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AND PLANNING: A CRITICAL ANALYSIS

Barbara Hayes-Roth

November 1980

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The United States Air Force

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Situation assessment and planning rely heavily on the decisionmaker's ability to project future conditions in the environment and the impact of tentative planned actions on those conditions. This note presents a cognitive analysis of the future projection process. It identifies three projection strategies--retrieval from experience, formal analysis, and mental simulation--and characterizes their strengths and weaknesses. It also discusses the impact of three general cognitive factors--operation at different levels of abstraction, motivational factors, and attribution problems--on the future projection process. Based on this analysis, the note proposes a cognitive technology for developing and training effective future projection processes. 38 pp. Ref.

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# A RAND NOTE

## PROJECTING THE FUTURE FOR SITUATION ASSESSMENT AND PLANNING: A COGNITIVE ANALYSIS

Barbara Hayes-Roth

November 1980

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Prepared For

The United States Air Force

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PREFACE

This Note presents a cognitive analysis of the future projection processes involved in situation assessment and planning. Although these ideas were developed in the context of military analysis, they should interest persons concerned with generic situation assessment and planning problems as well. The research was conducted under the Project AIR FORCE study effort "Fundamental Research in Information Processing and Decisionmaking in Command and Control."

SUMMARY

This Note presents a cognitive analysis of the future projection processes involved in situation assessment and planning. We propose that situation assessment and planning entail five component functions: identifying causes for action, evaluating the consequences of action versus inaction, generating tentative plans, evaluating alternative plans, and executing a selected plan. Each of these component functions requires projection of future conditions. Identifying causes for action requires projection of future conditions in the environment based on past and present conditions and a model of the prevalent forces in the environment. Evaluating the consequences of action versus inaction requires projection of future conditions, conditional on the introduction of generic actions into the world model. Generating tentative plans requires projection of resource requirements and projection of effects and side effects for alternative actions. Evaluating tentative plans requires projection of potential interactions among planned actions, potential undesirable contingencies, and the overall outcomes of executing tentative plans. Executing a selected plan requires projection of the effects and side effects of executing subsequent planned actions, given the outcomes of previously executed actions.

Our analysis identified three cognitive strategies for future projection. Retrieval from experience entails using knowledge of similar past situations as indicators of likely outcomes for the situation at hand. Analysis of problem-specific information entails inferring likely future conditions from observable features of the situation. Mental



simulation entails working through actions under consideration and mentally "observing" outcomes. Each of these strategies has distinctive strengths and weaknesses, discussed in the Note.

We also identified three general cognitive characteristics that affect the future projection process: people's ability to operate at different levels of abstraction, the impact of motivational factors on future projection, and people's difficulty in attributing the outcomes of planned actions to particular future projection behaviors.

Within this general framework, the Note also examines alternative conceptions of expertise. Knowledge-based or experience-based conceptions of expertise are not likely to predict accurate future projection performance. Rather than attempting to identify existing experts based on these criteria, we should cultivate future projection experts in accordance with cognitive considerations such as those outlined above.

The final section suggests preliminary methods for improving the future projection process. To capitalize on cognitive strengths, we suggest developing a cognitive technology for future projection. The technology would define and operationalize generic future projection strategies, the circumstances under which each is appropriate, and the strengths and limitations of each strategy. In order to compensate for cognitive weaknesses, we suggest incorporating in the technology methods for relieving people of certain functions or for correcting systematic errors in their performance of those functions. Several such methods are outlined in the Note.

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## I. INTRODUCTION

Situation assessment and planning are primary activities of military analysts. Both tasks rely on the analyst's ability to project the future. In situation assessment, the analyst must recognize potential dangers and opportunities in the environment. In planning, the analyst must plan actions to circumvent or minimize imminent dangers and to exploit opportunities. This paper examines the cognitive processes used in future projection and their impact on situation assessment and planning.

The paper is organized as follows. Section II characterizes the several aspects of situation assessment and planning that rely upon future projection. Section III describes three cognitive strategies that people use for future projection and the advantages and disadvantages of each. Section IV describes more general properties of human cognition and their potential impact on future projection processes. Section V discusses the role of expertise in future projection. Section VI proposes some preliminary methods for improving future projection.

## II. FUTURE PROJECTION IN SITUATION ASSESSMENT AND PLANNING

Figure 1 illustrates the military analyst as situation assessor and planner. As Figure 1 shows, situation assessment and planning comprise five component functions. As a situation assessor, the analyst perceives, characterizes, and evaluates conditions in the environment. The analyst receives a variety of intelligence and sensor reports and interprets them in terms of a world model. The world model represents the analyst's understanding of the predominant forces in the environment, their likely behaviors and interactions, and the range and probabilities of possible consequences. Based on his or her interpretation of the sensor reports, the analyst (1) identifies particular causes for action and (2) evaluates the consequences of action versus inaction for each recommended cause. As a planner, the analyst determines an intended course of action. In response to the situation assessment, and again making use of the world model, the analyst (3) generates tentative configurations of planned actions and (4) evaluates their effectiveness. Based on this evaluation, the analyst selects a plan and (5) executes it, monitoring and guiding plan execution to a successful conclusion.

Each of the five component functions requires projection of future conditions. The remainder of this section characterizes the type of future projection required for each function and its impact on the overall situation assessment and planning process.

