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Problem Solving and Decisionmaking: An Integration

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SUMMARY

In this paper an attempt is made to redress a critical fault of decisionmaking and problem-solving research. That fault is a lack of a standard method to classify problem or decision states or conditions. A basic model is identified and expanded to indicate a possible taxonomy of conditions which may be used in reviewing previous research or for systematically pursuing new research designs. A generalization of the basic conditions was made to indicate that the conditions are essentially the same for both concepts, problem solving and decisionmaking.

INTRODUCTION

Problem solving and decisionmaking are two areas of behavior that have always intrigued behavioral scientists and the general public. The association of these two processes with thinking and of thinking with the unknown activity within man, accents and intensifies the intrigue. In reviewing an extensive body of literature in both these areas two phenomena are noticed. First, there appears to be a relationship between the two, and second, there is not a great deal of clarity about the boundaries of either. The ease with which a problem-solving task becomes one of decisionmaking and a decisionmaking task becomes a problem-solving task can be seen repeatedly in the literature. It would not be difficult to select a research study from both areas and find upon comparison that the major dimensions of each study are similar. Although different words may be used, the type of condition that is required for a decisionmaking study or a problem-solving study is basically the same.

Although the general condition is the same, there appears to be a considerable amount of variation in the conditions addressed. Therefore, a criticism that must be leveled at both areas of research is that there is no standard definition for the condition studied. It would appear propitious at this time to make more definitive statements about the condition to be studied. If in fact the condition for each type of research is a general one, some statement should be made; if the condition is not general, then a statement should be made for each. The purpose of this paper is to develop a general condition model that is applicable to both areas and expand that model to allow for a taxonomy of conditions. Perhaps the present situation is a function of historical antecedents.

Historically, the literature that covers these areas is generated about two major approaches: (1) the initial studies on thought by the earliest behavioral scientist who adopted a problem-solving design to study animal and man initiating a vast quantity of information on problem solving, and (2) the concern for improved production through better decisions emphasized in the work of scientist in management and administration which focused on decisionmaking. The two approaches which initially addressed rather narrow aspects of a special area have expanded to the degree that a commonality across the areas has been established. Problem-solving research has broadened from simple trial and error problems into complex situation problems such as the prisioner's dilemma. While decisionmaking research jumped from single decisionmaking tasks to major multidecision interactive situations that may be encountered in an executive meeting. Which comes first — decisionmaking or problem solving? Although some discussion is encountered on this topic, it is not a relevant question. Larson (1962), for example, indicates that a problem condition precedes a decision and maintains that the critical aspect of decisionmaking is defining the problem. The relationship between the two is what is important. The major problem of any review of these areas is the varied scope and type of material presented. The key issue is what condition is necessary for a decisionmaking or problem-solving task. Much of the confusion over controversial results springs from the inability to establish a standard definition of problem solving or decisionmaking. This inability is anchored in how the situation or condition is defined. The condition, which must exist before a decisionmaking or problem-solving study is completed, seldom is discussed directly in detail. What is elaborated to an adequate degree is the operational task to be accomplished, that is, series of analogies and selection of a new director. Clarification of the underlying condition of the task is avoided. The basic conditions of the operational task must be delineated if systematic research is to exist. An evaluation of the operational task in each type of study may provide some insight into the situation.

This report represents the work accomplished by the AFHRL Technology Office located at NASA Ames Research Center. The effort was accomplished in support of a NASA Project in the area of Resource Management. The material presented was developed by the AFHRL Tech Office and provided to the Man Vehicle Systems Research Division of the Life Sciences Directorate as a possible source of planning for the later stages of their project.

PROBLEM SOLVING

In a problem-solving task the subject is placed into a task situation, provided some basic material, information or equipment, and expected to solve a "problem." The determination of whether a solution has been reached is signaled by making a final or end response. A final response is the one the scientist has established as correct and the one he is waiting for. An end response is a response that the subject in some way indicates is the last to be given in this situation. If the end response is acceptable to the scientist, the problem is solved; if it is not acceptable, the subject is sent back for more activity or told that the response was wrong. In the first case, the problem situation is still there; in the second, the subject is finished with that problem. Frequently, problem-solving situations have only one acceptable solution. Historically the research has been dominated by the single-solution problem. It has only been in the past 15 years that more complex multisolution problems have been emphasized.

