

ON THE ANALYSIS AND DESIGN OF HUMAN INFORMATION PROCESSING ORGANIZATIONS<sup>†</sup>

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## ABSTRACT

The design of human organizations where members perform routine tasks under the pressure of time is considered. A three-phase approach is outlined. In the first phase, normative decision rules that specify ideal human behavior are obtained. In the second phase, implementations of these decision rules are devised, and descriptions of actual human behavior and workload are developed. Finally a third phase integrates design elements by placing parameters of the implementations for best organization performance, subject to individual member workload limitations. To illustrate the approach, a specific design problem is considered.

## I. INTRODUCTION

To accomplish tasks that are too complex for individuals, humans have devised and evolved a variety of organizational structures. Despite their proliferation, however, organizations have not readily yielded to the development of rigorous methods of analysis and design. This is due in part to the inherent complexity of situations where individuals are required to coordinate their efforts so that some overall objective is achieved. Another factor is the necessity to assess whether individuals within the organization are capable of doing their assigned jobs; that is, whether their induced workload is within their limits. This paper presents an approach to organization analysis and design that is appropriate for a particular class of organizations. Specifically, consideration is focused on those organizations that (a) involve routine human information processing tasks, (b) incorporate a well-defined organizational goal that is held by all members (i.e. the organization is a team), and (c) have a short amount of time available for individual information processing tasks (e.g. a few seconds or minutes). Organizations that are of this class can be found in tactical command and control situations.

While the approach is believed to be generally applicable to members of above class, it is limited to those organizations for which (1) tractable analytic models exist and (2) related descriptive data exists. These two conditions are currently very restrictive.

The paper is organized as follows. The next section discusses a three-phase approach to the design of organizations. In the third section, a specific task is presented for which an organization is desired. The design approach is then used to develop an organization to accomplish the task. Section four presents results of tests of the design, and a fifth section summarizes and concludes the paper.

## II. DESIGN METHOD

The approach to organization design used in this paper focuses on where and how in the design process to include consideration of human characteristics and limitations. With this in mind, an approach with three distinct parts, or phases, is pursued. Figure 1 shows the relationship of these phases. Given a (possibly general) statement of the task for which an organization

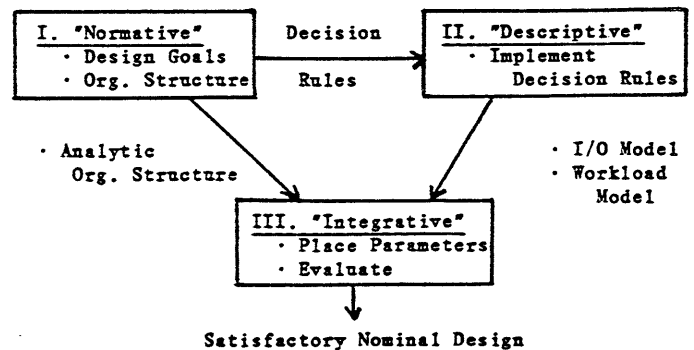


Figure 1 Organization Design Approach

is desired, the first phase in the process establishes a basic organization structure, which is expressed in analytic terms. The initial step in doing this includes the specification of the number of members, their interconnection, and their protocols for communication. It also includes the expression of design goals in terms of an objective function, as well as the delineation of the possible inputs and outputs to each organization member. In other words, everything about the organization structure is specified in analytical terms, except the mapping from inputs to outputs to be made by each member. Phase I is completed by solving an optimization problem that determines what these mappings should be. The resulting decision rules represent the desired behavior of organization members. As such they are job descriptions that are to be realized as closely as possible by actual human behavior in the organization. Execution of Phase I is thus normative in nature. In this context, and also in view of the class of organizations under consideration, models and results from the mathematical investigation of teams [1] are complementary to the issues that are addressed in Phase I of the organization design process.

