

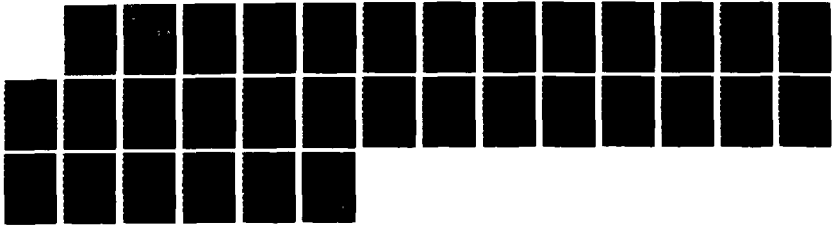
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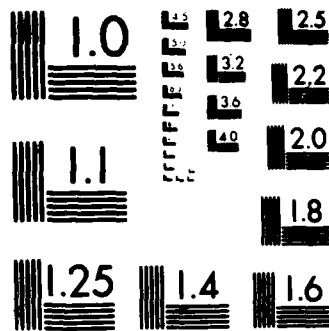
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UNIVERSITY OF SOUTHERN CALIFORNIA

FINAL RESEARCH REPORT

VALIDATION, ERROR, AND SIMPLIFICATION
OF DECISION TECHNOLOGY

Ward Edwards
and
William G. Stillwell

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SSRI RESEARCH REPORT 80-5

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FINAL RESEARCH REPORT

VALIDATION, ERROR, AND SIMPLIFICATION
OF DECISION TECHNOLOGY

William G. Stillwell
and
Ward Edwards

Social Science Research Institute
University of Southern California

Research Report 80-5

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TABLE OF CONTENTS

Acknowledgements.	ii
Disclaimer.	iii
I. Introduction.	1
II. Why One Should Care About Validation, Error, and Simplification.	2
III. Experimental and Theoretical Studies.	3
A comparison of importance weights.	3
Evaluating credit applications.	4
Reference Effects	5
Equal weights, flat maxima, trivial decisions	6
Functional relationships.	8
Rank weighting in MAU decision making	9
IV. Some Implications	10
V. References.	15

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DISCLAIMER

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Advanced Research Projects Agency or of the United States Government.

I. Introduction

This final report summarizes the work by the Social Science Research Institute, University of Southern California, on contract No. N00014-79-C-0038 from the Advanced Research Projects Agency, Department of Defense. The research conducted during this contract period from December 15, 1978 to June 30, 1980, under the direction of Professor Ward Edwards, the Principal Investigator, grew out of a program of research supported by ARPA for the study of decision making and the decision sciences. Edwards (1973, 1975), Edwards and Seaver (1976), and Edwards, John, and Stillwell (1977, 1979) summarize previous research.

The proposal leading to this contract called for research on three specific topics: Validation of multiattribute utility elicitation techniques, simplification of assessment procedures for multiattribute elicitation, and error in utility judgment. Our research on these and other topics is contained in six technical reports which have been produced or are now being prepared. Summaries of these technical reports appear in this report.

This report, in addition to providing the summaries of our technical reports, attempts to examine how the three topics fit together, what the findings we have made with respect to them mean for decision technology, and where to go from here.

II. Why One Should Care About Validation, Error, and Simplification

Application of the ideas and procedures of decision analysis in DOD and other contexts has been expanding at a phenomenal rate, while training of qualified analysts has proceeded much more slowly. We expect both trends to continue. The combination of exponentially increasing demand and linearly increasing supply has already created a problem that we expect to become much worse: How can we make decision analytic aid widely available without sacrificing standards of quality? If training more analysts is an adequate answer only in a too-long run, we need another. A second answer, which has motivated much of our work for the last two or three years is decision analysis without the analyst.

What must we do to make decision analysis without the analyst feasible and effective? First, we must simplify both models and elicitation procedures, without undue sacrifice of validity of either. In many situations, decision makers can perform analyses of sufficient complexity for a good decision with minimal-to-no resort to an analyst--if the methods are easy enough to understand and use. Our validation work grows in part from this goal. We investigated elicitation techniques that cover the range from theoretically sophisticated, judgmentally complex procedures to techniques that call for little or even no elicitation. We were seeking an answer to the question, "how simple can the elicitation be and still capture, not only the judgments of the respondent,

but also his or her specific expertise?" To foreshadow one of our main conclusions, the answer is "very simply indeed!"

In order to ask this question sensibly, we were forced not only to develop simple methods, but to satisfy ourselves that they worked. This step, much neglected in the history of the development of decision analytic methods, is not satisfied by use of such criteria as client satisfaction or even convergent validation with holistic judgments. It specifically requires criterion validation--which is what we used.

