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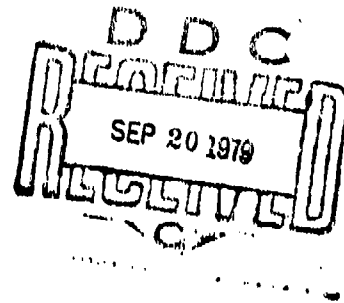
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UNCERTAINTY AND DECISION MAKING

Terence R. Mitchell

Technical Report 79-19

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This final report on 3+ years of research reviews studies in the causes of uncertainty, theoretical developments in uncertainty, the consequences of uncertainty and the applications of theory to uncertain situations. Further, work on a contingency model for selection of decision strategies is outlined and related research is described.		

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Background

The original purpose of the contract was to investigate the issue of uncertainty in the decision process. Our intention was to study the causes and consequences of uncertainty, to develop theories that dealt with uncertainty in a variety of ways and to develop measurements of the construct that were reliable and valid.

As the research progressed over the four-year period we found that our efforts split into two major areas of research. The first area dealt almost exclusively with the topics described above. We studied the ways to measure uncertainty, what caused it and its consequences. However, in pursuing this line of work it became apparent to us that uncertainty was just one part of a larger picture. More specifically, we became interested in the broader question of how people chose decision strategies when faced with a variety of types of decisions. Uncertainty was one of the major factors in this selection process but there were others. This type of analysis led us to develop a model of decision strategy selection. The second major area of work concerned the development of this model and its empirical verification. We will discuss each of these two areas in turn.

Some final preliminary comments are needed. The following review is not meant to be a detailed description of all of our research. Rather, we will concentrate on a brief description of the research studies that were most productive and try to provide integrative summaries. More detailed reports are available in technical report form.

Uncertainty

To some extent this work followed a logical pattern. We did a few empirical studies which examined the causes of uncertainty. While these studies were being run they gave us some new ideas of a theoretical nature as well as prompting some methodological work on the measurement of uncertainty. This research was in turn followed by studies designed to discover the consequences of uncertainty. These areas of research are, therefore, described in that order.

Causes of Uncertainty

Our concern here was to discover what factors of a situation or decision task produce uncertainty. Some likely candidates were the credibility and reliability of information sources, the amount and type of information at hand, the degree to which the task was structured and familiar and the extent to which the person had control over the situation and the components of the task.

We conducted two series of lab studies to investigate the sources of psychological uncertainty. The first of these (Beach, Mitchell, Deaton and Prothero; Report #76-80) examined the variables of information relevance and source credibility. Briefly, two separate studies were carried out. In the first study, the subjects received information about a job candidate and had to judge the candidate's probability of success in a specific job. The information varied in its relevance for the job and the credibility of the source. We believed that subjects would be more uncertain about the usefulness of information when it was from a low credibility source or was not particularly relevant for the job at hand. This uncertainty would result in a "discounting" of the information in terms of its impact on the judgment of the candidate's success.

The results indicated that both factors and their interaction had an important impact on success judgments and that they controlled about the same amount of variance. The underlying discounting mechanism occurred and appeared to be multiplicative in nature rather than subtractive.

A second study was conducted using impact statements about possible nuclear power plantsites as the information input. Three pieces of information were provided about each site and each bit of information varied in terms of its source credibility (high vs. low), the probability of the impact actually occurring (.75, .50, .25) and the content of the impact (Growth, Local Institutions and Demography).

Each subject rated 216 different sites in terms of their favorability as a nuclear power plant site. A rating was made after each of the three items of information

were read. So, the subject would start with a 100% favorable opinion, receive the first bit of information, make a judgment, receive the second bit of information, make a judgment, and receive the final bit of information and make a judgment. We could, therefore, determine from these ratings the degree to which the different independent variables (credibility, probability, and content) had an effect on the favorability judgments.

The results were similar to the first experiment. Both probability and credibility and their interaction had an effect on favorability judgments. The content of the impact played a minor role in determining these judgments. Again, the discounting mechanism appeared to be multiplicative. People combine these factors in a multiplicative fashion rather than in an additive fashion.

The second series of studies was conducted by Olga Crocker (Report #77-11). The first experiment treated the control of information flow and the orderliness of the information as the independent variables. We believed that more control and more orderliness would lead to less uncertainty than the reverse of these conditions. The tasks involved three scenarios (estimates of financial contributions for a worthy cause, commitments to purchase a product and signing a petition) in which items of positive or negative information were given to the subjects. The results showed a main effect for orderliness on uncertainty and satisfaction. The more orderly the information, the lower the uncertainty and the higher the satisfaction. The control of information flow was unrelated to uncertainty.