Having determined, in the form of a decision rule, the information processing that each member is to perform, a second phase of the design begins in which decision rules are implemented. "Implementation" includes the specification of a collection of physical equipment, such as displays and response mechanisms, that the human is to use in order to accomplish the processing required by the decision rule. Also included is the specification of how the human is to use this equipment to perform his assigned task. Given the physical set-up and the directions for using it, a model is then developed that describes the organization member's behavior as the task is executed. This model has two components. The first is a description of the actual input/output behavior realized. The second is a measure of the workload induced by task execution. Both descriptions will in general depend on settings of parameters that are part of the physical task set-up, and also on variables that relate to how the organization member chooses to perform his task. Furthermore, since human information processing is subject to limitations, there will in general exist a maximum value of workload against which to compare the workload induced by the task. Thus Phase II of the design process is one that involves human modeling, but is such that a focus exists, in the form of a job description, for the tasks that are to be implemented. Techniques and models from human factors analysis, man-machine

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systems investigations, and cognitive psychology can be brought to bear to accomplish Phase II of the design.

The first two phases of design result in related, but distinct, design elements. On the one hand is an analytic organization structure that has been developed assuming ideal human behavior. On the other is a set of decision rule implementations that have been constructed so that actual human behavior can match, as closely as possible, that which is desired. The match is not necessarily perfect, however, particularly given human errors and workload limitations. Thus a third phase is necessary to integrate design elements in order to complete the organization design. In this phase the descriptions of actual input/output behavior are substituted for the decision rules in the analytic organization structure and the structure itself is augmented with the workload models. Then a constrained optimization problem is formulated to place parameters of task set-ups and parameters that relate to information processing choices available to members. The problem seeks to optimize organization performance, but does so in view of workload-related limitations of individual members. The solution to this problem is a nominal organization design that can be evaluated with respect to design goals.

Operation of the organization as designed requires that parameters of the physical task set-ups be set to the values obtained from solution of the constrained optimization problem. In addition, values obtained for information processing parameters can be interpreted either as prescriptions for how a member should be trained to exercise his information processing options, or as predictions for how he will. Successful completion of Phase III terminates the design process, although it may require several iterations on previous design steps before a satisfactory nominal design is obtained. The next section illustrates the design approach by applying it to a specific problem.

III. DESIGN EXAMPLE

Problem Statement

Suppose that the situation illustrated in Figure 2

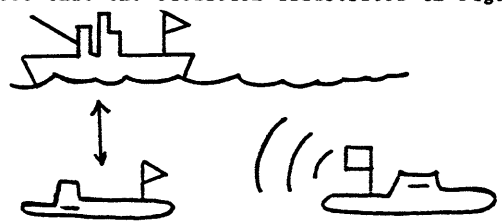


Figure 2 Illustration of Design Problem

is presented as a design problem. Two platforms, one surface and one submerged, are to perform, in a coordinated manner, a detection task regarding the presence or absence of another submerged target. Observations distinct to each platform are available each  $\tau_0$  time units, and it is required that repeated detection decisions be made at this rate, with a maximum delay of  $\tau_d$  time units between a pair of observations and the detection decision associated with that pair. Furthermore, there is to be limited communication between platforms. It is desired to minimize the probability of error in detection, but in any case to make it less than the fraction  $\bar{J}_0$ . For this set of conditions, an organization is to be designed. To do this, the approach discussed in the previous section will be used.

Phase I

To begin the design process, a basic organization structure must be specified. In the present situation, it is natural to assume a two-member organization. Moreover, the task itself is one that falls within the class of distributed detection networks [2]. Thus a tandem structure is assumed for the organization, as shown in Figure 3. The presence or absence of a target

