system and three ways to model the process. This section provides a general discussion of how to conduct a study to explore and test the fit of the model with empirical data. We briefly outline the design for the study, indicate generally how the variables will be measured, discuss appropriate methods of analysis, and provide a procedure for validating the computer simulation model.

Design

A laboratory design is to be used rather than a field study since the initial focus is on the endogenous system. Later stages of the research might incorporate groups with specific histories operating in their ordinary settings. The data necessary to estimate the parameters of the set of difference equations and to test the goodness-of-fit of all three forms of the model may be collected using one group observed at multiple points in time. This time series design allows us to study the dynamic properties of the four major variables in the group interaction model.

A task group will be studied to allow for more control over the topic of discussion. A time interval of one observation per 15 seconds was chosen. This sampling unit was chosen in the hopes of capturing the trajectories of the variables over time, and to avoid aliasing and related problems (Arundale, 1979). The appropriateness of this interval will be examined directly in the research.

The number of group members will be three to simplify coding in the initial study. Future studies should consider manipulating group size as an exogenous factor.

Operationalization of Variables

Observational instruments (trained coders) will be used for data collection. The group under study will be videotaped to facilitate coding of the interaction. The coding of the observational data will be based on clock time as opposed to event time since the model posits the behavior of variables as a function of clock time.

The data to be collected must of necessity provide enough information for testing the model. Chapple (1971) provides insight into the type of data which might be appropriate for sophisticated scientific analysis. He states that "one must seek variables which can be defined operationally and can be measured in equally spaced (interchangeable) units along some dimensions so that a full set of tools of mathematical analysis can be applied to them" (p. 142). Fink and Huber (1977) support this notion in their discussion of the advisability of continuous variables: "the variables as described here are continuous, so that one may meaningfully speak of amount as well as existence of change" (p. 2618). In their study, ratio-level measurement was employed to take advantage of a wide range of mathematical techniques. This was accomplished operationally through magnitude estimation as described by Hamblin (1975).

Coders will be trained to use ratio-level scales in assessing the values of the variables of interest.[2] For each of the four observed variables, a magnitude estimation measurement scale based on a modulus of 100, which indicates "average," will be used. Each 15 second segment will be viewed once, and each of the four major variables will then be evaluated relative to a hypothetical "average" segment. Estimates will take into account non-vocal and non-verbal behaviors not otherwise included in relational analysis or other analyses of interaction transcripts. Expectancies and discrepancies will be computed from the observed amounts from the appropriate time intervals (t-2 and t-1, respectively).

Analyses

The analyses will consist of five parts or steps: (a) exploratory analysis of the empirical data, (b) test for goodness-of-fit of the difference equation form of the model and estimation of parameters, (c) estimation of the differential equation parameters, (d) running the computer simulation model to obtain computer generated data, and (e) validating the computer simulation form of the model.

Various exploratory data analytic procedures will be performed on the data to examine it for symmetry, homoscedasticity of errors, and normality of errors (McNeil, 1977; Mosteller & Tukey, 1977; Tukey, 1977; Leinhardt & Wasserman, 1979). In addition, based on the difference equation form of the model, the data will be examined for autocorrelation and stationarity (Hibbs, 1974; Ostrom, 1978). Based on the results of the exploratory analyses, the data will be reexpressed as needed to meet the assumptions of the linear estimation procedure to be used for goodness-of-fit tests and parameter estimation.

To estimate the parameters and test the goodness-of-fit of the difference equation form of the model, a full information maximum likelihood (FIML) method will be used. Since the difference equations form a set of simultaneous equations, a FIML procedure which will test the model as a whole and simultaneously estimate all of the parameters is desirable. LISREL IV (linear structural relationships) is a FIML computer program which has been chosen to test the overall model and estimate the parameters (Jöreskog & Sörbom, 1978).

Once the parameters of the difference equations have been estimated, the parameters of the differential equations can be obtained by reexpression of the set of difference parameters.[3]

The fourth step is to write the program for and run the computer simulation form of the model to obtain computer generated data. DYNAMO will be used as the simulation language (Pugh, 1976). DYNAMO treats flows within systems as continuous in time rather than discrete events, although the latter can be added as the model is refined. It can also deal with variables in aggregated form. The computer program will consist of two fundamental types of equations corresponding to the system's levels and rates. These equations specify the changing interactions of the variables as time advances. They are continually recomputed after small time intervals of equal duration to yield successive new states of the system. The intervals are short enough to approximate continuous variation. Levels are determined first, and then the results are used in rate equations. DYNAMO equations can be easily written based on the flow diagram in Figure 3.

The fifth and last step will be to validate the computer simulation form of the model. The major validation concern is how well the computer generated data corresponds to the empirical data in the difference equation form of the model. LISREL IV has the capability of analyzing two groups of data simultaneously. By treating the empirical data and the computer generated data as two groups based on the difference equation form of the model and constraining all parameters to be equal over the two groups, LISREL IV can test the goodness-of-fit of the computer simulation form of the model as a whole.