The second experiment by Ms. Crocker included as independent variables orderliness, the status of the source of information, the primacy versus recency of positive information items, and whether judgments were made sequentially or finally (after each item of information or only at the end). The task involved the judgment about the likelihood of success of a set of eight job candidates; each subject saw 20 items (some positive, some negative) about each candidate. Orderliness was again significantly related to uncertainty in the predicted manner as was the status of the source.

High status sources and high orderliness produced low uncertainty and high satisfaction. The primacy/recency and sequential/final variables produced no significant differences.

In summary, we have examined in the lab a number of possible causes of uncertainty. Of most importance are the status of the source, the reliability and relevance of the information and the orderliness of the information. People are more confident and less uncertain about information that comes from a high status source, is reliable, relevant and orderly. In general the order of importance of those factors is as they are listed above. Our intuition suggests that we spend lots of time worrying about the content of information and little time worrying about who communicates it and in what fashion. These latter factors would appear to be very important in the process of reducing uncertainty. We also conducted a field simulation to look at some causes of uncertainty. Sam White, in a followup to some earlier work (#77-12) hired people to transpose and compute some numbers from stock exchange transactions. The tasks were enriched or unenriched and they worked with a supportive or nonsupportive co-worker (confederate). A supportive co-worker resulted in higher productivity and satisfaction than a nonsupportive co-worker and enriched tasks affected attitudes but not performance. The greatest uncertainty (ambiguity) occurred when (a) the task was enriched but there was a nonsupportive co-worker or (b) the task was unenriched but there was a supportive co-worker. Thus, when the task and co-worker cues are incongruous the employee was more uncertain about the job and somewhat less satisfied. When we combine this study with Wee's work (discussed later) we have a fairly impressive picture of what causes uncertainty about one's job and the consequences of this uncertainty.

Theory and Method

Our work in these areas was partly a reaction to our empirical work. Two theoretical papers were written as well as a methodological effort. This latter research was designed to test the validity of our uncertainty measure.

The first theoretical contribution was presented in Larson and Mitchell (#76-3). The concern was one's uncertainty over their behavioral control. The theory postulates that people desire to have control over outcomes. That is, they like to control the consequences of their actions. When they are uncertain about this level of control they find it aversive and seek information to reduce this uncertainty. The paper presents a detailed discussion of how uncertainty about control over outcomes is related to other theories in the social psychological literature and its relevance for performance on problem solving tasks.

The unique contribution of this theory is its scope. Most research on control has focused primarily on the effects of having total control versus no control. The Larson and Mitchell paper analyzes intermediate levels of control and is a dynamic model. More specifically, the model makes predictions about both increases and decreases in control as well as the affects of all levels of control. This theoretical analysis resulted in a number of studies on the consequences of uncertainty which will be discussed later.

The second paper concerned with a theoretical issue was by Clark Johnson (#77-10). His work was directed at how uncertainty is aggregated. That is, when we must utilize a set of informational cues, each of which is somewhat uncertain, how do we do it? Five studies were run in which the task required a judge to make a series of quantitative judgments and express his uncertainty about the accuracy of each. Then, the judgments were summed on a calculator and the judges expressed their uncertainty about this overall sum. It was found that the latter uncertainty was reasonably close to being the sum of the former. That is, an additive model initially seems best. However, it is possible that a weighted average would be a better model; subsequent research will have to decide.

This is an important line of research because every subjective judgment is of necessity accompanied by some degree of uncertainty about its adequacy. When the judgments are about probabilities, uncertainty is a second-order probability and says, in essence, that a point estimate must be treated with caution commensurate to its

second order probability. That is, "I think the probability is .92, but I'm not too sure about it and I therefore won't act too rashly." Knowing how uncertainties are combined can help us determine the overall uncertainty contained in a whole series of informational items.

Accompanying the theoretical work was some methodological work to support some of our measures used in our research. Jim Larson and Andy Reenan completed a study that verifies that our favored measurement of uncertainty, the Equivalence Interval, is sometimes the same thing as asking for confidence (#77-9). The EI is better, however, because it makes sense for point judgments whereas confidence does not. That is, if you were to estimate the proportion of Naval personnel who are women to be 12% you should not be very confident because the chances are good that your judgment is not precisely correct, even 11% or 13% would prove you wrong. The EI allows you to indicate a range of possible judgments all of which are "in the ballpark." If you are fairly certain that the true percentage is in the vicinity of 12% your EI should be narrow, say 10%-14%. On the other hand, if you are not very sure, the EI should be wide, say 1%-25%. EI appears to be a good measure of second order subjective probabilities and behaves much like a confidence interval.