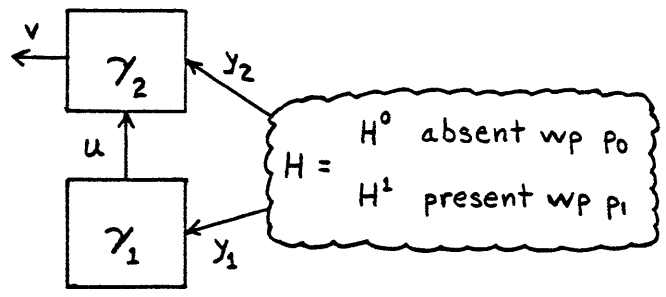


Figure 3 Organization Structure

is modeled as two hypotheses  $H$ , where  $H \in \{H^0, H^1\}$ .  $H = H^k$  with a priori likelihood  $p_k$ . Observations by each platform are assumed to be conditionally gaussian, with  $p(y_i | H = H^k) \sim N(m_{ik}, \sigma_i^2)$  ( $i = 1, 2; k = 0, 1$ ). Furthermore, observations are presumed to be related to incoming signal energy, which implies that  $m_{i0} < m_{i1}$ . For the particular situation under consideration,  $p_0 = 0.4$  and  $(m_{11} - m_{10})/\sigma_1 = 2$  and  $(m_{21} - m_{20})/\sigma_2 = 2.6$ , arbitrarily. Based on the observation received by the submerged platform ( $y_1$ ), a value of  $u$  is selected and communicated to the surface platform. To incorporate the limited communication condition into the organization structure,  $u$  is restricted to two values:  $u \in \{0, 1\}$ . Thus the first member provides only an indication regarding the target's presence or absence. The surface platform uses this indication together with the observation  $y_2$  to decide a value of  $v$ , where  $v \in \{0, 1\}$ . The latter is the overall detection decision of the organization. This process is to be repeated over and over as each new set of observations  $\{y_1, y_2\}$  arrives every  $\tau_0$  time units.

In the structure described above, everything has been specified in analytic terms except how values of  $u$  should be determined from observations  $y_1$  and how values  $v$  should be determined from  $y_2$  and  $u$ . These unspecified elements are the decision rules for each organization member. To determine what they should be, an optimization problem is formulated to find the set of decision rules  $\{\gamma_i^*\}$  that minimizes organization detection error.  $\gamma_1^*$  and  $\gamma_2^*$  are known to be threshold tests:

$$\gamma_1^*: \begin{cases} \text{if } y_1 \geq t_1^* & u = 1 \\ \text{else} & u = 0 \end{cases}$$

$$\gamma_2^*: \text{if } u = j \text{ and } \begin{cases} y_2 \geq t_{2j}^* & v = 1 \\ y_2 < t_{2j}^* & v = 0 \end{cases} \quad j = 0, 1$$

The values of  $t_1^*$ ,  $t_{20}^*$ , and  $t_{21}^*$  depend on the relative quality of each member's observations and on the a priori likelihood of  $H$ . Basically, the first member selects the second member's threshold and in so doing biases the decision of the second member. Furthermore, it happens that  $t_{20}^* > t_{21}^*$ , so that the direction of the bias is consistent with the first member's indication.

Phase I of the design process is now complete. An analytic organization structure exists that reflects the conditions of the problem. Decision rules for each member have been determined that represent the ideal behavior of organization members. Attention is now focused on implementing these decision rules so that the

Similarly, the overall average response time  $T_{p1}$  is a combination of the individual option response times:

$$T_{p1} = (1-q_1) \cdot \bar{t}_{SCR} + q_1 \cdot \bar{t}_{FG} \quad (4)$$

The model given by eq.(3)-(4) is essentially the Fast Guess model of Yellot [4], which is one of the mechanisms by which humans can trade speed for accuracy. Note that this model has two parameters: the threshold position  $t_1$ , and the fraction of fast guessing  $q_1$ . Determination of values of these parameters is made at a later stage in the design process and is done with respect to overall organization performance.