### SITUATION ASSESSMENT

Identifying causes for action. In the simplest circumstances, the analyst considers a static situation and identifies a cause for

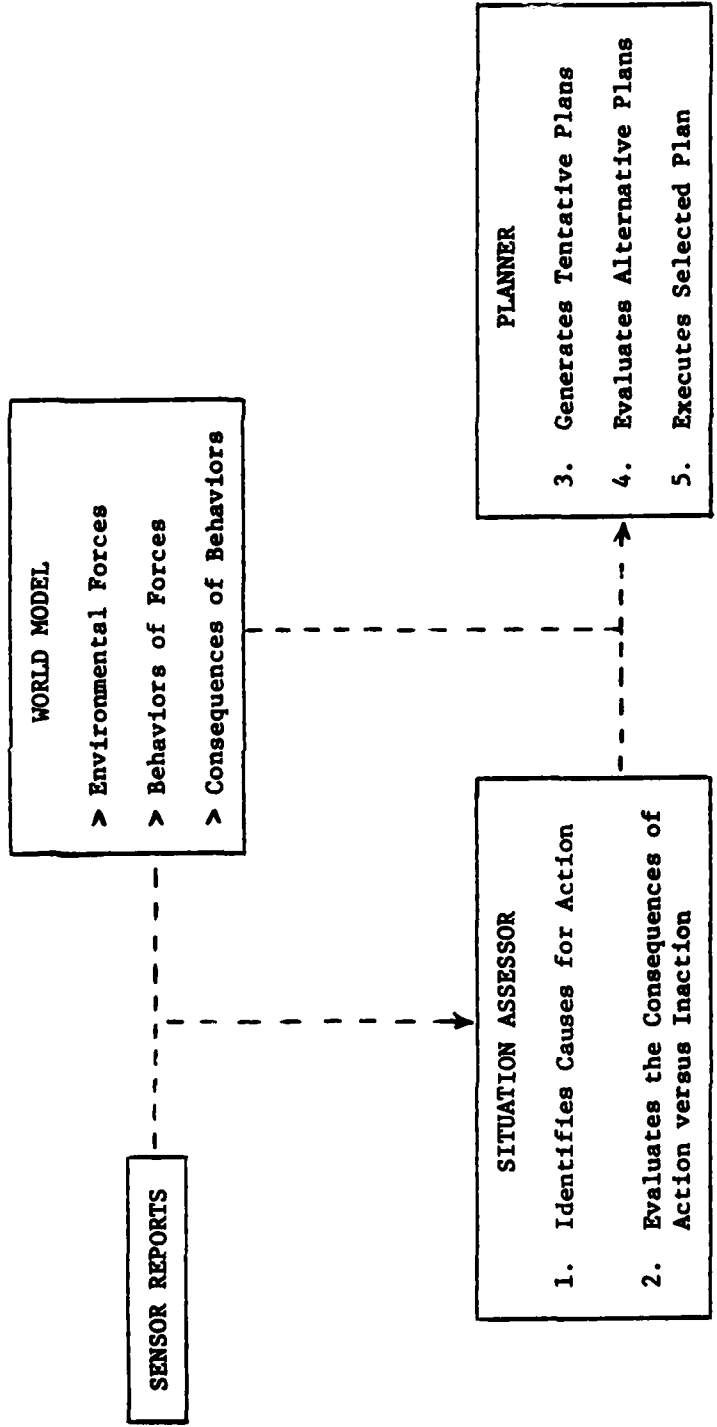


Figure 1. The Military Analyst as Situation Assessor and Planner

peremptory action. This requires no projection of future conditions; the analyst can simply assess potential dangers or opportunities among present conditions and identify causes for action.

However, the analyst more frequently copes with a dynamic situation and identifies a series of causes for action over time. In this case, the analyst must consider potential dangers and opportunities among future, as well as current, conditions. While past conditions are recorded and some present conditions are observable, the analyst cannot readily foresee future conditions. Therefore, he or she must use the world model to extrapolate from past and present conditions to project relevant future conditions. Thus, one type of future projection required of military analysts is:

Projection Type 1.

Given (a) past and present conditions in the environment  
and (b) a world model  
Project future conditions in the environment

Example 1.

Given (a) that country A has recently massed land forces  
on its border with country B  
and (b) a model of country A's expansionist policies  
Project that country A will invade country B

This type of future projection defines the space of potential causes for action. From among these projected futures, the analyst must identify imminent dangers and available opportunities. Errors could lead to failure to identify important causes for action or to identification of inappropriate causes for action. These types of errors would ramify throughout the situation assessment and planning processes.

Evaluating the consequences of action versus inaction. In addition to identifying causes for action, the analyst evaluates the consequences of action versus inaction for each cause. This evaluation provides one basis for allocating resources among identified causes during planning.

Consequences are hypothetical future conditions expected to occur as a consequence of action versus inaction. Again, because the analyst has no objective indicator of potential consequences, he or she must use the world model to project them. In the case of inaction, the analyst can extrapolate from past and present conditions to future conditions, as described above. In the case of action, the analyst must introduce generic actions into the world model and infer consequences. Thus, a second type of future projection required of military analysts is:

Projection Type 2.

Given (a) past and present conditions in the environment  
and (b) a world model  
and (c) a cause for action  
and (d) that some generic action is taken for the cause  
Project future conditions in the environment.

Example 2.

Given (a) that country A has meager military resources  
and (b) a model of country A's disinclination to  
engage in unsuccessful confrontations  
and (c) the imminent invasion of country B by country A  
and (d) intervention on behalf of country B  
Project that country A may not invade country B

This type of future projection provides a valuable input to the planning process and influences the selection of goals from among the identified causes for action. Errors in projecting and characterizing the consequences of action versus inaction could produce plans with



suboptimal or inappropriate goals. They could also result in a failure to plan for critical goals.