Consequences of Uncertainty

Besides the causes of uncertainty it was also important to understand its consequences. Initially, we felt that uncertainty was probably seen as an obstruction to effective decision making and choice behavior. We felt that people would probably behave differently under different conditions of uncertainty and that they would try to reduce uncertainty.

We have conducted a number of studies which look at the results or consequences of being uncertain about a situation or decision problem. Jim Larson's work (built on his theory of control over outcomes) suggested that uncertainty would (a) be aversive and therefore avoided and (b) result in attempts to reduce uncertainty by seeking new information.

Two studies were conducted to test the first hypothesis. In both cases, subjects were given an opportunity to choose between various settings in which they could work. The expected reward was the same but the uncertainty varied. As expected, people systematically preferred those settings in which uncertainty was low rather than high.

Three studies were conducted by Larson to test the information seeking hypothesis. All of the experiments employed a reaction time task in which the control and the uncertainty about the control over outcomes (a monetary reward) were manipulated. While there was some evidence that people who reported high uncertainty sought more information the support was not as strong as that found for the first hypothesis.

A second consequence of uncertainty was pursued by Ms. Crocker in the work mentioned earlier. Her research seemed to show that high uncertainty leads to a greater dispersion or variance of answers within a group while low uncertainty reduces this uncertainty. Since group decision making usually requires some sort of consensus of group members, the implication is obvious: The more uncertain the group members are, the less likely they are to reach agreement about a solution to a problem.

A third hypothesis led us to do some research with rats. We believed that (a) deprivation causes uncertainty and (b) uncertainty (caused by deprivation) leads organisms to choose small short term rewards over large long term rewards. In other words, deprivation causes organisms to "live in the present rather than the future." Much of our stereotypes about socially deprived groups in our society include this idea.

However, it is somewhat difficult ethically and methodologically to induce meaningful deprivation in humans. So, we deprived rats and gave them the option of a small reward (quickly received) or a large reward (for which they had to wait). The results on this research indicated that the animals expressed a greater preference for the larger, and more delayed reinforcement when they were either presently deprived or had a past history of deprivation. This is potentially a very significant study

because it suggests that deprivation contrary to popular opinion may not be the cause of preferences for immediate reward.

Our final set of studies dealing with the consequences of uncertainty are related to organizational issues. Jay Bourgeois, Dan McCallister and Terry Mitchell (#77-7) tested a hypothesis that ran counter to current conventional theory. Most organizational behavior textbooks argue that when a decision maker is faced by an ambiguous, uncertain environment he should "loosen up the reins and be flexible." On the other hand, when faced with a structured, predictable problem, a more regimented approach is desired. While the proper match of these factors is supposed to lead to the most effective decision making process and organizational design it seemed counter intuitive to us.

Based on our theoretical work we hypothesized that people would naturally do the exact opposite of what was most effective. We felt that they would tighten up when faced with uncertainty and loosen up when faced with certainty. We ran three studies to test this hypothesis. Business students and practicing managers were asked to assume the role of President of a new division of a well-established manufacturing firm. The description of the environment of the firm was exactly the same for everyone except that there was great uncertainty for one group and certainty for the other. They were asked to make a number of decisions about how the organization should be designed and various problems solved.

The results supported our hypothesis. When faced with an uncertain environment, the subjects pulled in the reins and tightened up. They set up a very rigid, highly structured organization. The reverse was true in the certain condition. These results suggest that people act in a manner that is diametrically opposite of what is predicted to be most effective.

The final study on the consequences of uncertainty was carried out by Weed (#78-15). His work covers both the causes and consequences of uncertainty. The research investigated the effects of three environmental characteristics (leadership

style, goals, and task structure) on psychological uncertainty and the resultant effect on performance and satisfaction. People were hired to work on a blueprint task requiring some clerical-type activities. They worked under a structuring or considerate leader, with or without goals and on a structured or unstructured task. The results indicate that each of these variables is related to uncertainty and that uncertainty is in turn related to satisfaction and performance. In general, a structuring leadership style, specific goals and a structured task result in lower uncertainty and lower uncertainty results in higher satisfaction and productivity.