For the second organization member, an implementation for the decision rule  $\gamma_2^*$  is chosen as shown in Figure 6. Depending on the signal from the

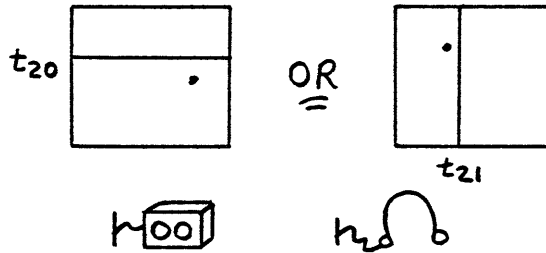


Figure 6 Second Member's Task

first member, threshold  $t_{20}$  or  $t_{21}$  is selected to be used by the second member. If it is the former,  $t_{20}$  is displayed as a horizontal line and the observation  $y_2$  is displayed as a vertical displacement. If  $t_{21}$  is selected, the threshold is displayed vertically and  $y_2$  is a horizontal displacement. Two horizontally arranged mechanical buttons are used to record responses. The left button is used if  $y_2$  is left ( $t_{21}$ ) or down ( $t_{20}$ ) and the right button is used in the complementary situations. Recall that the second member is viewed as subject to deadline on each response. An auditory mechanism has been used to indicate that the deadline has passed, which is represented by the headphones in Figure 6.

As with the first member's implementation, if the second member has enough time, he can perform his task flawlessly. The (average) processing time required for the task, denoted  $T_{p2}$ , depends on the amount of threshold switching. Denote by  $q_0$  the quantity  $p(u=0)$ . Figure 7 shows one subject's observed processing time

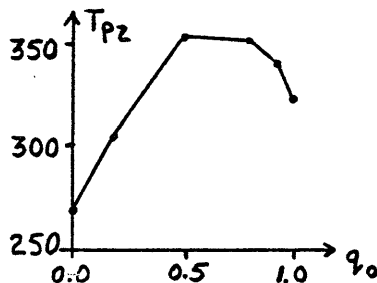


Figure 7 Second Member Processing Time

versus  $q_0$ , which is the fraction of threshold  $t_{20}$ 's use. A considerable overhead for switching is evident, as well as a difference in processing time for horizontally and vertically displayed thresholds. So long as  $t_2$  is greater than the time required, however, actual input/output behavior can be expected to match desired behavior.

If the time required ( $T_{p2}$ ) is less than the time allowed ( $t_d$ ), errors will be made as the member is

forced to trade accuracy for speed. One representation of this tradeoff is due to Pew [5], who suggests a log-linear relationship between the odds ratio (# right divided by # wrong) and response time. Using this representation, Figure 8 gives the speed/accuracy

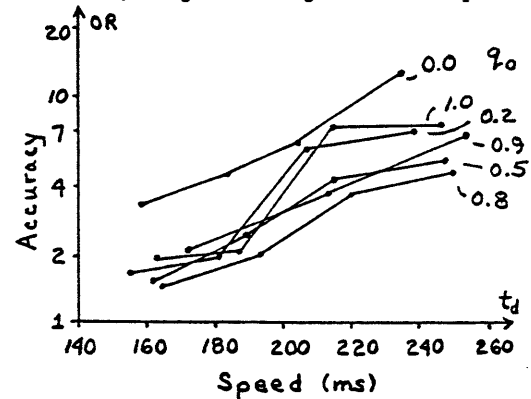


Figure 8 Second Member Speed/Accuracy Characteristic

characteristics for the second member's task as evidenced by one individual.

To obtain the results shown in the figure, several hundred responses were recorded at each  $q_0$  condition using various deadlines. The data at each  $q_0$  level were then rank-ordered by response time and partitioned into groups of a few hundred responses each. For each group, the average time and the odds ratio were computed. These values are the coordinates plotted in Figure 8 as representative speed/accuracy operating points.

The deadlines used were chosen such that insufficient time was available to do the task with highest accuracy. For operation in this region, it is evident that as  $t_d$  decreases there is a general decline in accuracy. Moreover, for given  $t_d$ , it is apparent that as  $q_0$  increases from 0 up to near 0.8, accuracy decreases. This is a direct result of the processing time requirements of the task as given in Figure 7. As  $q_0$  increases still further toward 1.0,  $T_{p2}$  decreases and accuracy improves.