### PLANNING

Generating a configuration of intended actions. In generating a configuration of intended actions, the analyst must consider alternative causes for action and alternative actions for individual causes. In each case, the analyst must project costs and benefits for individual actions planned to occur at future times. This judgment must take into account potentially changing environmental conditions. One type of cost associated with individual actions is resource requirements. Thus a third type of future projection required of military analysts is:

#### Projection Type 3.

Given (a) a cause for action  
and (b) an action a to be performed at time t  
and (c) past and present conditions in the environment  
and (d) a world model  
Project the resources that will be consumed by performing  
action a

#### Example 3.

Given (a) the imminent invasion of country B by country A  
and (b) the immediate provision of auxiliary troops to  
country B  
and (c) that country A has meager military resources  
and (d) a model of country A's disinclination to  
recruit foreign troops  
Project that N auxiliary troops will be necessary

Two general types of errors can occur in this type of future projection: underestimation and overestimation of required resources. Underestimation of required resources would produce an unrealistic plan, one that aimed to serve too many causes or too ambitious a cause, given

the available resources. Such a plan might, at best, usurp unplanned resources and, at worst, fail to execute successfully. Overestimation of required resources would produce an unnecessarily conservative plan, one that aimed to serve too few causes or too modest a cause, given the available resources. Such a plan would execute successfully but would achieve less than a more realistic plan.

The specific effects and side effects of individual actions could entail both costs and benefits. These projections must also take into account potentially changing future conditions. Thus a fourth type of future projection is:

Projection Type 4.

Given (a) a cause for action  
and (b) an action a to be performed at time t  
and (c) past and present conditions in the environment  
and (d) a world model  
Project the effects and side effects of the action

Example 4.

Given (a) the imminent invasion of country B by country A  
and (b) the immediate provision of N auxiliary forces to country A  
and (c) that country B has meager military resources  
and (d) a model of country B's reluctance to engage in unsuccessful confrontations  
and (e) country C's growing antagonism toward us  
Project that country A will not invade country B  
and that country C will criticize the intervention

This type of future projection impacts strongly on the plan's efficacy. Errors in projecting the effects of individual actions could produce a plan that fails to achieve its goals. Errors in projecting side effects could produce a plan that entails counterproductive or undesirable side effects.

Evaluating a tentative plan. Even a plan constructed from individually sound components can entail undesirable outcomes. Therefore, the planner must evaluate each alternative plan he or she generates in its complete form. The planner must project potential interactions among independently planned actions, environmental contingencies that could interfere with planned actions or alter their effects, and the overall outcomes of the plan. Again, because actions may be planned to occur at arbitrary future times, these judgments must take into account potentially changing environmental conditions. Thus, three additional types of future projection required of military analysts are:

Projection Type 5.

Given (a) a planned course of action  
and (b) past and present conditions in the environment  
and (c) a world model  
Project potential interactions among planned actions.

Example 5.

Given (a) a plan to provide country B N auxiliary troops immediately and to withdraw them in 30 days  
and (b) country A's meager military resources  
and (c) a model of country A's expansionist policies and disinclination to engage in unsuccessful confrontations  
Project that country A may simply postpone the invasion

Projection Type 6.

Given (a) a planned course of action  
and (b) past and present conditions in the environment  
and (c) a world model  
Project potential undesirable contingencies

Example 6.

Given (a) a plan to provide country B N auxiliary troops immediately and to withdraw them in 30 days  
and (b) country A's meager military resources  
and (c) a model of country A's disinclination to recruit foreign troops  
Project that country A might recruit foreign troops and outnumber the total forces defending country B

Projection Type 7.

Given (a) a planned course of action  
and (b) past and present conditions in the environment  
and (c) a world model  
Project the overall outcomes of executing the plan

Example 7.

Given (a) a plan to provide country B N auxiliary troops immediately and to withdraw them at time t  
and (b) country A's meager military resources  
and (c) a model of country A's expansionist policies and disinclination to engage in unsuccessful confrontations.  
Project that country A will not invade country B as long as auxiliary troops are present

Each of these three types of future projection is critical to effective plan evaluation. Projection of interactions among planned actions evaluates the plan's efficacy. Errors can result in positive evaluations of plans whose component actions work against one another or whose interactions produce undesirable side effects. Projection of undesirable contingencies evaluates the plan's robustness. Errors can result in high evaluations of plans that work well only under special circumstances. Projection of the overall outcomes of plan execution evaluates the general productivity and cost of tentative plans. Errors can lead to acceptance of low-quality plans or to preferences for sub-optimal plans.

Executing planned actions. As the saying goes: The best laid schemes of mice and men often go awry.[1] Therefore, once the analyst has selected a plan, he or she must control plan execution, guiding it to a successful conclusion. The analyst must monitor executed actions, comparing their effects to intended plan outcomes and detecting side effects. Whenever necessary, the analyst modifies planned actions to insure satisfaction of the original goals. Depending upon the situation, the analyst may also perform some dynamic replanning, responding to dangers and opportunities encountered during plan execution.

Because plan execution is a dynamic process occurring in real time, the analyst cannot restrict his or her attention to static events developing along the way. The analyst can not respond to static events quickly enough to be effective. Instead, the analyst must project planned actions and their consequences somewhat ahead of real time. That way the analyst can be prepared to respond quickly to important events as they arise. Thus, another type of future projection required of military analysts is:

Projection Type 8.