DECISIONMAKING

In the decisionmaking task the subject is placed into a task situation, provided some basic material, information, or equipment, and expected to reach a decision. The decision is generally measured by the arrival at an end response. The acceptable end response is a choice of action. The choice may be "correct" or "incorrect" depending on the research design, but more frequently it is not considered in those terms. The process by which the subject arrives at the end response is the critical concern. Decisionmaking tasks initially were viewed as choices that required clarification. Once clarified the choice was obvious. The trend toward concern with major decision situations still has this flavor but introduces a complexity that precludes such a simplistic notion.

COMPARISON OF PROBLEM SOLVING AND DECISIONMAKING

As has been indicated, there is a degree of similarity between the two basic tasks as studies in most controlled research. The problem-solving studies which began with animals have escalated into areas of group problem solving and problem solving under uncertainty. The decisionmaking research studies have always dealt at complex decision levels and are dominated by how-to-do-it methods. Although both areas of research are seeking to study the process, most studies shed little light on this aspect of the situation. In spite of the emphasis on the process, there has not been a great deal of analysis of the process. In problem-solving research, the process is discussed after the data have been collected; in decisionmaking research the process typically is identified in some form prior to task completion. Problem-solving research has generated far more empirical studies than decisionmaking research. Problem-solving strategies and decision strategies have been repeatedly established to train someone to make the correct response under specific situations, but there is little or no evaluation of the techniques. There are no competing techniques or studies to compare technique A with technique B. Neither area has been clarified to a level of sophistication that allows for the hypothesis of alternative theories. One reason for this is the lack of specificity of what is a problem-solving or a decisionmaking condition.

BASIC CONDITION

There are some commonalities between the problem-solving and decisionmaking tasks. In both types of research the subject must identify and select a method of attack. In the problem-solving task, the method must be applied to obtain the solution. In decisionmaking, the method is only identified with the application implied. In either case, a method must be identified to move from the problem or decision state to a choice or solution that terminates the decision or problem condition. In problem solving, the application usually has rapid feedback of results; in decisionmaking the quality of the decision may never be assessed.

In order to effectively grasp the effect of previous research in the areas of decisionmaking and problem solving, some order must be established in terms of the operational conditions that are applied. The diversity of conditions used as operational measures of problems or decision points range across those concerned with when to build a new plant or how a monkey can secure a banana. A major difficulty is the lack of standardization of conditions used in research studies. In addition, the requirement for the research may be so specific that a unique set of conditions is developed for each study. Therefore, it is appropriate to begin with a definition and basic model of the condition that might describe a problem or decision task. Drawing on other research (Reitman, 1965) a decision-problem condition is said to exist when "A condition or state exists and another condition or state is desired." The method of attaining the new state will be called a transition. The basic model of a decision-problem condition is shown in figure 1. The initial state is indicated by A and the final or end state is indicated by B.

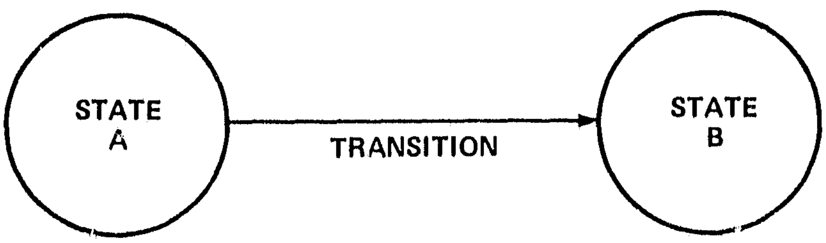

Figure 1.— Basic decision-problem condition.

The basic model of the decision-problem condition would apply to a problem-solving situation as follows. In the problem situation, the initial state may be the given information, or some subset of the information provided. For example, given the problem, "If Betty has 2 apples, 6 oranges, and 5 bananas, and Roger has 3 apples, 3 oranges, and 5 bananas, how many bananas do they have together?" all the information for state A is provided and state B is indicated. The only task is to make the transition from state A to state B. Assuming the transition is addition, then the model of the condition is as shown in figure 2.

What is the problem? To determine how many bananas the two have together. Five plus 5 equals 10. We can expect one of two responses from the subject: a correct response or an incorrect response. A correct response will lead to the assumption that the transition used was addition. An incorrect response does not indicate as much, addition may have been used incorrectly, or some other transition applied.