A model for the second member is abstracted from the data in Figure 8 as follows. Denote by  $f$  the logarithm of the odds ratio. Then a linear approximation for each speed/accuracy locus can be written in terms of  $f$ :

$$f = f_s(q_0) \cdot (t_d - t_c(q_0)) \quad (5)$$

where  $f_s$  and  $t_c$  are quantities that are chosen to best represent observed behavior. Table 1 gives the values

Table 1 Second Member Model Parameters

$q_0$	$f_s$	$t_c$
0.0	0.0217	117
0.2	0.0190	130
0.5	0.0152	132
0.8	0.0142	137
0.9	0.0143	119
1.0	0.0209	136

estimated from the data in Figure 8. To express the behavior represented by  $f$  in a form consistent with  $\gamma_2^*$ , define  $q_2$  to be the input/output error rate. Then

$$q_2 = (1 + e^f)^{-1} \quad (6)$$

and the input/output behavior of the second member can

human organization members can attempt to realize their desired behavior.

## Phase II

Implementation of the decision rules  $\gamma_1^*$  requires the specification of how each member's observations are to be presented so that the proper threshold comparison test can be made. It is also necessary to provide a mechanism for recording each member's response to a particular observation. Furthermore, for each of the two physical task set-ups, a description of human behavior at that task is needed. This includes a model of the member's performance at making threshold comparison tests. It also includes a model for the workload of the task. In this design situation, processing time will be used to derive a measure of workload.

Given the overall limits on processing time for the organization ( $\tau_0$  and  $\tau_d$ ), implementation of the decision rules will begin by allocating this time between organization members. The first member will be required to process observations at the same rate that they arrive. That is, on the average, he must make a threshold comparison test every  $\tau_0$  time units, where

$$\tau_1 = \tau_0 \quad (1)$$

This leaves  $\tau_d - \tau_0$  time units for passing the message  $u$  between members and for the second member to respond. Communication between members is assumed to take negligible time. Thus the second member is allocated  $\tau_2$  time units, where

$$\tau_2 = \tau_d - \tau_0 \quad (2)$$

By contrast with the first member, however,  $\tau_2$  will be regarded as a deadline. The notion is that each decision by the second member will be constrained to take no more than  $\tau_2$  time units. In practice,  $\tau_2$  will be interpreted as the maximum average response time, assuming a narrow distribution of response time values.

This allocation of time is a design choice, and other choices are made later. In practical applications, good engineering practices will dominate these choices. In this research context, choices have been made to illuminate interesting aspects of organization behavior, often at the expense of pragmatic considerations.

Consider now the task of the first member. He is to compare an observation  $y_1$  with a threshold  $t_1$  and then decide a value of  $u$ . One way for him to do this is shown in the upper part of Figure 4. Observations  $y_1$  are presented visually in the form of a horizontal "crossbar pattern", where the midpoint of the pattern is the value of  $y_1$  observed. The member then decides whether the pattern midpoint is left or right of the vertical threshold and responds by depressing one of two mechanical buttons. The vertical threshold is positioned according to the value of  $t_1$ . In the lower part of Figure 4, the distribution on observations  $y_1$ , i.e. pattern midpoints, is shown (solid) as the weighted sum of two conditional distributions  $p(y_1|H^*)$ .

The first member is constrained to process patterns at a rate of  $\tau_1$  time units per pattern. The dial at the top of the display indicates to the member how many patterns are waiting to be processed. It advances clockwise as patterns join the queue. Since the patterns are to be processed at the same rate they arrive, the member must maintain the dial position at or near vertical in order to meet his processing rate constraint. Whether or not this is possible depends on the average time required to process patterns. The time to view and respond to a pattern, i.e. to make a

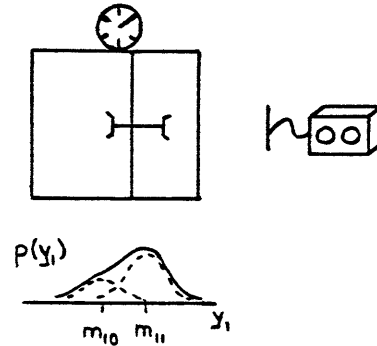


Figure 4 First Member's Task

"stimulus-controlled response (SCR)", varies with the position of the threshold  $t_1$ , however. Figure 5 shows

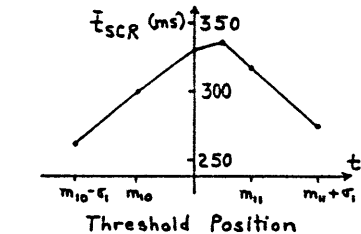


Figure 5 Average Response Time For First Member

experimentally observed variation of average SCR time with respect to the threshold position for one subject; the results are representative of those obtained from other subjects as well.

