UNRESTED NETWORKS AS SELF-DESIGNING SYSTEMS

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ABSTRACT

This study was designed to examine the nature of self-design in the structuring of small work groups. A simulation model of a communication network was used to permit an All-Channel network to determine a self-designed structure. The results indicated that the task productivity or rates of solution are independent of the continual self-design process. Further, the recognizable forms of network structure did not substantially deviate from an all connected network. The communication structure continued to vary even though a steady state solution rate had been attained for some time.

INTRODUCTION

The study of organizational design is currently evaluating this premise: because implementation clarifies design and design clarifies implementation it is only sensible to emphasize the design of organizations as self-design. (9) In fact, the underlying theme of current investigation in this area is the organization as a self-designing system.

What are some of the characteristics of self-designing systems, how might they be applied to a controlled experimental setting and what types of methodology would be appropriate to further examine this premise?

First, these general characteristics of self-designing systems are freely adapted from Weick (9).

1. Self-design involves arranging, linking and decoupling sets of elements to change consequences from those currently obtained.
2. Self-designing organizations must contain the provision for continual evaluation of current designs.
3. Issues of self-design focus on the processes responsible for the designs with the emphasis on those processes that reflect the need for and create alternative arrangements of activities.
4. A self-designing system or organization continually must deal with the reality that adaptations often restrict further subsequent adaptability.
5. Designs are frequently constructed in the absence of performance criteria. Or, structure may not always follow strategy.
6. It is often difficult to separate implementation from the self-designing feature of structure as these elements evolve simultaneously.

Second, a paradigm which fits these characteristics in a controlled setting is the Communication Network Experiments (CNE) (1), (2), (6), (8). Specifically, the All-Channel network where the structural arrangement is free to vary or self-design as a result of the sending, receiving and content of messages, is ideally suited to examine the aforementioned premise. Research activity in CN subsided in the late 1960's because of an inability to establish any unifying concepts around which the myriad of performance results for various networks could be explained. Recently, (2), (10) the task productivity among communication networks has been shown to be described by the power function $Y = AX^B$ when learning and reinforcement are permitted in problem solving over long periods of time.

In brief, group problem solving behavior in these controlled settings exhibited a substantial transition period, characterized by an acceleration in solution rates leading to an equilibrium level. Contingencies of reinforcement permitted Wheel, Circle and All-Channel networks to achieve and maintain these steady state levels. Although the different networks took longer to achieve an optimum rate of performance they all reached such a level of performance given sufficient time. Prior to these recent findings the maximum number of trial problems for experimental groups was 60. The time necessary for CNE groups to reach optimal productivity is fairly long (approx. 300-350 trial problems) so long, in fact, that one must question the generalizability of findings from previous work. The structural development of an All-Channel network over the time necessary to establish a steady state of behavior would, therefore, provide a suitable experimental setting to examine the self-design process of organization.

This study addresses the question, <u>how will the process of self-dseign be manifested in an unstructured group over time</u>. Are there any recognizable patterns which are formed at the various transition states? Some of the inconsistent results previously recorded concerning this question may be explained by the transitory stage in which those experiments were terminated. (25 to 60 problems)

METHODOLOGY

A model of CNE was developed then tested using an experimental design that permitted examination of the long-term effects of reinforcement and learning upon task performance and structural design. Computer simulation was selected as the means to perform this examination. There were several reasons for using a computer simulation model:

1. A long-term study is required for inclusion of learning transition states. The need to isolate and control variation, plus the cost and continuity required over long periods for such experiments, can be assisted by a simulation methodology.
2. Most studies are not of long duration and present only a snapshot of continual behavioral processes within groups. A simulation, on the other hand, can deal with feedback properties, stochastic elements in the process, and changes that occur throughout a specificed time period.
3. Human behavior of individual systems elements may be thoroughly understood, but the relationship of the elements, and consequently the behavior of the system or process as a whole, may not be. Simulation can determine and highlight the behavior of the total system in a deductive fashion.
4. Computing machines operate sequentially, in a well-defined temporal sequence. The model builder is forced to specify this sequence and must consider, at minimum, which operations precede each other, and in doing so, takes a first step toward causal identification (4). Therefore, the integration of behavioral processes required for a simulated process demands deliberate and careful construction to synthesize past empirical work.
5. A conceptual model may have a number of gaps which are more readily perceived in the course of constructing a simulation. Because many findings have to be incorporated to achieve a mathematical model for simulation, the rigor of this approach lends formalization to theoretical statements.