In short, uncertainty seems to (a) be aversive, (b) be disruptive of group decision processes, (c) produce low satisfaction and performance and (d) lead to a structuring and tightening of the environment. Thus, we have fairly convincing evidence that uncertainty results in behavior that in many situations is harmful to effective decision making and organizational performance.

Applications

Since uncertainty does have some detrimental effects, we have investigated some ways it can be reduced or eliminated in the hopes of increasing individual and group effectiveness. Some of this work has involved reviews of techniques already in use and some has produced original research.

One review was written by Marcia Deaton (#76-4). This paper investigates the use of multi-attribute utility theory (MAUT) as a means of dealing with complex and uncertain decision problems. She shows how various decomposition strategies such as the use of decision trees and hierarchical models can reduce the problem to meaningful chunks and facilitate decision performance. Studies are reviewed from the areas of urban planning, water quality assessment, medical diagnoses, birth planning and career preferences.

A second review by Mitchell and Beach (#75-75) surveys the use of expected value type models to predict and facilitate occupational choice (a decision about which great uncertainty is reported). The results from over 20 empirical studies

show clearly that these models can accurately predict career choices. It also shows that teaching people how to use such models increases their satisfaction with their choices and retention on the job. By providing actual information about (1) the likelihood that a given individual with his or her own skills and abilities can make it in a given field and (2) the likelihood that various occupations will result in various organizational rewards, the task of making such a choice becomes significantly easier.

In summary, uncertainty seems to have a variety of detrimental effects. It is avoided and frequently dealt with improperly. It seems to reduce motivation and satisfaction with a task. Based on all of our research, however, there seems to be a number of effective strategies for reducing uncertainty. People can be trained to decompose or break up the problem and to use expected value-like models. Reliable and high information sources can be used and information should be presented in an organized fashion. Organizations can introduce goal setting and train their leaders in particular ways. All of these tactics seem to be important ways in which individual decision making and motivation can be effected positively in the organizational setting.

Decision Strategies

In the middle of our research on uncertainty it became clear to us that while uncertainty was an important element in the decision process it was only one factor out of many. We began to shift our focus to a prediction of what strategies people actually choose to make decisions and the variables that effect this strategy selection. The following discussion outlines the model we developed and its empirical support.

The Contingency Model of Decision Strategies

The initial statement of the theory by Beach and Mitchell (#76-6) argues that people possess diverse strategies for making decisions and that the one they use is contingent upon the characteristics both of the decision problem and of the person

himself. We argue that one can array these strategies on some sort of continuum running from Quick-and-Dirty to Analytic--where the former represents what people most often do and the latter represents what decision theorists keep telling them they should do. The paper explores the different kinds of strategies, and outlines possible factors that might lead to selection of one strategy over another (see Table 1).

The two most important sets of variables are the decision problem characteristics and the characteristics of the decision environment. Subsumed under the environmental characteristics are such things as (1) reversibility, (2) significance, (3) accountability, and (4) time and/or money constraints. Our hypothesis was that more analytic strategies tend to be selected as a means of dealing with uncertainty and in the face of irreversible, significant decisions for which the decision maker is accountable and has few constraints.

A paper by Christensen-Szalanski and Beach (#77-8) provides a mathematical representation of the above theory. Different cost curves are postulated for decision problems varying in uncertainty based upon the characteristics of the problem and the person. The decision maker is predicted to choose that strategy with the greatest expected net gain: a type of cost-benefit analysis. The paper explores this selection mechanism in detail and examines the implications of variations in the costs and benefits. Four sets of studies have been conducted to test propositions from both the Beach and Mitchell model and the cost benefit analysis suggested by Christensen-Szalanski and Beach.

First, Jay Christensen-Szalanski performed four very precisely controlled experiments that speak to the most central concepts of the model--the cost/benefit analysis that guides strategy selection and dictates the decision maker's certainty that the decision will be adequate (#77-14). Results of the four experiments were consistent with the predictions of the selection mechanism. Experiment 1 showed that as the benefit of making a correct decision increased, problem solvers took more time to reach a solution and were more confident in their answers. Experiment 2 showed that

this result was not a direct result of increased benefit and that the linkage was more complicated. That is, a problem solver's confidence in the accuracy of his or her solution appears to be related to the fact that more valuable problems make potentially more accurate, complex, and costly strategies worth using. This is supported by the finding that confidence increases when the problem solver uses potentially more accurate strategies but remains unaffected by changes in benefit when the strategy is held constant (Experiment 2).