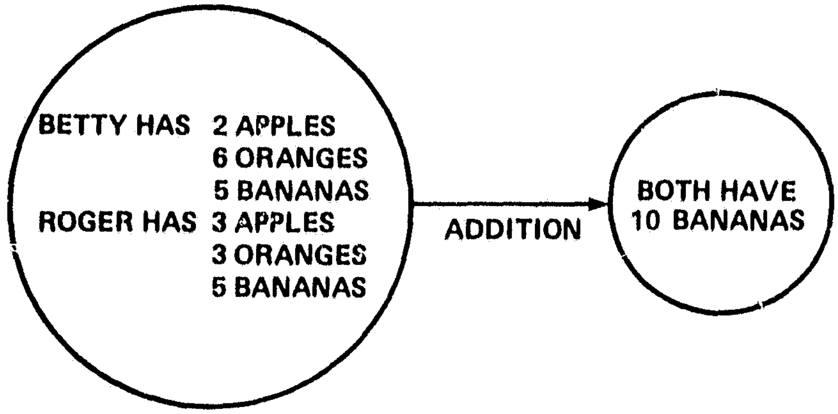

Figure 2.— Basic model applied to the problem.

By modifying this condition in terms of the information provided, we have a decisionmaking task. The subject is asked the following: "If Betty has 2 apples, 6 oranges, and 5 bananas and Roger has 3 apples, 3 oranges, and 5 bananas, do they both have 10 bananas?" In order to make this decision, the same process would be applied. The requirement to determine the number of bananas and then compare that to a final state of 10 is what makes this a decision task and not a problem-solving task. The decision task, in this case, is more complicated because not only is addition applied, but also a comparison is made; however, the condition still demands the initial state, end state, and transition. Again, there is a correct and incorrect answer. A "yes" answer implies that a valid decision process was applied and the transition was addition. A "no" answer does not tell us as much. In either case, we do not learn much about the process, but gain some information about the subject's capability of solving problems or making decisions. The basic decision-problem condition model applies to both cases.

The information provided that established the initial state and desired end state shows that the condition is the same for both types of research. A state exists, a transition is required, and an end state is indicated. It is interesting to note that in neither research condition do the subjects have an interest in the two fruit owners or in their bananas; however, they will obediently perform the prescribed task. In laboratory research the element of commitment is assumed and generally obtained; in field studies, commitment may be a variable of interest which must be manipulated (Janis and Mann, 1976).

EXPANDED MODEL

This simple model provides the basic aspects of both the problem-solving and decisionmaking conditions and represents the decision-problem condition. As can be seen from the literature, the types of conditions that are of most interest are far more complex than the two given in the example. To adequately model these types of conditions, the basic model must be expanded. If the three variables concerned are assumed to have two possible values, known and unknown, then the basic model will consist of eight possible variants. In the diagram of this property (fig. 3), a solid line indicates a