Given enough time, i.e. if  $\bar{t}_{SCR} < \tau_1$ , the subject is able to decide left or right of the threshold with near perfect accuracy. For example, at  $t_1 = t_1^*$ ,  $\bar{t}_{SCR}$  is approximately 330 ms. If  $\tau_1 > 330$ , then the member will virtually realize the ideal behavior determined by  $\gamma_1^*$ . However, as  $\tau_1$  decreases below  $\bar{t}_{SCR}$ , the member is observed to make errors as he tries to maintain the required rate.

Rather than incur SCR errors, an alternative processing option will be provided to the member: the option to "fast guess (FG)". Fast guessing means that the member ignores the pattern presented and responds arbitrarily. This takes about  $t_{FG} = 180$  ms, which is considerably less time than a stimulus-controlled response. Thus the member can presumably fast guess enough times to meet the rate constraint, and can carefully process patterns the remainder of the time. It is assumed that a 50/50 bias is used by the member when fast guessing. This is enforced experimentally by having the subject depress both buttons when choosing to fast guess. These responses are then assigned a 0 or 1 value with equal likelihood before being passed to the second member. The investigation of how bias in guessing affects the organization's operation is of interest. A companion paper in this volume [3] discusses such effects.

Thus the model of the first member's behavior at his task is as follows. Let  $\bar{k}$  designate a conditional distribution on outputs, given a particular input. The overall input/output conditional distribution for the first member,  $\bar{k}_1$ , is determined as a combination of the conditional distributions corresponding to the individual options:

$$\bar{k}_1 = (1 - q_1) \bar{k}_{SCR} + q_1 \bar{k}_{FG} \quad (3)$$

In eq.(3),  $q_1$  is the fraction of fast guessing.

summarized by the conditional distribution  $\bar{k}_2$ :

$$\bar{k}_2: \text{ if } u = j \text{ and } \begin{cases} y_2 \geq t_{2j} \\ y_2 < t_{2j} \end{cases} \begin{cases} v = 1 \text{ wp } 1 - q_2 \\ v = 0 \text{ wp } q_2 \\ v = 1 \text{ wp } q_2 \\ v = 0 \text{ wp } 1 - q_2 \end{cases} \quad j = 0, 1 \quad (7)$$

Eq.(7) implicitly assumes that the member exhibits no bias in his errors and also that changes in  $t_{2j}$  do not affect  $q_2$ . For the range of operating regions considered here, both of these assumptions are valid to first order. Note that even though  $t_{2j}$  values do not enter directly into accuracy considerations, it is not necessarily desirable to leave them at their respective decision rule values, since the effects of switching may make it advantageous to adjust  $t_{20}$  and  $t_{21}$  to relieve both members' workload, to the benefit of the overall organization.

### Phase III - Integration

The elements of the organization design, which are its basic structure and the decision rule implementations, have now been established. To integrate the elements, the models of actual input/output behavior realized by organization members are substituted into the analytic organization structure for the decision rules and the structure itself is augmented with constraints derived from workload considerations. In the structure that results, there are five variables that have not been specified: the thresholds  $t_1$ ,  $t_{20}$ ,  $t_{21}$ ; the guessing fraction  $q_1$ ; and the actual deadline assigned to the second member  $t_d$ . To complete the process of integration and thereby obtain a nominal organization design, these variables are to be placed in order to optimize organization performance, but also in view of workload limitations of individual members. Specifically, the problem to be solved is stated as