Given (a) an intended plan of action  
and (b) past and present conditions in the environment  
and (c) a world model  
and (d) the effects and side effects of previously executed actions  
Project the effects and side effects of executing subsequent planned actions

---

[1] In Robert Burns' original Scottish: "The best laid schemes o' mice an' men gang aft a-gley." To a Mouse (1786).

Example 8.

Given (a) a plan to provide country B N auxiliary troops immediately and to withdraw them 30 days later  
and (b) country A's previous massing of land forces on the border of country B  
and (c) a model of country A's expansionist policies  
and (d) country A's withdrawal of forces to points within close range of country B's border  
Project that removal of auxiliary forces will lead to renewed aggression by country A

Errors in execution-time projections can limit a plan's achievement of the original goals or permit unprojected side effects to occur unchecked.

The eight types of future projection outlined above illustrate the pervasiveness of projection problems throughout the situation assessment and planning process. The quality of military analysis relies critically upon the quality of accumulated future projections. This dependency points to a need to better understand the cognitive processes analysts use in future projection. What projection strategies do analysts use? What are the advantages and disadvantages of alternative strategies? What other cognitive factors influence future projection? What makes an analyst an expert future projector? How can we assist or improve upon future projection? The remainder of this paper addresses these questions.

### III. COGNITIVE STRATEGIES FOR FUTURE PROJECTION

Despite differences among the several types of future projection discussed above, they are amenable to similar cognitive strategies. This section characterizes three strategies, each of which can be applied to all eight types of future projection, and outlines the strengths and weaknesses of each strategy.

#### RETRIEVAL FROM PAST EXPERIENCE

In some circumstances, an analyst may have past experiences that are similar to the problem at hand. In that case, he or she may rely on those experiences as indicators of likely outcomes in the present circumstances. For example, the analyst may be trying to project country A's intended behavior following its massing of troops on the border of country B. The analyst could infer likely behaviors by analogy to past situations in which country A or similar countries engaged in similar military exercises under similar circumstances.

The major strengths of the experiential strategy are ease of application and intuitive appeal. It requires no research or computation. The analyst can simply reflect on the features of similar past experiences and infer corresponding features for the present problem. This kind of process generally has enormous intuitive appeal, particularly for the analyst. People tend to be quite confident in judgments based on their own experience (Ryback, 1967). This makes sense, given that the experiential strategy underlies almost all of human learning. However, confidence in the experiential strategy can itself become problematic, as discussed in Section V below.

The experiential strategy has several potential weaknesses. Foremost among them is the possibility that the analyst's experiences do not bear at all upon the problem at hand. Presumably, the world is an orderly system. The more features two events share in common, the more likely they are to share additional unobserved features. However, an analyst's past experiences will rarely share the preponderance of their features with the problem at hand. Typically, the analyst's experiences will share a small, unknown proportion of their features with the problem. In such cases, it is largely conjectural that unobserved features in the problem can accurately be inferred from corresponding features in the experiences.

A second potential weakness is that the validity of inferences relies upon the analyst's ability to retrieve relevant past experiences and to discriminate those that bear directly on the present problem from those that are merely similar. A substantial body of recent research has investigated the internal representation of conceptually related knowledge and the retrieval of such knowledge for interpreting new events (e.g., Franks & Bransford, 1971; Hayes-Roth & Hayes-Roth, 1977; Hayes-Roth, 1974, 1976; Minsky, 1975; Oldfield, 1965; Posner, 1969; Schank & Abelson, 1977). Despite differences in theoretical approach, these analyses agree that retrieving relevant past experiences and discriminating them from similar experiences are complex psychological processes.

Human retrieval mechanisms are heuristic in nature. They do not automatically retrieve prespecified chunks of knowledge. They retrieve associatively related chunks of knowledge. Whether or not a particular



experience is retrieved depends upon a number of factors, including the current retrieval cue (e.g., foreign occupations of small, under-developed countries), the relative salience of related experiences, and the relative recency and frequency of prior retrieval of those experiences. The set of retrieved experiences may or may not include the best comparison experience for the problem at hand. Further, the set of retrieved experiences may contain various kinds of errors. Individual experiences will almost certainly be incomplete. Some of them may embody inferred as well as directly observed information. Some may incorporate information originally observed in or inferred from two or more different experiences. The validity of retrieved experiences and their degree of similarity to the present problem limit the validity of the conclusions inferred from them.

Given a distribution of retrieved experiences, the analyst can apply different rules to infer consequences for the current problem. For example, the analyst could identify the single best analogy, observe the features for that experience, and generalize them to the current problem. Alternatively, the analyst could identify the most common features across a set of retrieved experience and generalize them to the current problem. Obviously, there are many other rules the analyst might apply. The point is that different rules can produce different conclusions. Further, a number of studies have shown that people use arbitrary rules to draw inferences from aggregations of experience (e.g., Tversky & Kahneman, 1974).

ANALYSIS OF PROBLEM-SPECIFIC INFORMATION

Under certain circumstances, the analyst may be able to infer future conditions analytically from observable information. Some problems permit computation of future conditions. For example, if an analyst observed that an invading land force from country A was approaching the capital city of country B at a particular rate and from a particular distance, he or she could compute the number of days until the invading force would arrive at the capital. Some problems permit formal reasoning to infer future conditions. For example, if the analyst observed (a) that country B had declared an intention to resist any attempts at invasion and (b) that country A was preparing to invade country B, he or she could deduce an impending conflict. Finally, some problems permit informal reasoning to infer future conditions. For example, if the analyst observed that country A had massed forces along the border with country B, he or she might infer that an intention to invade country B was the most likely explanation.