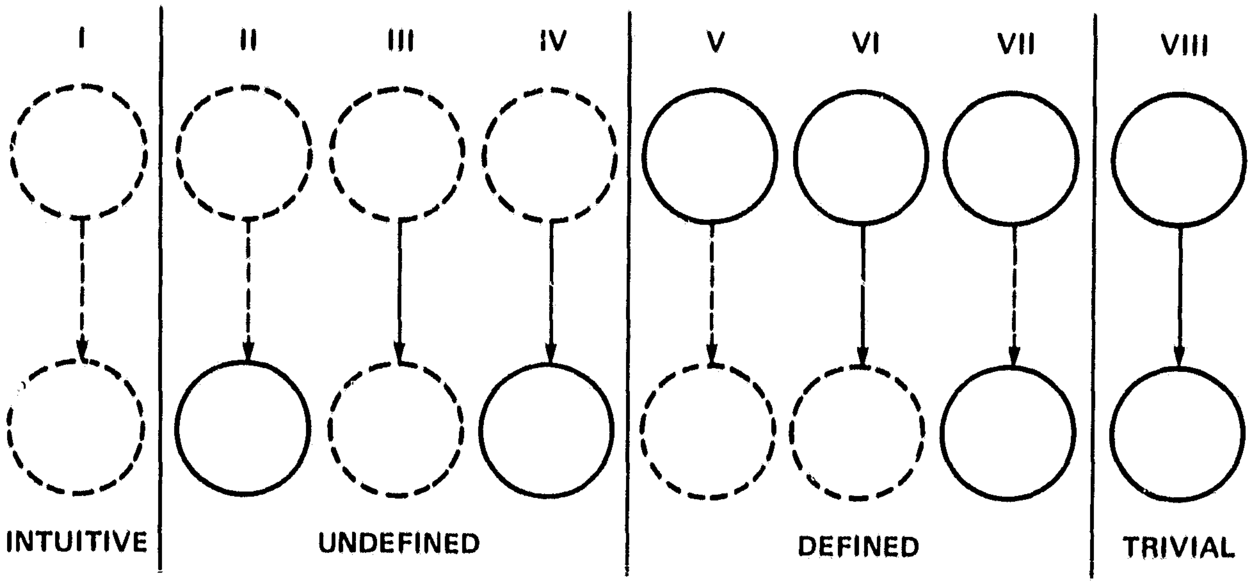

Figure 3.— Decision-problem condition models.

known variable and a dotted line an unknown variable. The eight variations are shown in figure 3. As can be seen, the models have been grouped into two sets of three models and the two extremes isolated. Model VIII represents a condition in which the initial state, transition, and end state are all known. In a problem task the transition would be made and success or failure would be dependent on the ability of applying the transition. In the decision task a choice would be made to apply the transition. Model VIII depicts the final map of a successful decision-solution selection. Once the subject reaches this point the solution or decision is established. The process that reduces the condition to the basic model is the critical factor. Therefore, model VIII is termed "trivial," indicating a model that once obtained is, in essence, the solution or decision. It is the state the problem solver or decisionmaker is attempting to achieve to accomplish the task.

Model I represents the opposite of model VIII in that no elements are known. This model is termed "intuitive" because it represents a nebulous condition of feeling or concern. This type of model is so undefined that it cannot represent a decision-problem condition in its initial form. It should be noted that most decision-problem conditions may begin as intuitive feelings; however, it is only when they are partially defined, so that at least one element is known, that they are considered decision-problem conditions. Another way of viewing the set of models would be as a dynamic set of stages within the decision-solution process. A decision-problem condition would emerge from model I, and as it is clarified and defined it evolves into a model with one, then two, then three known elements until it finally solidifies as a model VIII. The actual definition of the initial state, transition, and end state is usually the process of interest, especially in more complex decision-problem conditions. It must always be remembered that although these models may represent a reasonable approximation of how an individual can resolve the problem or make the decision after fully clarifying all three dimensions, a decision can be made or solution generated at any point. That means that one may, without any clarification, apply a transition and achieve the end state. This may be either a case of what people like to call "luck" or a result of a clarification process that was not indicated in the information gathering phase of the study.

The basic condition selected for a study largely defines the subtasks that must be completed to terminate the condition. The process of clarification from the condition provided to a decision or solution will not be considered in this paper. As can be seen in the models presented there are three possible subtasks, each involving the clarification of one of the model's dimensions. A condition that has two unknown dimensions may be more difficult than one with one unknown. In addition, the difficulty encountered may be dependent on which dimensions are unknown. For example, when the initial state is unknown the resolution may be more difficult than when the end state is unknown.

CORRECT DECISION SOLUTION

In either problem solving or decisionmaking, the implication of correctness may be a concern. In the traditional sense, a correct decision or solution may be established or predetermined. The more complex conditions of interest explore problems or decisions that do not necessarily have a correct response. There may exist a series of correct responses but they are seldom all inclusive. In the more realistic conditions drawn directly from actual operational situations the responses are only noted and not evaluated. This lack of evaluation also explains why few prescribed decision-problem solving methods are ever tested.

One must be aware of the "correctness phenomena," however. Whether a correct resolution exists or not, either in the research design or by definition, the subject will expect and seek out a correct resolution. This predisposition on the part of subjects is especially important if the research is concerned with creativity. Decision-problem conditions that have an absolute solution and those that do not would logically be treated as the same, but there may be some basis for each requiring a different clarification process or at least a variation of a basic clarification process. It has even been suggested that larger decision-problem conditions may require a special individual for each step of the process (Newman, 1963).

INITIAL STATE

Based on the initial state, the models were grouped into two sets: those in which state A is known, termed "defined," and those in which state A is unknown, termed "undefined." "Ill-defined" is a term used in the literature, but it is not necessarily associated with only undefined initial states. If we review the two sets of models we see that in the defined set the task to be accomplished is to discover or identify either or both of the unknown elements of the transition or end state. When this is accomplished a model VIII (fig. 3) is attained. In the case of defined decision-problem conditions we know where we are and that we must get somewhere else; how and where are to be determined. Model V is the more difficult case because two unknowns must be clarified and identified. Model VI is interesting in that it describes a condition of knowing the initial state and the transition, but not the end state. This condition lends itself to responses without further analysis. In other words, it allows for immediate action disregarding clarity of outcome. This model is frequently encountered in organizations that demand action. Model VII probably reflects what is generally conceived as a problem condition. We know the initial state and end state; what requires clarification is the transition or method. In the decision mode, it is selecting from a developed set; in the problem mode, it is selecting from a developed set and applying the method. Interestingly, using this basic type of condition the selected decision is not necessarily tested, while in the problem mode the solution is tested.