Error is important because (a) it puts an upper bound on criterion validity, and (b) it is likely to vary among elicitation methods. If a theoretically sophisticated elicitation method leads to more error, random or systematic, than a less elegant one, the less elegant one may well be preferable for that reason alone.

Yet another approach to performing decision analysis without the analyst consists of developing prototypical decision structures, applicable to whole classes of decisions. Though we regard this as a highly promising strategy, we have done no research relevant to it.

III. Experimental and Theoretical Studies

III.A. A comparison of importance weights for MAUA derived from holistic, indifference, direct subjective, and rank order judgments.

College student subjects were taught a four attribute MAU model of diamond worth using the paradigm of multiple cue probability learning and outcome feedback. After training,

subjects assessed MAU weight parameters via a variety of elicitation techniques. Three task variables were manipulated: monetary payoff versus no payoff, task uncertainty (1% versus 18% error variance in criterion), and number of learning trails.

Results showed little difference between levels for any of the task variables in terms of either weight parameters or composite matching (derived from consistent application of the weights used to generate outcome feedback compared with application of judgmental weight sets). Significant differences were found between elicitation procedures for the mean number of inversions in rank ordering of attributes with bootstrapping (weight parameters derived via regression from holistic judgment of profiles) providing the least inversions. However, despite this difference between weight judgments, comparisons of composite worth derived from these weight sets showed that all elicitation procedures did well, with minimal differences between them. A number of rank weighting procedures resulted in equally high quality composite worth measures.

III.B. Evaluating credit applications: A validation of multi-attribute utility techniques against a real world criterion.

Credit loan officers from a California bank served as subjects in a criterion validation of multiattribute utility elicitation techniques. The criterion against which the judgments were compared was a statistically derived credit scoring model which the bank uses to determine creditworthiness of applicants for credit cards and small unsecured loans.

Results of this experiment are very similar to those from the MCPL experiment discussed above. Weight parameters showed some difference between techniques with holistic bootstrapping and constant sum point distribution procedures providing weight sets that corresponded most closely to weights from the bank model. From a practical standpoint, however, three indices of decisions produced by those weight sets showed that all decomposition procedures produced high quality decisions while the holistic procedure produced somewhat inferior results. Again, as in the MCPL experiment, several rank order weighting procedures performed at the high level of the other, more difficult assessment procedures.

III.C. Reference effects: A sheep in wolf's clothing.

In many of its forms multiattribute utility elicitation depends on comparison of holistic profiles to derive weights (or, as they are sometimes called, scaling constants) for attributes in decision problems. The typical judgment called for is a difference between two profiles, the first with a given attribute at its best level, the second with that same attribute at its worst level, and in each case the rest of the attributes at some common level for each of the two profiles. A recent paper (Yates and Jagacinski, 1979) argues that these holistic judgments may be subject to systematic bias due to the values given to the irrelevant variables. They also report data which, they suggest, shows the existence of just such a bias.

In response to this paper, Barron and John (1980) show that the findings are easily accounted for by a multiplicative MAU model rather than the hypothesized judgmental bias. They also exhibit sufficient conditions for two other predictions, i.e., no effect and the opposite effect. Finally, Barron and John present multiattribute evaluation data exhibiting these latter two effects.

III.D. Equal weights, flat maxima and trivial decisions.

This study differentiates between the evaluation of decisions and evaluating decision rules in multiattribute utility decision making. The authors, John and Edwards, show that in fact, most decisions are relatively trivial and any decision model that incorporates the correct attributes, properly oriented (more is better than less or less is better than more) will result in high quality decisions when compared to an optimal decision rule. The authors go on to show that this "high quality" of decisions is a direct result of the set of options that are being considered. When a large set is included, with many that would not be chosen using any decision rule (sure losers), and many that are obvious choices under any rule (sure winners), of course, all rules will seem to do well. An interesting decision problem is the correct selection from among those in the set of contenders, i.e., the options remaining after sure winners and sure losers are removed from the option set. Thus, for evaluation of decision rules the nature of the contender set must be known.

In a Monte Carlo simulation study the authors examined some typical decision problems, to find the expected numbers of sure winners, sure losers and general contenders resulting from varying model choice (additive versus no restrictions), expected correlations between pairs of attributes (either .2, 0, .5, or .9), proportion of alternatives to be chosen (less than 2% to 50%), number of dimensions (2, 3, 4, 5), and initial number of alternatives (50 or 100). They found that as attributes become more highly positively correlated, the percentage of sure winners and losses increases dramatically while the number and percentage of contenders decreases. Higher numbers of dimensions leads to more contenders and fewer sure winners and losers. Finally, the additive utility restriction leads to quite modest increases in sure winners whereas the proportion of sure winners seem to increase roughly linearly with the proportion to be chosen. Comparable statements can be made about sure losers.