The major strength of the analytical strategy is that the premises from which the analyst draws inferences can be made external and explicit. Thus, they do not rely upon the ambiguities of human memory and they can be independently verified. Similarly, the inference procedure the analyst uses can be made explicit and subjected to scrutiny.

The analytical strategy also has several potential weaknesses. Foremost among them is that it may not be possible to infer the most important conclusions from observable information. In most zero-sum games, the opponent strives to conceal crucial information and to present misleading information. The analyst's ability to infer useful

information from observed information is inversely related to the opponent's skill at concealment.

A second potential weakness lies in the relative effectiveness of different analytical procedures. Some procedures, such as the computational example given above, are fairly reliable. Barring unforeseen circumstances, the current distance of a force from its target and its current rate of approach provide a sound basis for inferring the force's arrival time. However, even computation may prove unreliable if it is based on unsubstantiated assumptions. Other procedures, such as the informal reasoning example given above, are still less reliable. While preparation for invasion is a common reason for massing forces at a border, it is not the only possible reason. Therefore, the analyst may have to qualify certain inferences, depending upon the procedure used to generate them. In addition, as mentioned above, people use many arbitrary rules to draw inferences from data (e.g., Tversky & Kahneman, 1974). These procedures are highly suspect.

Finally, the analyst's ability to apply any procedure effectively depends upon his or her ability to detect important conditions among the observed information. In many cases this may not be a simple matter of noticing conditions that are individually important. Rather, it may require the analyst to notice several related conditions simultaneously and to have in mind the particular analytical procedure that operates on them. Hayes-Roth and Walker (1979) have shown that, in such circumstances, people are prone to overlook critical information and, as a consequence, they fail to draw important inferences. In some cases, effective analysis may require a chain of inferences based on different

procedures. Two of the examples given above form such a chain. Using informal reasoning, the analyst could infer that country A's massing of forces on the border of country B indicated that it was preparing to invade. Using formal reasoning, the analyst could infer from this initial inference and country B's declared intention to resist invasion that the two countries would soon enter into conflict. The need to build such inferential chains can only exacerbate people's tendency to overlook important conditions.

#### MENTAL SIMULATION

For many problems, the analyst can project future conditions by mentally simulating events in the environment. The analyst begins by characterizing the conditions under which an action would occur and the resources that would be mobilized. He or she then works through the action step by step, accounting for the movement and behavior of agents, the depletion of resources, the production of effects and side effects, and any other ramifications of the action. Basically, the simulation provides a test-bed for testing potential plans. It permits the analyst to "observe" the consequences of potential plans and to adopt, modify, or reject them accordingly.

Mental simulation is a relatively recent concept in cognitive science, but it has proven useful in several paradigms. Wesson (1977) used mental simulation as the foundation for an automated air-traffic-control system. Hayes-Roth and Hayes-Roth (1978, 1979) discussed the importance of mental simulation as a cognitive component of planning. Klahr (1980)

demonstrated the usefulness of a programmable simulation as a tool for strategic planning.

The simulation strategy has two potential strengths. First, it encourages the analyst to enumerate conditions, effects, side effects, and other considerations that he or she might otherwise overlook. For example, straightforward computational methods would indicate how long it would take country A's land force, beginning at the border and traveling at speed s, to reach the capital city of country B. By simulating the progress of country A's land force from the border to the capital city of country B, the analyst might discover that intermediate geographical features were likely to impede the force's progress. Second, the strategy requires the analyst to make explicit various presumptions and expectations that influence his or her conclusions. This exposes the analyst's presumptions and expectations to scrutiny.

The simulation strategy also has potential weaknesses. First, the validity of conclusions based on mental simulation depends upon the quality of the simulation--its accuracy and completeness. Both represent potential pitfalls for the analyst. A second related problem concerns assessment of the simulation. Because the enterprise is, by definition, hypothetical, it is difficult to assess the quality of the simulation before choosing and executing a plan in the real environment.

A third problem concerns people's ability to perform mental simulations. There is some evidence that people naturally engage in such activities for some problem-solving tasks (Brown & Burton, 1975; Hayes-Roth & Hayes-Roth, 1978, 1979; Simon & Simon, 1978; Stevens & Collins, 1978). However, it is not clear that they can perform high quality

mental simulations for all tasks. Moreover, as the complexity and uncertainty of the task increase, the expected quality of people's mental simulations would decrease.

Finally, the simulation strategy may make analysts overconfident in the validity of their conclusions. Recent research has suggested that people tend to believe arbitrary assertions simply because they have been able to construct a plausible justification of them (Ross, Lepper, Strack & Steinmetz, 1977). There may be a similar tendency to believe that a carefully constructed simulation is an accurate representation of the environment.

#### IV. GENERAL COGNITIVE CHARACTERISTICS THAT AFFECT FUTURE PROJECTION

In addition to specific strategies, people have general cognitive characteristics that affect their ability to project the future accurately. These general characteristics presumably interact with specific strategies, such as those outlined above. This section describes three general cognitive characteristics that can have substantial effects on future projection: the ability to operate at different levels of abstraction, the interaction of motivational and cognitive factors, and limitations on the ability to attribute plan outcomes to appropriate antecedents.

##### LEVELS OF ABSTRACTION

Recent research has suggested that people's cognitive processes for situation assessment and planning can operate at different levels of abstraction (Hayes-Roth & Hayes-Roth, 1978, 1979; Sacerdoti, 1974; Stefik, 1980). Level of abstraction refers to the amount of explicit detail the analyst considers in making observations and decisions. At one extreme, the analyst can form a very abstract plan, specifying only the major actions to be taken. At the opposite extreme, the analyst can form a very detailed plan, specifying exact sequences of actions and the component operations necessary for executing each action.