The set of models called "undefined" may also have either one or two unknowns; however, in all cases the initial state is unknown. This condition is usually the type meant when discussing ill-defined problems. Two models in this set have two unknowns, so they would be more difficult to resolve than model IV. Model IV is seldom if ever encountered in the literature. It is a condition that most subjects find acceptable. It only becomes a decision-problem condition when an evaluation is required in terms of progress. Model II is representative of a great many decision conditions. This is a case in which the end state is known, but the initial state and transition are not. All too frequently this condition is resolved by defining the transition so that a model IV is obtained and no further analysis is taken. Model III represents a condition that exists too often. The transition is constantly being applied but neither the initial nor end state is known and if it is continued, there exists an open action loop with no completion phase. Model III may represent the trial-by-error situation or a skill acquisition task in a training context. Most ill-defined decision-problem research stems from a model II or IV condition.

Of the eight models, only six would be used in a research design. Model VIII would represent the correct model, and the general task for the subject is to clarify the unknown dimension of the condition to produce a model VIII. As was indicated, it would be anticipated that the difficulty of the task would be affected by the number and type of unknown dimensions.

COMPLEX CONDITIONS

This set of models provides a basis for the analysis of more complex conditions, for once the conditions are clarified into a model VIII form, there is only action to be taken. The type of action is determined by the process that clarified the model. The models introduced so far are flexible enough to account for a large proportion of the types of conditions frequently encountered; however, there exist some decision-problem conditions that are not covered by these models. An even more complex class of conditions is generated if the concept of multiplicity is assumed. What if there existed a set of conditions that had multiple initial states, transitions, or end states? Since decision-problem conditions of this type do exist, the models must be able to address them. The possibility of multiple initial states will be included in the final model set but will not be discussed in detail. The reason for this is that the conditions represent not a decision-problem condition but a more complex decision-problem sequence analysis. One aspect of this type of condition is the selection of the condition to resolve or setting priorities or resolving all the conditions in the sequence. By introducing multiplicity, five classes of conditions, each with eight variations, are introduced. There are then 40 different variations of the basic model. Figure 4 shows the possible classes applied to model VIII.