The use of a simulation methodology followed the accepted stages of algorithm construction (4): system movement consonant with empirical findings, generation of data amenable to validation tests, and examination of data generated to test hypotheses.

Model validity was tested by comparing both original and replications of time-path data for similarity, and by comparing simulated data against the Burgess (2) benchmark laboratory CNE study.

Experimentation with the model involved changing the structural dimensions of the network such that communication patterns would conform to either a All-Channel or Circle hierarchy.

MODEL DESCRIPTION

Several definitions are required for understanding the model:

1. Trial - The total number of messages, or time units, required to complete the group task constituted a trial. The task for each simulated network member was to send a sequence of messages to other participants in the network such that solution was reached by everyone. Learning to employ shortened sequences of messages constituted the primary of each simulated member. (See Figure 2, Box 1)
2. Round - The basic time unit in the simulation was that interval of time in which each simulated subject had an opportunity to send or request one message to or from another network member. Such an exchange is called a round.

A hypothetical network of four simulated members was constructed. Each member was represented by a specific set of two behavioral attributes. Values assigned to these attributes were identical for each member at the beginning of each simulation experimental run; they were modified according to the simulated experience in the particular network and varied over time. Attributes denoting each simualted member were:

1. selection of a channel (another member of the network to whom to communicate).
2. selection of a message or another communication desired.

In a typical laboratory CNEs subjects send messages at will until all members acquire the answer. The simulation model (program) is not as flexible. Because of the sequential nature of the computer, "send" messages proceeded as follows:

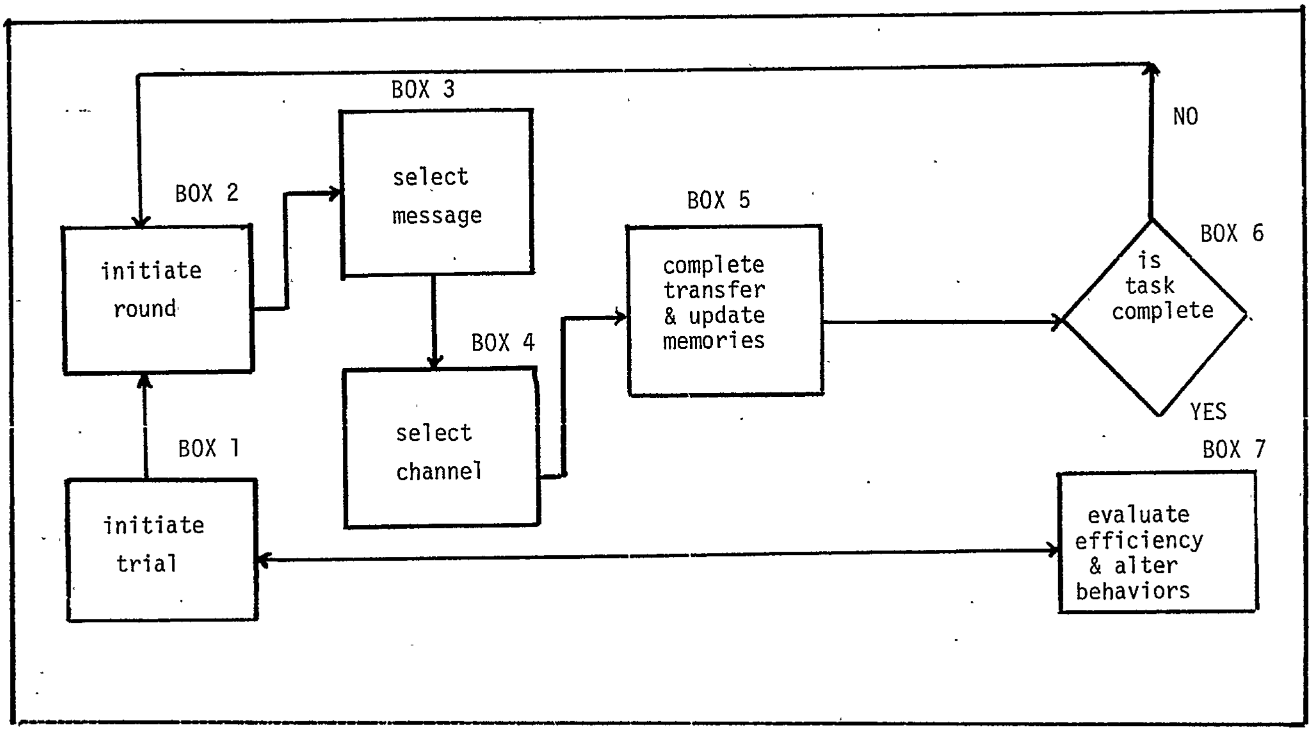
1. Each MAN (simulated subject) selects a message to send (or decides to wait). [See Figure 1, Box 3]
2. The same MAN then chooses a permissible channel or other MAN to receive the message. [See Figure 1, Box 4]
3. The messages are sent; all information vectors and matrices are updated and such other changes as may be required. [See Figure 1, Box 5]