Experiment 3 showed that an imposed limit on expendable cost can eliminate certain strategies from consideration for selection. When the cost constraint prevents the problem solver from using the strategy dictated by the cost-benefit analysis for the problem, the problem solver uses the potentially most accurate strategy which yields the greatest net potential gain and that can be executed within the time constraint. When using a "time-constrained" strategy, the problem solver's confidence remains unaffected by increases in benefit while his or her regret for lost opportunity increases with increases in benefit.

Experiment 4 illustrated part of the model's generality. The selection mechanism dictates the strategy that should be selected by the problem solver for the given problem task. This selection process is independent of whether the problem solver accurately assesses the cost of using a strategy or its potential accuracy. Whereas differences in training and mathematical aptitude were found to influence a problem solver's confidence, accuracy, and cost curve, it did not appear to influence the strategy selection process.

The second and third sets of studies of the contingency model focused on the environmental dimensions that determine the decision maker's perceptions of the task demands. Marcia Deaton Huffman gave "bare-bones" scenarios that described decision situations and asked subjects to evaluate them in terms of the dimensions designated by the model and to select a strategy for making the required decision (#78-16). Her results show that the model-dictated dimensions indeed define decision tasks and that

the way in which they combine is the same as the model proposes.

Dan McAllister also completed a series of three studies testing the contingency model in more realistic settings (#78-17). These studies consisted of actual business decision problems being solved by managers and business students. Accountability, reversibility and significance were manipulated (2 x 2 x 2 designs) in each of the studies. In the first two studies the manipulations were presented in the cover story describing the decision problem and subjects were asked to play the role of a manager facing the problem. They were asked to choose one of four strategies to solve the problem, and these strategies varied in the amount of effort and analysis required. For example, one problem was a personnel selection problem for an unimportant/important position on a temporary/permanent basis and the decision was being made alone/with others. The third study actually manipulated the variables directly on the participants in the study. For example, accountability was manipulated by having half the subjects believe they would be required to publicly defend their decisions in a group discussion.

The results showed strong support for the theory. All three studies produced main effects in the predicted direction for accountability, reversibility and significance. The more accountable, the less reversible and the more significant the problem the more analytic the strategy selected to solve the problem.

One final study on the "Contingency Model of Decision Strategies" was carried out. Most of our previous investigations (e.g., Szalanski, McAllister, Huffman) did not look at specific task characteristics that influence the strategies people use when making decisions. A study conducted by Bill Waller was designed to look at these issues. Using an accounting problem as the task, subjects were required to make a decision about which decision strategy to use when investigating a series of variances (discrepancies between expected and actual costs). The manipulated independent variables were the importance of the problem (to the individual and to the company) as well as the stability of the information available. The results

showed that both factors influenced strategy selection in the predicted direction. Greater significance (to oneself and the company) as well as unstable information led to the selection of more analytic strategies.

A summary of this second aspect of our work is quite positive. We seem to have developed a model which helps to explain why and how different types of decision strategies are used. Since previous decision literature has tended to focus on normative models and "the one best way" this type of contingency model is a dramatically different approach which we believe is a more fruitful way to analyze the decision process. A fruitful line of practical inquiry might be to train people to understand and perhaps more accurately choose decision strategies. Such a program would be similar to the technique used by Vroom and Yetton in that people would be instructed in diagnostic techniques which would help them analyze decision problems and choose decision strategies more effectively.

Conclusions

We started out to study uncertainty in decision making. Our research was able to pinpoint some of the causes and consequences of uncertainty as well as some ways to reduce it. Along with this effort was a stream of research that focused on the role of uncertainty in the broader context of selecting strategies for different types of decisions. This contingency model of strategy selection from both a theoretical and practical perspective should increase our understanding of the decision process and hopefully our effectiveness.

Over the past three years we wrote 21 technical reports and 18 of those resulted in published papers. There were numerous talks, paper presentations, and symposiums as well. It was a productive three years and we were glad to have the opportunity to do the research.

Table 1
Variables Comprising the Model

The Variety of Decision Strategies	Task Characteristics	Decision Maker Characteristics
1 - Aided-Analytic	1 - Decision Problem Characteristics	1 - Knowledge
2 - Unaided-Analytic	A - Unfamiliarity	2 - Ability
3 - Nonanalytic	B - Ambiguity	3 - Motivation
	C - Complexity	
	D - Instability	
	2 - Decision Environment Characteristics	
	A - Irreversibility	
	B - Significance	
	C - Accountability	
	D - Time and/or Money Constraints	

DECISION RESEARCH
University of Washington

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