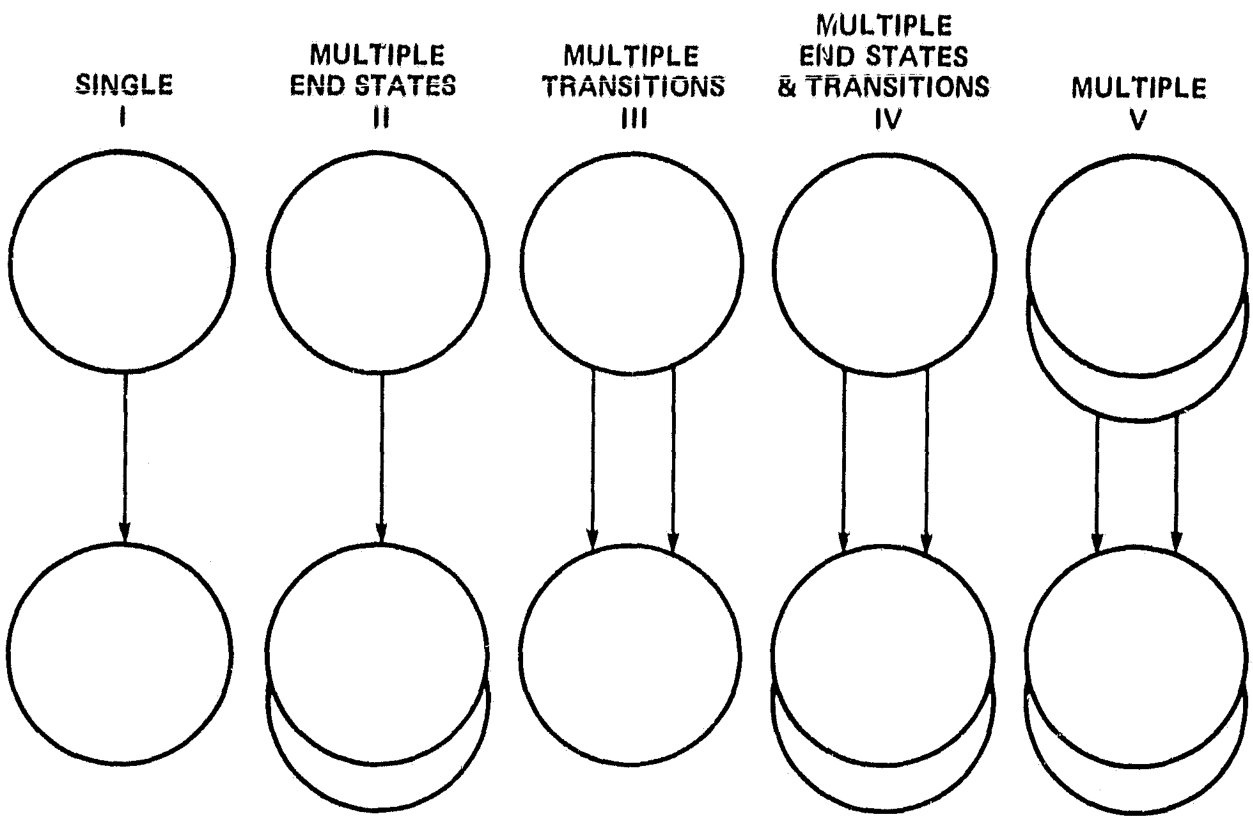

Figure 4.— Classes of conditions across model VIII.

The class variations are presented for model VIII for clarity. All five class variations of model VIII represent the final or end model that would be obtained after a decision-problem process had been completed. They are the culmination of the process in which all elements have been clarified. In class II models, the introduction of multiple end states may be a model of what is called "decision under uncertainty." This is because one transition may lead to two or more end states. It is conceivable that a situation might occur in which only one transition but several end states are identified without any way of knowing which will be attained. Presumably any of the end states would be acceptable.

In the class III set, the initial and end states are known, but there are two or more transitions that will attain the end state. In class IV, the complex condition occurs in which several transitions may result in several end states. (Note that each transition may end in each end state.) Finally, class V conditions occur in which two or more end states may result from two or more transitions starting with two or more initial states. These models are appropriate when the process of interest is that of multiple decision-problem analysis; this latter process is not within the scope of this paper.

In expanding the classes across 8 models, 40 possible models are generated. A complete set of the models is provided in figure 5. This set of models represents an extreme variety of decision-problem conditions by only assuming three dimensions with two possible characteristics. What has been provided is possible basic taxonomy or decision-problem conditions that are found and could be used in problem solving or decisionmaking research. The more simple problems used in animal and child studies are the class I models V-VII; the types of conditions used in studies of complex decision tasks are of the class IV model II-IV varieties.

The application of this taxonomy to the types of conditions used in past research may require a degree of content analysis, but allows for a method to review research that will contribute more substantial conclusions than if more liberal terminology is used to select and group the available research. In producing a decision-problem research design the use of this type of taxonomy allows for an improved operational definition and insures a more refined statement of the results. It is only through the adoption of this type of scheme that decision-problem conditions can be studied with some degree of control. Synthetic decision-problem conditions can be developed around these models so that the results from several studies can be compared with more confidence. Methods can be developed to allow for the training of the subject to transform the decision-problem condition into a model VIII type and therefore arrive at the decision-solution. The making of a decision-solution is a matter of choice or application when all aspects of the decision-problem condition are clarified. The clarification of the decision-problem condition is the important process. In problem solving and decisionmaking the task requirements are slightly different, but the conditions are the same and the clarification process may be the same. The reason for one condition being labeled "solved" and another "decided" is a function of the demand characteristic, not of the condition or of the clarification process.