Simulation values for these behaviors changed as a function of prior task success. A probabilistic reinforcement component was included which increased the likelihood of maintaining and readopting behaviors (selection of message and channel) only when they reduced the number of communications required for group solution. Conversely, this likelihood was reduced when selection of either channels or messages was deleterious to the group's solution time. [See Figure 2, Box 7]

In CNEs which included consequences of feedback, there seems little doubt that feedback often improves performance. Feedback was included as the end of each trial by permitting comparisons of current behavior to past successes (shorter sequences) for each MAN. This procedure is representative of human behavior in CNEs (3).

The process each MAN's problem-solving behavior followed, in the model, was composed of four stages (5).

Figure 1. Basic task process of the communication network model.



1. searching
2. comparing
3. remembering
4. altering behaviors

VALIDATION

Burgess ran his CNEs in four-person groups for 800 trials. For both Wheel and Circle networks, the time needed for solution per trial over these 800 trials was best described by the messages required for solution and X denoted the trial number. Burgess found that the minimum number of messages for solution (a steady state) was reached for Wheel networks at approximately 200 trials and Circle networks required just over 300 trials to reach a steady-state level.

To validate a power-function model, both the simulated data and the break points in those data (indicating the onset of a steady-state level of productivity) must conform to the function. An efficacious technique to obtain the break points is to specify a rate of improvement or slope, in the regression line after which achievement of a steady state can be operationally defined. It was this procedure which was adopted in this study.

Two validation tests are reported here, first a goodness-of-fit test with the overall laboratory data; second, a goodness-of-fit with break points.

The R^2s for cumulative solutions for simulated Circle runs over the 800 trials are presented in Table 1. In each instance, the power function best described the data. This agrees with Burgess' conclusions. The R^2s for the six runs reported were 0.99+. Burgess R^2s for his ten experiments were 0.99 using the same power function, $Y=AX^B$. As a comparison, the linear fits attempted on the simulated data were .54 of the R^2s.

Table 1. Regression coefficients for six Circle networks: number of messages required for successive task solution.

Run Number	A	B	R^2	Standard Error of A	Standard Error of B
1	-3.668	1.239	.9944	.0248	.0032
2	-3.977	1.276	.9956	.0227	.0029
3	-3.744	1.258	.9966	.0192	.0025
4	-3.729	1.259	.9962	.0202	.0026
5	-3.862	1.222	.9976	.0152	.0020
6	-3.862	1.273	.9954	.0029	.0030

Further, as with individual learning, the simulated groups exhibited an initial transition period during which their response rates steadily increased. Also organizational patterns developed in all networks. A patterns of relaying messages had either been achieved or was in progress when CNEs of short duration had ended. These patterns were reflected in the model by the probabilities of channel selection. In almost every case, each group (run)had developed an organizational structure which persisted throughout the 800 trials. Also, the structures were different for each group.

Burgess reported that Circle networks required slightly over 300 trials to reach a steady-state of productivity or solution rate. To the extent that the simulated data for Circle networks conform to this break point in productivity, confidence in the model's predictive ability would be further enhanced.

Steady State. The operational defintion of a steady state was set at 0.0005 improvement of the solution rate relative to the starting conditions or initial rate. For the first five trials, an average rate was calculated, and was used as the initial productivity rate. Once the solution rate per trial reached 0.0005 of the average first five trials, the steady state had been achieved.