The most important finding is that, regardless of the correlation among dimensions in the original set, the correlation of dimensions in the contender set will be negative--with size dependent on number of dimensions. This is expected, since sure winners and sure losers achieve that status by doing well or badly on all dimensions.

The result presents an interesting dilemma in evaluating decisions, rules, approximations, etc. The methods by which options enter an option set are often ill-specified and seldom systematic. Yet most techniques for evaluating decision rules

depend on how well they do within the original option set. It is, for example, consideration of the entire option set that leads to the effectiveness of equal weights.

Since any decision rules should be capable of identifying sure winners and sure losers, a strong case supports the view that decision rules and procedures should be evaluated according to their performance on contenders only. Such a case leads to two conclusions, (1) none of the past conclusions about robustness of decision procedures in the presence of various kinds of error are as sure as we thought they were, but (2) the amount of utility loss produced by a suboptimal decision rule is relatively small if measured over the whole option set, though often much larger if measured over the contender set only. Choice of which standard to use in evaluating a decision rule seems to be a relevant philosophical question.

III.E. Functional relationships between risky and riskless multiattribute utility functions.

Expected utility theory and conjoint measurement theory form two major classes of models and assessment procedures to construct multiattribute utility functions. In conjoint measurement theory a value function v is constructed which preserved preferences among riskless multiattributed outcomes. The risky utility function constructed in the framework of expected utility theory, also preserves such riskless pre-

ferences. In addition it is an appropriate guide for decisions under uncertainty since its expectation preserves risky preference among gambles. Since both u and v are order preserving functions, they must be related by a strictly increasing transformation. However, u and v need not coincide or be related through any special functional forms, unless some simple decomposition forms are assumed. More restricted functional relationships obtain, if u and v are assumed to be either additive or multiplicative. In particular, u can be shown to be linearly, logarithmically, or exponentially related to v , depending on which function is additive and which is multiplicative. A recent paper by v. Winterfeldt (1980) proves such functional relationships based on the theory of functional equations. Techniques are described to assess the parameters of these functions.

III.F. Rank weighting in multiattribute utility decision making: avoiding the pitfalls of equal weights.

Wainer, 1976 discusses a number of conditions that, once they hold, assure high quality prediction from equally weighted prediction attributes. A study by Stillwell and Edwards (1979), takes the opposite tack, describing a number of conditions, commonly found in decision, rather than prediction, situations that could lead to large losses in utility from the resulting decisions if equal weighting of evaluative dimensions were used. The study goes on to suggest that rank weighting of evaluative dimensions provides a remedy for these situations and at the same time retains much of the most appealing characteristic of equal weighting, simplicity of elicitation.

To make the point the study reanalyzes the data from three multiattribute utility decision making studies, comparing the results of several rank weighting procedures, as well as equal weights, to those from the judges in the original elicitations. It was found that equal weights led to large decrements in the correlation of composites when compared to rank weighting of attributes. In general, the rank weighting techniques provided remarkably good approximations to the assumed "true" weights provided by the judges. Within the conditions of this study and for the purposes of multiattribute decision making, rank weights seem to be sufficient improvements over equal weights to warrant the extra effort involved in their elicitation.

IV. Some Implications

In the aggregate, the findings of these studies begin to suggest approaches to implementing the slogan "decision analysis without a decision analyst."

The first point is that, at least as far as weighting is concerned, we apparently can trust the results obtained from research on college students to generalize effectively to results obtained from highly trained experts working in the topics of their expertise. Moreover, it seems to make little difference which elicitation technique for weights is used, so long as that technique incorporates at least rank-order information. Equal weights are clearly inferior, and holistic judgments used as a basis for inferring weights have special problems of their own. But virtually any form of rank weighting

procedure is likely to do as well as the most sophisticated Keeney-Raiffa elicitation techniques. Rank weighting can be done easily, and does not require the intervention of a decision analyst.

The second point is that, at least for monotonic physical dimensions, shapes of single-dimension utility functions make little if any difference. It follows that straight lines will be admirable proxies for any monotonic utility function, for all purposes other than those to which issues of risk aversion are directly relevant. We would in fact argue that they work well in contexts in which attitude toward risk is important also, but the data and thinking of this year's program do not bear on the argument.