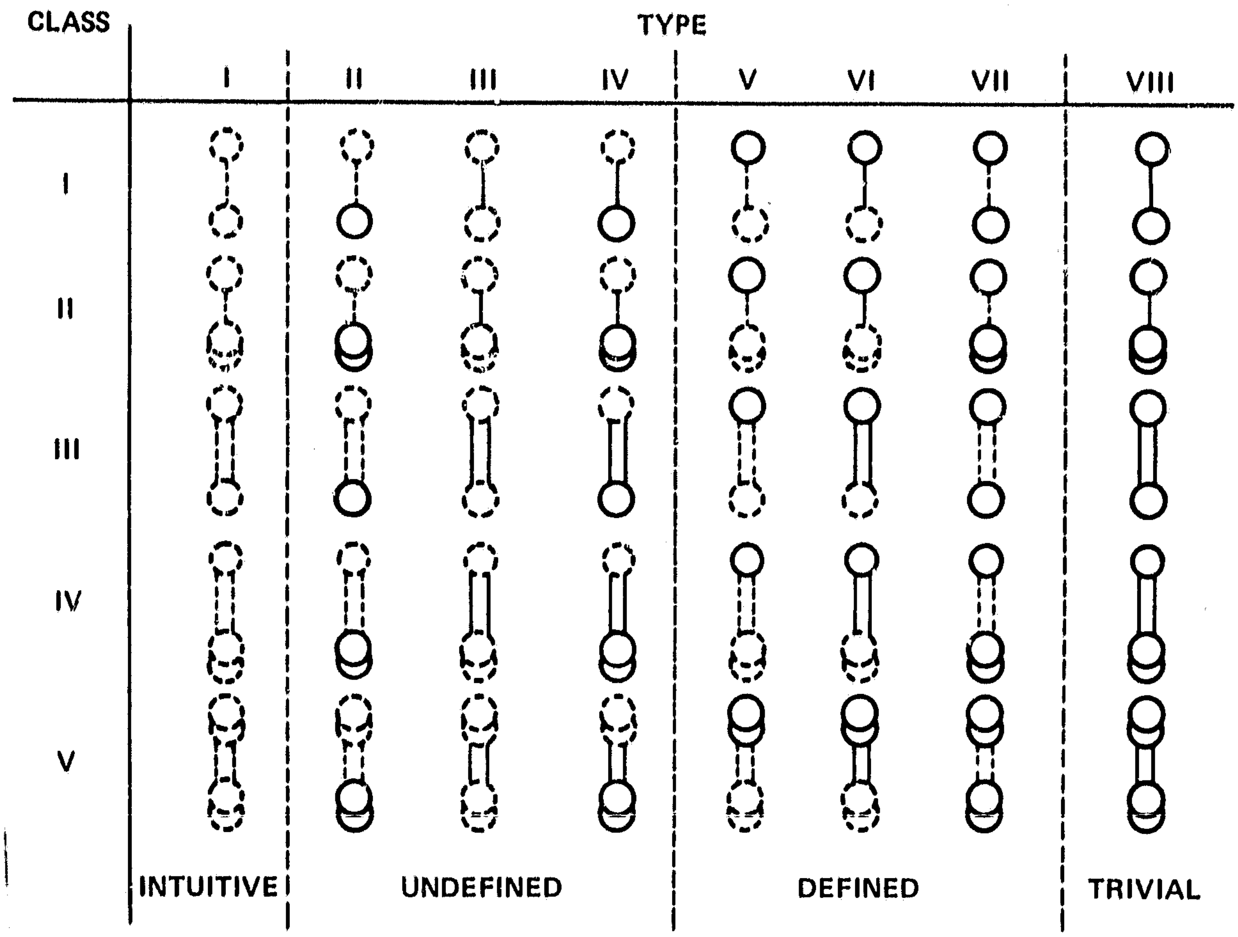

Figure 5.— Total decision-problem condition variations.

DECISION-PROBLEM PROCESS

Explanations of the decisionmaking processes and problem-solving processes are fairly abundant. They may be called techniques or methods, but if they are analyzed they have a fairly consistent set of properties. Because there exists no contrary evidence that would lead one to assume that these techniques are incorrect, a general model of the process is assumed. The model should be accepted and tested, not just applied. Alternative models, which may be more effective, should also be generated. The model will be called the clarifying-process model rather than decisionmaking or problem-solving model. Therefore, the implication is that the process necessary to solve a problem or make a decision is the same. The model consists of five stages: (1) identifying the situation, (2) determining options, (3) establishing outcomes, and (4) manipulating, evaluating, and analyzing information.