CONCLUSION

In this paper, we presented and conceptually defined the major components of the group interaction process (communication, involvement, conflict, and centralization) and discussed the nature of their interdependence. From the four major components, we defined a set of actual values, a set of expectancies, and a set of discrepancies. Based on these variables, we then presented a set of difference equations, a set of differential equations, and a computer simulation as three forms of the model of the group interaction process. A time series study was suggested for collecting the necessary data to test the model. Appropriate methods of analyzing the empirical data and testing the model were discussed.

The next step will be to develop the magnitude estimation scales for the variables and to train coders in the use of these scales. Once the empirical data have been collected and coded, it will then be possible to begin to determine how well our conceptualization models the group interaction process.

NOTES

1. The procedure for transforming the difference equations to find the partial slopes (a_{ij}) in the differential equations are presented by Coleman (1968), Doreian and Hummon (1976), and Fink and Huber (1977).

2. While we recognize that each of the variables in this study could be measured at different levels of analysis, we have chosen to begin with the "global group" level for this initial study. Future studies should seriously consider the problems of aggregating variables towards developing "composition" theories which specify "relations among forms of one construct present at different levels of analysis" (Roberts, Hulin, & Rousseau, 1978).

3. See note #1.

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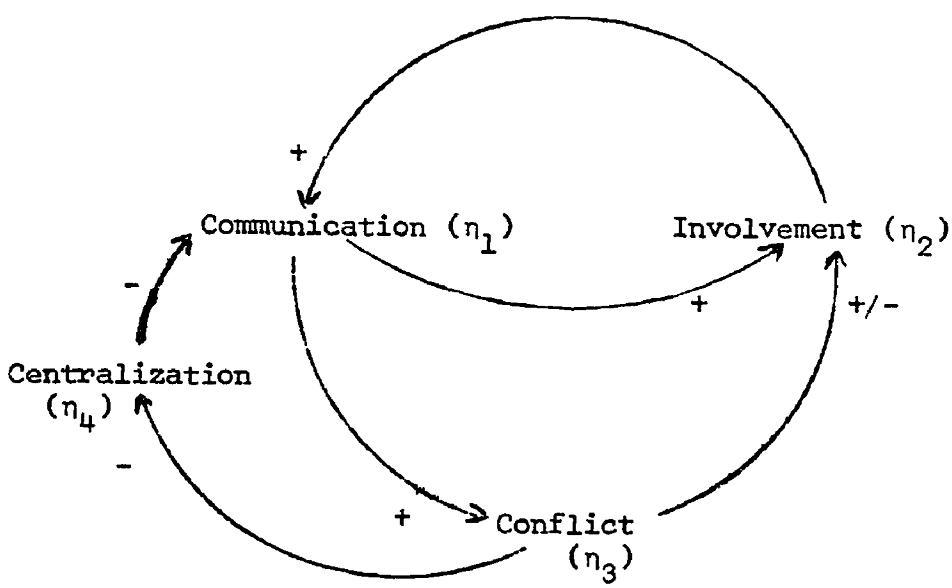

Figure 1. Causal loop diagram of the group interaction process.