Similarly, people can perform future projection functions at different levels of abstraction. For example, in projecting future dangers and opportunities in the environment, the analyst can restrict attention to very general conditions or analyze those conditions in great detail. In projecting the overall outcomes of a planned course of action, the

analyst can consider simple success or failure in achieving planned goals or analyze the details of the projected success or failure. Similar distinctions can be made for each of the eight types of future projection outlined in Section II and these are independent of the particular strategy the analyst uses.

The capacity to operate at different levels of abstraction has obvious advantages. Operating at high levels of abstraction greatly simplifies the problem-solving task facing an individual (Newell & Simon, 1972). The individual can ignore distracting details and focus on the most important features of the problem.

However, the level of abstraction at which an individual operates can influence the accuracy of his or her conclusions. Working at a low level of abstraction forces the individual to attend to problem details, some of which may constrain the set of acceptable conclusions. Because working at a high level of abstraction does not force this systematic attention to details, the individual may reach a conclusion that is inappropriate. For many problem-solving situations, this does not pose much of a problem. The individual works in a static problem environment and can "generate and test" a number of alternative solutions.

In the case of future projection, the level of abstraction at which an individual operates can have profound consequences for the quality of the conclusions reached. Here, the individual works in a dynamic problem environment. Many problem elements are unspecified, except as the individual imagines them and future projection provides the individual's only opportunity to "generate and test" alternative conclusions.



A recent study (Hayes-Roth, 1980) illustrates the potential problems caused by projecting future conditions at high levels of abstraction. The study focused on people's projections of resource requirements and the impact of those projections on the remainder of the planning process. Subjects were given a list of candidate goals corresponding to the causes for action an analyst considers. They then formulated a plan for achieving some subset of those goals. Because of severe time limitations, subjects had to give careful attention to the time required to achieve individual goals. This was an important criterion for deciding which goals to include in the plan. In one condition, subjects operated at a high level of abstraction and did not enumerate all of the time-consuming actions required to achieve individual goals. These subjects systematically underestimated time requirements and, as a consequence, planned more goals than they could realistically achieve in the time available for plan execution. In another condition, subjects operated at a low level of abstraction, enumerating all of the time-consuming actions required to achieve individual goals. Their time estimates were much more conservative. As a consequence, they planned fewer goals, but their plans were more realistic. These results were obtained regardless of which particular projection strategy subjects used.

The level of abstraction at which analysts operate can influence the other types of future projection discussed above, with equally serious consequences. For example, if an analyst were projecting the effects and side effects of alternative actions, operating at a high level of abstraction might obscure differences among the actions. If an

analyst were projecting the potential interactions between several planned actions, operating at a high level of abstraction might obscure subtle but important interactions.

As these examples illustrate, the level of abstraction at which analysts operate represents an implicit tradeoff between the cost of attention to extraneous details and the possibility of overlooking crucial details. In many cases, it may be difficult to determine an "optimal" level of abstraction. However, it is important for analysts at least to be aware of this tradeoff.

#### INTERACTION OF MOTIVATIONAL AND COGNITIVE FACTORS

Although human beings exhibit sophisticated cognitive capabilities, they are by no means purely cognitive creatures. People exhibit a number of other distinctively human characteristics, such as personality, emotion, and motivation, which can influence their cognitive activities. Because situation assessment and planning processes explicitly focus on the establishment and achievement of goals, they are particularly vulnerable to motivational factors. The danger is obvious: the analyst may tend to project desired futures, rather than realistic futures.

The study by Hayes-Roth (1980) discussed above demonstrated the power of motivational factors to distort people's projections of resource requirements. The study included a comparison between two conditions, varying the urgency of the candidate goals presented to subjects. Presumably, subjects were more motivated to achieve urgent goals than to achieve less important goals. When presented with urgent goals,

subjects systematically underestimated the time required to achieve individual goals. As a consequence, they planned more goals than they could realistically achieve in the time available for plan execution. When presented with less important goals, subjects' time estimates were more realistic. As a consequence, they planned fewer goals, but their plans were more realistic. Again, these results were obtained regardless of which particular projection strategy subjects used. Thus, ironically, being faced with urgent goals motivated subjects so strongly that they produced inferior plans.

Motivational factors could have equally serious effects on the quality of other types of future projection. For example, in projecting future conditions from past and present conditions, an analyst may be reluctant to project undesirable conditions. In projecting the effects and side effects of individual actions, the analyst may focus on positive effects and minimize negative effects. Whereas these expressions of optimism may be adaptive under certain circumstances (Alloy & Abramson, 1979; Tiger, 1979), in a military context they would have disastrous consequences.

#### ATTRIBUTION OF PLAN OUTCOMES TO APPROPRIATE ANTECEDENTS

One of the most powerful cognitive mechanisms people have is the ability to learn from experience--either their own or others' experience. By observing contingencies between particular behaviors and outcomes, people learn to behave in ways that maximize desirable outcomes and minimize undesirable outcomes. A critical prerequisite for this kind of learning to take place is the ability to attribute particular

outcomes to appropriate antecedents. That is, the individual must be able to identify valid contingencies between behaviors and outcomes and between other preconditions and outcomes. Valid attribution can be a formidable problem in complex situations. In addition, people exhibit certain biases that limit the validity of their attributions.