Identifying the situation is a clarification of the initial state. This consists of determining the initial state of either the problem or decision. In determining the choices, a clarification of the transition is made. For a problem condition, we evaluate the possible transitions; for a decision condition, the possible choices are evaluated. It should be noted that in either case some type of action is implied; this is necessary for computing the solution or implementing the choice. In establishing the outcomes, we are clarifying the end states. In order to clarify these three dimensions, information manipulation takes place. This consists of the reviewing and ordering of the available information and synthesis or evaluation strategies. It may also include the procurement of new information to be interpreted and integrated with the available information. Based on the information acquisition and evaluation, some selection rule or rules are established. The selection rule is a critical aspect of this process and reflects criteria used to weigh possible transitions and end states or, more formally, a mathematical model to be applied that will provide a resultant product. The selection rule may be complex or arbitrary, but in any event it is applied. Frequently, selection rule approximations are applied that reduce the set of transitions but still do not identify the optimum one. Once the selection rule is established the data are ordered and the rule applied identifying the solution or decision. Therefore, a decision is made or a solution established. After the choice is made there is associated a mode of action, a completion point and an expected outcome. The mode of action is the implementation of the selected transition and the completion point is attained when the transition is completed. The expected outcome is the end state.

In this type of research we generally make the mistake of ignoring the subject's capability. In decision-problem conditions in which high le[illegible]s of information are either provided or are available, the subjects capability to synthesize is of great importance. As the amount of information decreases, the subject's knowledge or information store becomes dominant; that is, the subject has only previous experience to draw upon to address the task. As the information decreases below a certain degree, only crude estimates may be made; therefore, the task may degenerate into that of risk taking or of making choices under risky conditions. In field studies this situation generally occurs due to time or external constraints; that is, the task must be completed by a specified time. The more complex the condition, the more variable the effect of individual differences on the results.

The entire process assumes complete information availability, a completely valid selection rule, and no external intervention or change through time. Each of these assumptions is normally violated once the clarification process is removed from the control of a laboratory study. There are three reasons for the unavailability of information: it may be nonexistent, there may be resource constraints, or it may be unknown. The resource constraint is most often time, but is can be manpower, technology, or funding. A valid selection rule means the selection of appropriate decision variables which are also information dependent. The quality of the information may therefore weaken the selection rule. External intervention may occur in many ways, but it represents an activity that was not considered in the clarification process.

MULTIDIMENSIONAL DECISION-PROBLEM ASPECTS

In most laboratory or field studies a set of experimental decision-problem conditions is presented and dealt with independently. Many research efforts are concerned with the requirements to handle a set of decisions-solutions during a total period of time or with working at a series of decision-problem conditions that are related. If this is the case, the introducing of a dimension of sequencing and the addition of a task of assigning priority to each decision-problem condition must be considered. This is especially true when some degree of stress is introduced into the study, forcing rapid responses over fixed time periods.

Another dimension that may be of importance is that of multiperson groups or teams. If a group of persons is involved, then the personal interaction may be important or the experience of each person may be critical. In addition, the dimension of responsibility would become important if the set of decision-problem conditions was to be allocated to different persons. This would also require an integration management system to complete the series. The level of complexity introduced by these dimensions approximates the environment of most field decision-problem studies. The models presented provide a foundation for these types of studies but the other variables or dimensions would have to be measured. If a systematic application of the conditions provided is to be successful, then the addition of more dimensions must be gradual. Although many studies have been completed that address a considerable number of additional dimensions, it is hard to equate the results to any pattern or direction. The adaptation of the basic set of models as these to be used brings to rear the advantage of standardized conditions which will allow for more rapid advancement in knowledge about the clarification process.

CONCLUSION

In this paper an attempt was made to redress a critical fault of decisionmaking and problem-solving research. That fault was a lack of decision-problem condition standardization. A basic model was identified and expanded upon to indicate a possible taxonomy of conditions that may be used in reviewing previous research or for systematically pursuing new research. A generalization of the basic conditions was made to indicate that the conditions are the same for both types of research. A general model of the process, referred to as a clarification process, was discussed; it may well be appropriate for both types of research. If this is the case, the results of both areas should be renewed to gain insight into this process. Future research should avoid the superficial issue of decisionmaking or problem solving and concentrate upon the process.

The problems of individual differences, multidecision-problem sets and multiperson teams were briefly discussed as an indication of the complexity of the task of accomplishing research in these areas. It will only be when we are prepared to be more rigorous in research designs that a better understanding of the decisionmaking and problem-solving process will be attained. The large body of information reflecting studies in these areas stands as a silent reminder of the importance of these areas. It is now time to address the areas of decisionmaking and problem solving with more determination and scientific acumen.

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