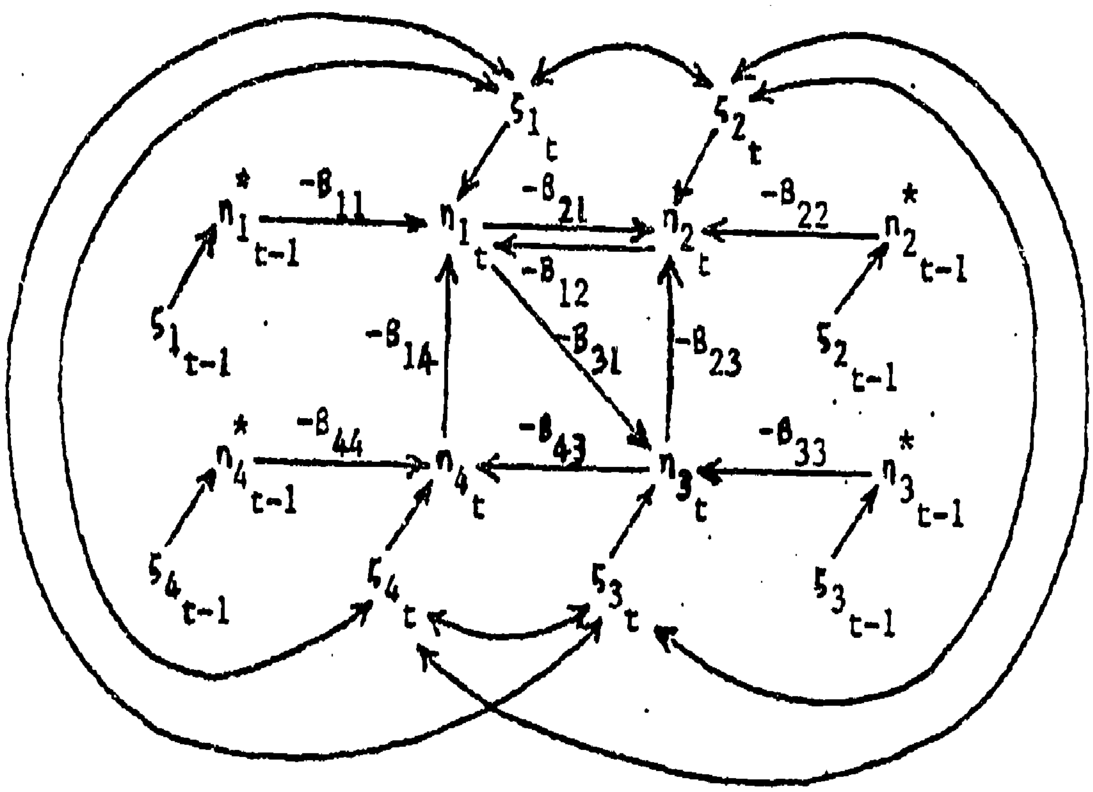

Figure 2. Diagram of the set of difference equations which form a single indicator theoretical model of group interaction.

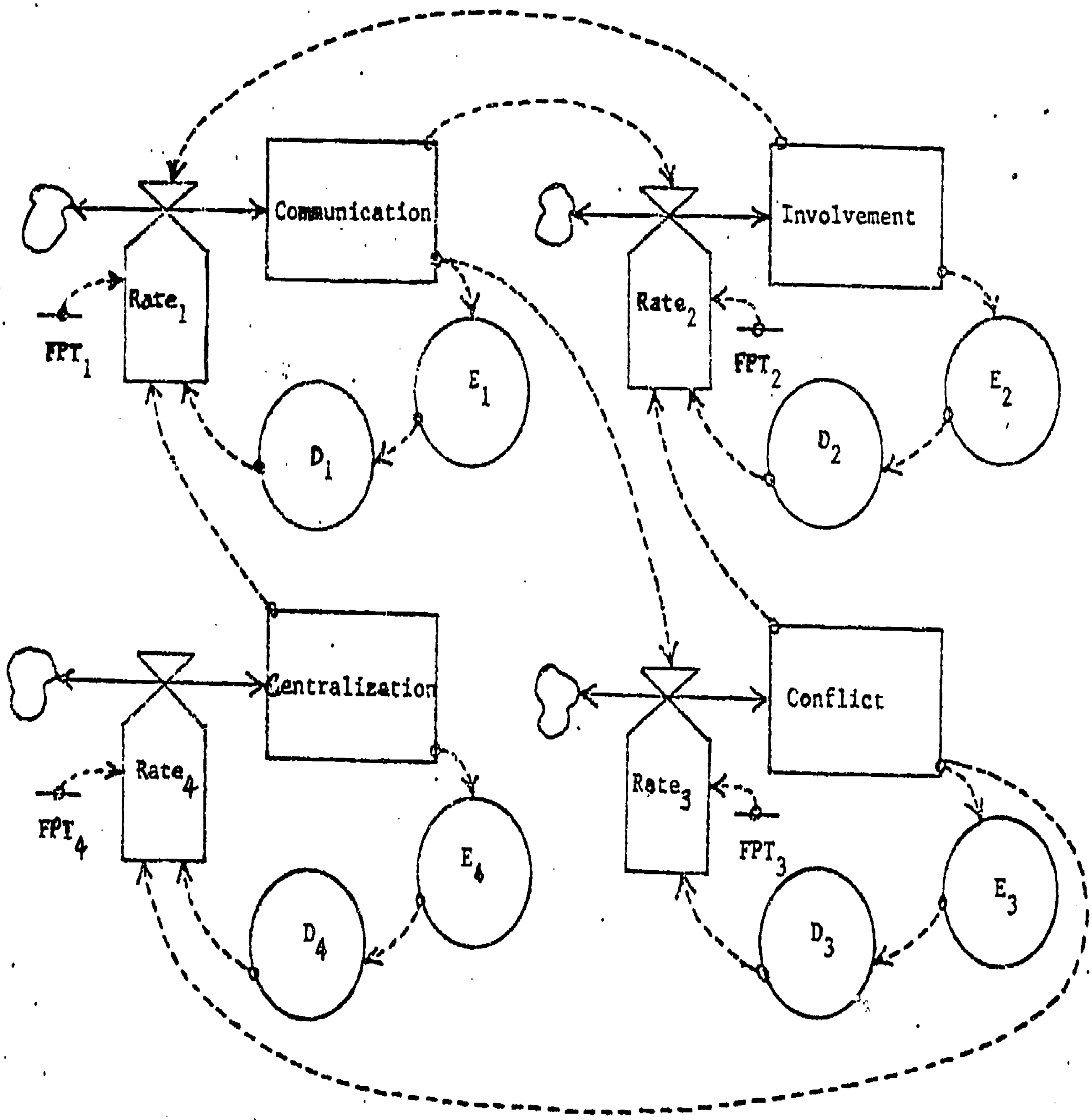

Figure 3. Flow diagram of the computer simulation form of the group interaction process (E_i= expected value at t-2, D_i= discrepancy, and FPT_i= fraction per time unit).