Planning problems are particularly complex. As discussed above, a finished plan represents the combined contributions of many planning subprocesses, including several different projection processes as well as selection, sequencing, coordination, and design processes. Plan execution does not provide feedback on the quality of each of these subprocesses, but only on the outcomes of the plan as a whole--what is accomplished, what resources are consumed, and perhaps a few details, such as which particular subgoals are achieved or neglected. This feedback is made more ambiguous by the possibility that situational factors, such as the occurrence of unanticipated, low-probability events, also contribute to plan outcomes. Thus, the feedback planners receive from plan execution is not diagnostic; it does not permit reliable attribution of plan outcomes to appropriate antecedent planning behaviors.

Certain biases in human judgment may interact with the complexities of attribution. Several studies have shown that people tend to attribute success at a task to internal factors such as their own ability or effort, but to attribute failure to external factors such as bad luck or task difficulty (Arkin, Gleason, & Johnston, 1976; Snyder, Stephen, & Rosenfield, 1976; Wortman, Costanzo, & Witt, 1976). In the present context, this could lead planners to attribute positive plan outcomes to their planning skills and to attribute negative plan outcomes to situational factors.

In practice, attribution of plan outcomes is a retrospective analysis of the contingencies among observed events. This activity is complicated further by people's tendency to rationalize the inevitability of such events. Florovsky (1969) has described this tendency toward "creeping determinism":

The tendency toward determinism is somehow implied in the method of retrospection itself. In retrospect, we seem to perceive the logic of the events which unfold themselves in a regular pattern with an alleged inner necessity. So that we get the impression that it really could not have happened otherwise. (p. 369)

Similarly, Wohlstetter (1962) has observed:

It is much easier after the event to sort the relevant from the irrelevant signals. After the event, of course, a signal is always crystal clear. We can now see what disaster it was signaling since the disaster has occurred, but before the event it is obscure and pregnant with conflicting meanings. (p. 387)

(See also: Fischhoff, 1975; Tversky & Kahneman, 1974; Lofland, 1969; Rosenhan, 1973; Schur, 1971; Walster, 1967.)

This kind of bias would prevent analysts from assessing the validity of their own future projection processes. The conclusions would be obvious: processes that successfully project observed futures must be valid; those that do not must be invalid. Thus, the apparent inevitability of events observed retrospectively may prevent analysts from making subtler attributions of the outcomes of their future projection activities and, as a consequence, prevent them from improving their future projection processes.

## V. THE ROLE OF EXPERTISE

Because future projection is such a difficult task, one might view it as an art, rather than a science. From that perspective, instead of attempting to formalize and validate future-projection processes, perhaps we should simply rely upon the talents and acquired skills of "experts." However, expertise may be imputed to individuals for various reasons and may entail attendant weaknesses. Let us consider three reasonable operationalizations of expertise and their potential weaknesses.

Knowledge as expertise. Individuals who have extensive knowledge of a problem domain are frequently identified as experts. Presumably, this knowledge gives them greater insight into the dynamics of the problem environment and, as a consequence, they should project future environmental conditions more accurately. Although domain knowledge is an eminently reasonable criterion of expertise and undoubtedly bears some relationship to future projection performance, it may not, in and of itself, reliably discriminate accurate from inaccurate future projections. As discussed above, the particular projection strategy an analyst uses, as well as more general cognitive factors, can influence the validity of his or her future projections. Moreover, there is some evidence that domain knowledge is a better predictor of confidence than of accuracy. Several studies have shown that increasing the amount of information subjects have about a problem domain continues to increase their confidence in their ability to solve problems long after their problem-solving accuracy reaches an asymptote (Goldberg, 1959; Oskamp, 1962, 1965; Taft, 1955).

Experience without feedback as expertise. Individuals who have experience performing a particular task are frequently identified as experts. Presumably, their experience gives them greater familiarity with the dynamics of the problem environment as well as greater skill at performing the necessary functions. However, military analysts attempt to solve many problems, while receiving feedback on only a few, if any of them. Several studies have shown that experience without feedback reliably improves individuals' confidence, but rarely improves their performance (Gallenbeck & Smith, 1950; Greenspoon & Foreman, 1956; Hunt, 1961; Landsman & Turkewitz, 1962; Ryback, 1967; Seashore, Underwood, Houston, & Berks, 1956; Thorndike, 1931; Waters, 1933).

Experience with feedback as expertise. Even if we define experts as individuals with many experiences in which they obtained feedback, there are potential problems. As discussed above, experience in future projection typically provides minimal feedback regarding the outcomes of performance and little or no feedback regarding the relationship between outcomes and specific aspects of performance. This makes the analyst vulnerable to the several types of attribution bias discussed above. Moreover, there is some evidence that people are biased processors of the feedback that is available to them. Einhorn and Hogarth (1978) reviewed a number of studies showing that people are much more influenced by their successes than by their failures. However, it is not logically possible to distinguish valid from invalid procedures simply on the basis of positive outcomes. Thus, expert analysts may rely on arbitrary future projection strategies based on idiosyncratic personal experiences.

As these examples illustrate, it may be impossible to identify true experts for future projection tasks. These tasks simply do not provide the kind of knowledge and experience that would permit analysts to develop their skills in systematic and reliable ways. At the same time, they provide the kind of context in which people are prone to become overconfident about their limited skills. While overconfidence is problematic in a variety of task environments (Einhorn & Hogarth, 1978; Fischhoff, Slovik, & Lichtenstein, 1977; Kahneman & Tversky, 1973; Koriat, Lichtenstein, & Fischhoff, 1980; Lichtenstein, Fischhoff, & Phillips, 1977), it can be devastating in a military context.