The third point is that the nature of the aggregation rule, from the limited set in common use by decision analysts, is sufficiently unimportant that one might as well settle for the convenient and simple weighted linear rule.

What does matter, then, if all these things do not? First and foremost, of course, is the structuring of the evaluative and/or decision problem itself. Whether a decision analysis is simple or complex makes little difference unless it deals with the correct options, the correct dimensions of the multi-attribute utility function, and the real decision makers and other stakeholders. None of this year's work bears on the important, and virtually unaddressed, problem of simplifying and validating the task of structuring decision problems.

Some decision problems come with relatively simple structures. This is especially true of problems that have a generic character. An obvious example in military environments is source selection for hardware procurement. Although the hardware, the potential sources, and the relevant dimensions of value will vary from instance to instance, such problems can be expected to have a generic structure. Aspects of the required performance will have been prespecified by the government; other aspects will be specified explicitly or implicitly by the sources. The sources are the options, and they will identify themselves. Cost variables are likely to arise; the decision about whether additional capability justifies additional cost will almost always need examination. And issues concerning the dependability, history of past cost overruns, history of past failures to deliver on time, and related questions about the sources will normally be relevant. It is by no means absurd to imagine that over time a generic model of source selection decisions might be developed, and that it could be combined with the simple elicitation techniques already discussed to permit its use without decision analyst assistance.

At a much lower level, a similar kind of argument applies to many personnel decisions. The options are often well known. The relevant dimensions are specified by the job description, plus whatever others may be relevant but not included in that document. Both original appointments and promotions could be so handled.

The idea of generic structures has already been applied to siting decisions, with considerable success, by Keeney. Our argument is simply that for decisions for which generic structures can be developed, the goal of decision analysis without the analyst is attainable now, based on what we already know.

But, unfortunately, most decisions do not lend themselves to generic structuring. Consequently, an obvious next step toward that goal is to think harder than we have been about how to facilitate the structuring process without the aid of an analyst.

The preceding discussion has assumed the validity and generalizability of our finding that decision-analytic elicitations meet the requirement of criterion validity. While our data are certainly encouraging, they come from only one study. Moreover, that study is concerned only with weights. Worst of all, the experts in that study were experts not only about the problem, but also about the criterion. A defensible interpretation of our results (which we do not believe) would be that we in effect asked our respondents to feed the criterion back to us, and, knowing it, they did so.

The obvious solution to that problem is to conduct experiments in a context in which (a) subjects are expert, (b) a criterion is available, and (c) the subjects know nothing of the criterion. Requirements a and c seem so nearly to contradict each other that such an experiment seems a priori hard to imagine. Nevertheless, it could be done if the criterion were developed from an appropriate data base as a part of the

validation study itself. Circumstances permitting that do exist.

Having studied only one kind of expert, we are in no position to generalize to other experts or other kinds of expertise. That limitation is inherent in every empirical study, and we do not apologise for it. Indeed, in view of the difficulty of finding available experts, we are pleased to have been able to study criterion validity with expert judges at all. It is distressing, though unavoidable, that the problem of what an expert is, how one recognizes him or her, and how expertise on a subject matter relate to expertise in decision technology in performing decision analytic tasks remains virtually terra incognita 12 years after development of the basic ideas that make such questions crucial. But these are among the toughest questions decision analysts must either face or assume away; it is not surprising that with few exceptions they have done the latter.

As decision analysis develops, our present sophisticated but unsystematic and unscientific knowledge about such questions will come to be replaced with real studies of them--but only gradually, as those controlling the time of experts come to be sufficiently impressed with the importance of such questions to be willing to invest that time in the research that can answer them properly.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report summarizes the research conducted under ARPA Contract No. N00014-79-C-0038. We examined the general topics of validation of multiattribute utility elicitation techniques, error in human preference judgment and simplification of assessment. Both theo- retical and empirical work is discussed. Experimental work showed that existing methods of elicitation of multiattribute utility weight judgments are valid in that they compare favorably with		

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an external criterion. This was found to be true with both student subjects in a contrived laboratory setting and with expert subjects working in the area of their expertise.

Theoretical work showed several paths to simplification of elicitation. Using the functional relationships between risky and riskless utility elicitation procedures, one study showed that with a few simply assumptions holding, the much simpler riskless assessment techniques must maintain the preference ordering implied by the more complex procedures. A second theoretical study defined conditions under which various simplifying weighting strategies can be expected to do well in terms of replicating the preferences indicated by more complex elicitations.

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