A series of regressions were obtained from six simulated Circle experiments. For runs1, 3, and 5, the slope of the regression lines are approximately equal to the critical rate at 300 cumulative solutions or trials. For run 2 this equivalence occurred slightly before 250 trials and just after 200 trials for run 4. The last comparison for run 6 indicated the break occurred slightly over 300 trials.

These visual observations tended to reassert that the model was reasonably accurate in determining equivalent breaking points.

Table 2. Regression coefficients for All-Channel networks: number of messages required for successive task solutions.

Run Number	A	B	R^2	Standard Error of A	Standard Error of B
1	-4.020	1.294	.9980	.0153	.0020
2	-3.250	1.193	.9918	.0287	.0038
3	-3.429	1.200	.9940	.0249	.0032
4	-3.745	1.251	.9940	.0259	.0034
5	-3.860	1.266	.9984	.0135	.0017
6	-3.643	1.243	.9934	.0268	.0035

Table 3. Matrix of communication patterns for two 4-man All-Channel networks after incidences of task experience.

Consecutive Task Solutions		All-Channel Run 1 MAN 1	MAN 2	MAN 3	MAN 4	All-Channel Run 4 MAN 1	MAN 2	MAN 3	MAN 4
	MAN 1	--	.31	.31	.38	--	.38	.35	.37
	MAN 2	.33	--	.33	.34	.36	--	.34	.30
20	MAN 3	.32	.33	--	.30	.37	.35	--	.28
	MAN 4	.37	.34	.29	--	.32	.34	.34	--
	MAN 1	--	.30	.39	.31	--	.42	.41	.17
	MAN 2	.32	--	.33	.35	.35	--	.33	.32
60	MAN 3	.28	.36	--	.36	.40	.35	--	.25
	MAN 4	.39	.15	.46	--	.35	.38	.37	--
	MAN 1	--	.31	.35	.34	--	.39	.36	.25
	MAN 2	.40	--	.40	.20	.33	--	.31	.36
100	MAN 3	.28	.25	--	.47	.33	.27	--	.40
	MAN 4	.38	.47	.25	--	.37	.21	.42	--
	MAN 1	--	.36	.37	.27	--	.29	.40	.31
	MAN 2	.34	--	.36	.30	.41	--	.39	.20
200	MAN 3	.25	.23	--	.52	.31	.38	--	.31
	MAN 4	.29	.43	.28	--	.38	.36	.26	--
	MAN 1	--	.31	.31	.38	--	.30	.31	.39
	MAN 2	.38	--	.37	.25	.36	--	.34	.30
400	MAN 3	.28	.35	--	.37	.24	.28	--	.48
	MAN 4	.33	.39	.28	--	.39	.35	.24	--
	MAN 1	--	.33	.33	.34	--	.34	.33	.33
	MAN 2	.33	--	.34	.33	.40	--	.38	.22
800	MAN 3	.24	.25	--	.51	.31	.29	--	.40
	MAN 4	.37	.36	.27	--	.27	.28	.45	--

RESULTS

A sample of the communication patterns for the four-man All-Channel networks is provided in Table 3. The matrix for each group was initialized at equal probabilities such that the likelihood of communication to any other network member was both unrestricted and not unbiased. The findings of all six simulated runs were approximately the same. The recognizable self-designed structures remained all connected networks. Although at times throughout the 800 problem-solving tasks, a MAN may have substantially reduced his communication with one other network member is proved to be a transitory state. In fact, the self-design of these networks asymptomatically revolved about the initialized matrix.

Throughout the trials of problem-solving behavior many messages or forms of communication were transmitted, most of which were not helpful in completing the task. This may explain the reduction of communication to any particular network member. However, over time these patterns would change back to higher interactions as a result of perceived reductions in task productivity. This process of self-design continued throughout the entire 800 trials even though a steady state level of performance or productivity had been attained hundreds of trials earlier.

Apparently, the process of self-design is a fluid, continual occurrence. The structuring process did not vary from that of an All-Channel network and is is independent of reaching an optimal or steady state level of performance. The output data from the simulation did indicate that one network was intiially much quicker to reach a steady solution rate, nevertheless it was indistinguishable in structural form from any other network group.

The findings of this study argue for the premise that self-design is an unstaoppable process for organizations. Even though there are not personnel changes and group performance levels can be considered optimal. Cumulative experience in group task performance did not halt this structural fluidity.

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