These observations do not imply that there can be no future projection experts. Although we cannot identify existing experts on the basis of knowledge or experience, we may well be able to develop experts with the appropriate training. This training would cover specific projection strategies, their strengths and weaknesses, and the circumstances under which they are appropriate. It would also cover general cognitive issues, such as those discussed in this section, to help the analyst exploit cognitive strengths and avoid cognitive errors.



VI. PRELIMINARY METHODS FOR IMPROVING FUTURE PROJECTION  
FOR SITUATION ASSESSMENT AND PLANNING

We have argued that people's cognitive strategies and more general cognitive characteristics bring both strengths and weaknesses to the future projection process. It seems apparent, therefore, that two complementary approaches can improve future projection: capitalizing on cognitive strengths and compensating for cognitive weaknesses. Preliminary methods in each of these categories are outlined below.

CAPITALIZING ON COGNITIVE STRENGTHS

People's cognitive strengths are at this point a primitive resource. They have developed naturally, with little informed cultivation. We can capitalize on cognitive strengths by developing a "cognitive technology" for future projection and then using it to train expert future projection analysts.

The cognitive technology would have several components. First, we should develop a catalogue of generic projection strategies. The three outlined in this paper presumably represent only a fraction of the strategies analysts might employ effectively. Second, we should formalize each strategy as a generic procedure that analysts can execute and communicate to one another. This formalization should parameterize general cognitive factors, such as level of abstraction. Third, we should identify generic circumstances under which each strategy is appropriate. Finally, we should characterize the strengths and limitations of each strategy as applied under particular circumstances and parameterizations.

Given a cognitive technology for future projection, we would train expert future projection analysts as follows. First, we would provide analysts with a repertoire of procedurally-specified future projection strategies. Second, we would educate the analysts regarding general cognitive factors, such as motivation and attribution, and the interactions between these factors and particular strategies. Third, we would train the analysts to know under what circumstances individual strategies are appropriate and to appreciate the strengths and limitations of particular strategy-circumstance combinations. Finally, we would train the analysts in the use of compensatory methods to correct weaknesses in the strategies they use.

#### COMPENSATING FOR COGNITIVE WEAKNESSES

We can suggest several preliminary methods for compensating for cognitive weaknesses of the sorts discussed in this paper.

Cognitive decomposition. In the discussion of levels of abstraction (Section IV), we observed a potential weakness: that analysts might operate at too high a level of abstraction, overlooking crucial problem details. One method an analyst might employ to compensate for this weakness is to cognitively decompose the elements of a problem and tentative solutions at successively lower levels of abstraction. That is, the analyst could attempt to think through the problem and solutions in successively greater detail. If the refinement process suggests that low-level details may be producing unanticipated effects or interactions, the analyst should continue to decompose the problem until he or she is satisfied that all important details have been uncovered. If, on

the other hand, the refinement process uncovers no significant effects or interactions among low-level details, the analyst can restrict his or her attention to a more abstract version of the problem. This method has had some success in facilitating the solution of problems that have a clearly defined part-whole structure (Armstrong, Denniston, & Gordon, 1975; Leal & Pearl, 1977; Merkhofer, 1977). We are suggesting that it might be generalizable to the kinds of future projection problems discussed in Section II of this paper.

Independence between projection and planning. Our discussion of motivation suggested another potential weakness: that motivational factors might lead analysts to project desired futures, rather than realistic futures. Because situation assessment and planning focus on the establishment and achievement of goals, they are particularly vulnerable to this weakness. One compensatory method analysts might employ is to separate future projection from decisionmaking. That is, different individual analysts could perform future projection and decisionmaking functions. This might protect the future projection process from motivational biases. Alternatively, we might regiment analysts' future projection behavior, extracting future projections in a neutral context and then providing them as inputs during planning.

Rule of thumb corrections. Each of the strategies and general cognitive characteristics discussed above carried certain inherent weaknesses when applied to future projection. If analysts understood how they themselves manifested these weaknesses, they could develop and systematically apply appropriate rule of thumb corrections. For example, an analyst might observe from experience that, for whatever reason,

he or she tends to underestimate resource requirements by a factor of two. The analyst could compensate for this bias by systematically doubling projected resource requirements.

Automatic aids. For many of the weaknesses discussed above, automatic aids might provide valuable assistance. For example, the simulation strategy is vulnerable to complexity factors. As the complexity of the projection problem increases, it becomes more difficult for the analyst to simulate it. The problem is that even if the analyst can enumerate all relevant factors, he or she may not be able to monitor all of their actions and interactions simultaneously. However, the analyst could formalize his or her understanding of these factors in a knowledge-based simulation and simply observe their actions and interactions.

Built-in robustness. Whatever future projection methods analysts use and whatever precautions they take to compensate for weaknesses, they must realize that errors, small and large, will occur. Knowing this, they can attempt to produce situation assessments and build corresponding plans that are robust under an expected range of circumstances. As Wohlstetter (1962) put it, we must

accept the fact of uncertainty and learn to live with it.  
Since no magic will provide certainty, our plans must work  
without it. (p. 401)

### CONCLUSIONS

In this section, we have outlined an approach to improving future projection for situation assessment and planning. The proposed cognitive technology and training regime are predicated on the assumption

that analysts bring powerful, but not yet fully realized intellectual capabilities to future projection problems. Research is needed to explore this potential and to develop effective methods for exploiting it. The proposed compensatory methods are predicated on the assumption that by its very nature, future projection must be approached with heuristic methods. This means that projections will be erroneous or biased in systematic ways. The methods presented above are illustrative. Research is needed to develop and refine these and other methods and to assess their utility.

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