#### Nominal Design - Constrained Organization (CNO)

min (organization detection error)

over: thresholds  $t_1$ ,  $t_{20}$ ,  $t_{21}$   
fast guess fraction  $q_1$   
second member deadline  $t_d$

subject to:  $T_{p1} \leq \tau_1$   
 $t_d \leq \tau_2$

Suppose that  $\tau_0 = 260$  ms and  $\tau_d = 500$ . Then  $\tau_1 = 260$  ms and  $\tau_2 = 240$  ms. These constraints are shown in Figure 9 on the respective models of organization members. In addition, a key linkage of the members is shown, which is the amount of switching that the first member's operation imposes on the second member. For the first member, the rate constraint is such that some fast guessing will be required, except where  $t_1$  is placed at its smallest possible value. The value of  $q_1$  is proportional to the distance between the average SCR time and the  $\tau_1 = 260$  constraint. As an example, if  $t_1 = t_1^*$ ,  $q_1 \approx 0.45$ . Placement of  $t_1$  not only establishes  $q_1$ , but it also determines the distribution on  $u$  and consequently the frequency of threshold switching by the second member. At its minimum and maximum values,  $t_1$  induces 5% and 95% use, respectively, of the horizontally displayed threshold  $t_{20}$ . Thus operation on a particular speed/accuracy locus by the second member is dictated according to the value of  $t_1$ .

In solving Problem CNO for the present design situation, it is straightforward to show that  $t_d = \tau_2 = 240$  ms, i.e. the second member should always use the entire amount of time allowed to him [3]. This means

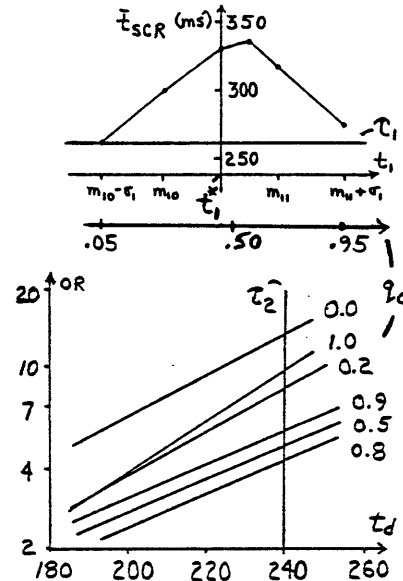


Figure 9 Illustration of Problem CNO

that the operating point of the second member will be somewhere on the vertical  $\tau_2 = 240$  ms line in the speed/accuracy model. In completing the solution, a basic tradeoff must be made. At one extreme is the option to retain the first member's ideal threshold  $t_1^*$ , which gives "high quality" indications, but cannot be used all the time. If this is done, the second member uses his thresholds with nearly equal frequency. This places operation at a reduced level of input/output accuracy. At the other extreme is the option to place  $t_1$  at its minimum value so that no fast guessing is required, but also so that all SCR responses are of lower quality. This in turn places the second member at a higher input/output accuracy operating level. Of course, there exist many other solution possibilities that are compromises between the two extremes.

The solution to Problem CNO for the values assumed in this situation, places  $t_1$  at its minimum value in order to improve the input/output accuracy of the second member. Though not indicated explicitly in Figure 9, placing  $t_1$  away from  $t_1^*$  also means that  $t_{2j} \neq t_{2j}^*$  in the solution to Problem CNO, since overall organization performance can benefit by adjusting the second member's thresholds to compensate in part for the loss of processing quality by the first member. One interpretation for the solution outcome is based on the fact that the second member has the "last word" on the detection decision. For the benefit of the organization, it is better to have this decision be associated to the second member's observation as much as possible rather than be directly opposed to it. It is worth compromising the quality of the first member's indication to do this. Such a tradeoff is not always the outcome of Problem CNO. [3] investigates the solution characteristics of an idealized version of the problem considered here, and documents that a number of qualitatively different solutions are possible.

A final consideration in Phase III is whether the nominal design obtained satisfies original design goals. For the current design problem, one criterion for evaluation is whether the detection error probability realized,  $J_0$ , is less than that which was specified,  $\bar{J}_0$ . Another criterion might be whether the performance level would be maintained if the a priori likelihood of H were to change during organization operation. It is not apparent to either member what the underlying likelihood of H is. Thus little adjustment can be expected from organization members should  $p(H)$  change. It may

therefore be desirable to take this into account when specifying the organization design. Assuming that the present design is satisfactory with respect to such evaluation criteria, the design process terminates.

#### IV. TEST OF ORGANIZATION OPERATION

There are several characteristics of the design obtained in the previous section that suggest hypotheses about organization operation. First, if  $t_1$  is set to its minimum value as per the design, there should be little fast guessing observed as the first member executes his task. Furthermore, there is a predicted percentage of switching that is part of the design and consequently a predicted level of input/output processing accuracy by the second member. Both of these hypotheses represent operation of organization members in regions that were previously examined when the descriptive models of their behavior were developed. Thus the predictions made are really tests of the validity of individual models.

A more interesting hypothesis about organization operation is the level of performance that will be realized. This is because the overall detection error of the organization cannot be inferred by individual members, but rather is a quantity that characterizes the organization. Furthermore, the design approach uses organization performance as the criterion for placing individual member parameters, and in effect discriminates in favor of one design solution over another based on predicted performance levels. Thus the extent to which actual performance of the organization matches that predicted represents a key test for the viability of the design approach.

For the organization under consideration, ideal behavior, which is determined in Phase I, yields a detection error probability of 0.06. Suppose now that the normative thresholds are left in place and that the organization is operated as it has been implemented. That is,  $t_{1j} = t_{1j}^*$  and  $t_{2j} = t_{2j}^*$ . However, because individual members are constrained fast guessing is required by the first member and a lower accuracy is induced in the second member. The predicted organization performance for this operating condition, designated as condition "B", is 0.21. The solution to Problem CNO, however, predicts a performance level of 0.15. This condition is designated as "A".

Given these predictions about performance, the organization was operated at the nominal design point (A) and also with the thresholds set at their ideal values (B). Two tests were made at each operating point; observed performances for the organization are shown in Table 2, along with the predicted values. A

Table 2 Performance of Organization

	Ideal (Phase I)	Nominal Design (A)	Normative Thresholds/ Constrained Members (B)
Predicted	0.06	0.15	0.21
Test 1	-	0.15	0.20
Test 2	-	0.14	0.20

reasonable agreement is apparent.

The levels of fast guessing and input/output accuracy predicted for individual members were also observed in the actual operation of the organization. In particular, no fast guessing was required in Condition A, and about 47% of the responses were fast guesses when operating under condition B. Input/output accuracy for Condition A was observed to be such that  $q_2$

was about 0.06. For Condition B  $q_2$  was near 0.16.

These results suggest two conclusions. First, failure to take human limitations into account can result in performance that is substantially different from that which assumes ideal human behavior. Second, there is considerable advantage to adjusting organization parameters in the situation where members are subject to workload limitations. Finally, the experimental results and conclusions presented here do not represent isolated behavior. [6] contains similar results using different individuals as organization members within the same basic organization structure.

#### V. SUMMARY

This paper has suggested an approach for the design of human information processing organizations for the situation where organization members perform routine tasks under the pressure of time. A main focus has been how and at what point in the design process to include consideration of human characteristics and limitations. A three-phase approach has been given for structuring the problem so that a balance is obtained between the complexities of considering how human behavior impacts every aspect of the organization and the hazards of neglecting consideration of human limitations in order to simplify the problem.

One of the advantages of the approach is that separation into normative and descriptive phases simplifies the design problem without greatly limiting design options. By deriving job descriptions for individual members in Phase I, a focus is provided for the execution of Phase II. A second advantage of the approach is that tradeoffs between member workload and organization performance are made apparent in the integration phase.

The design approach has been illustrated concretely by executing it on a specific design problem. The resulting organization design has been tested and found to operate as predicted. This demonstration is particularly supportive of the integrative design phase, since this phase represents a novel feature of the design approach. That there is agreement between observed and predicted operating characteristics is evidence that the approach is a valid one for organization design.

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