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SEQUENTIAL INFORMATION SEEKING: EFFECTS OF THE NUMBER OF TERMINAL ACTS AND PRIOR INFORMATION

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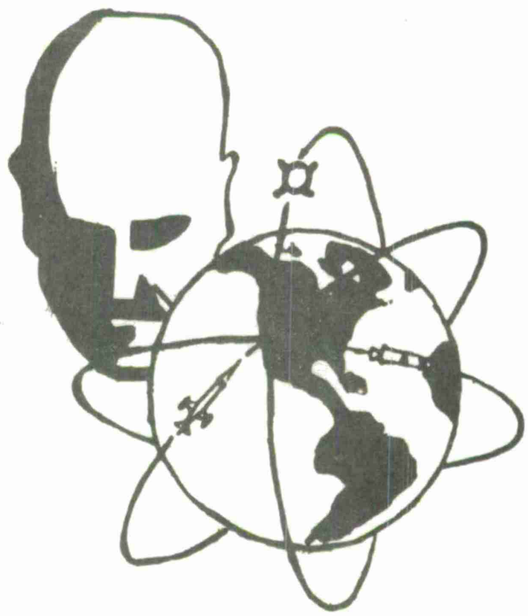
David M. Messick

DECISION SCIENCES LABORATORY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts



Project 4690, Task 469003

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FOREWORD

This study was conducted under Contract No. AF 19(628)-1610 at the Psychometric Laboratory, University of North Carolina, Chapel Hill, North Carolina. Dr. Albert Amon served as principal investigator and Dr. Anne Story, as contract monitor.

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ABSTRACT

An experiment was conducted by means of a digital computer in which 54 human Ss were faced with the task of sampling from a hypothetical binomial universe in which a proportion, p, of all observations were "top quality." Ss sampled the universe sequentially, stopping after some number of observations had been made to make a terminal decision by selecting the one of the S's mutually exclusive and exhaustive subsets of the unit interval which S believed contained p. The four experimental treatments were defined by the four combinations of the two decision partitions of the unit interval, one involving 3 possible terminal acts, the other having 5 alternatives, and the two prior frequency distributions, one a rectangular distribution over [0 - 1], the other being negatively skewed. Analysis of variance of the number of predecision observations taken indicated a) significant individual differences; b) significant S by treatment interactions; c) differences attributable to the decision partitions with more observations being taken in the 5-act case than in the 3-act case; and d) no effect of prior frequency distributions, but a tendency to take more observations in the second 16 trials than in the first 16.

PUBLICATION REVIEW AND APPROVAL

This Technical Documentary Report has been reviewed and approved.

for Donald W. Connolly
HERBERT RUBENSTEIN
Chief, Decision Techniques Division
Decision Sciences Laboratory

Roy Morgan
ROY MORGAN, Colonel, USAF
Director
Decision Sciences Laboratory

SEQUENTIAL INFORMATION SEEKING: EFFECTS OF THE NUMBER OF TERMINAL ACTS AND PRIOR INFORMATION

Introduction

The study of human decision making has engendered interest in the intimately related problem of human information processing. One aspect of this problem, namely how much information does a person require prior to making a decision, has received considerable attention in the past decade. Irwin and Smith (1956) used a task in which Ss had to determine whether the mean of a set of numbers, seen sequentially, was greater than or less than zero. The average number of observations taken increased both with the variability of the numbers in the set and with the proximity of the actual mean to zero. In a later study Irwin and Smith (1957) replicated their earlier findings and found in addition that Ss took more observations prior to making a decision when the payoff for a correct decision was $1.00 as opposed to $.50 and when each observation cost 1/2¢ as opposed to 1¢.

Becker (1958) used a sequential sampling task to determine the extent to which humans could be assumed to be using Wald (1947) strategies. More recently this same model has been evaluated in psychoacoustic investigations by Swets and Green (1961). These studies have suggested that Wald's information-seeking scheme may provide an adequate first approximation to some aspects of human decision making.

Pruitt (1961) found that more information was required for a person to change a decision than for a person to make a decision between the same two alternatives. In a recent study by Lanzetta and Kanareff (1962), it was found that people took more information when an observation cost nothing and a correct terminal decision was worth 5 cents than when they had to pay 5 cents for each item of information and received a payoff of 30 cents for a correct terminal act. The experimental task in this study was contrived in such a way that the strategy which maximized expected profit was the same in both conditions.

The present study is designed to investigate the effect of two additional variables on predecisional information seeking: the number of possible terminal acts and the information available to the decision maker prior to his beginning the task. From the point of view of Bayesian decision theory (see Edwards, et al., 1963) both of these variables are important in determining how much information "should" be observed prior to making a decision. In general, the larger the number of possible terminal acts, the more predecisional information is needed, and the more prior information available about which of the terminal acts is correct, the less current information need be observed prior to decision. [1]

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[1] This is an exceedingly gross statement of predictions which can be derived from the Bayesian position. Much more detailed predictions will be available in a forthcoming report which will be used to analyze the data from the point of view of optimal information-seeking strategies.

Method

Subjects

The subjects (Ss) were 54 male undergraduates enrolled in the University of North Carolina. The Ss were all selected from a subject pool being developed for studies in human decision making. Each S had taken a battery of personality tests and had participated in a decision making study by Collins (1963).[3]

Instructions

All Ss were instructed to imagine that they were employed by a canning factory. The following is a summary of the instructions. "Your job is to have incoming shipments of produce inspected to determine the proportion of 'top quality' items in each shipment. For each type of produce which might be encountered (e.g., tomatoes, cucumbers, watermelons, etc.) the company has a specific grading policy which depends on the uses to which the product can be put. For example, from tomatoes the company makes a number of different foods. Tomato soup is made from shipments having fewer than 20 percent top quality tomatoes. From shipments having between 20 and 50 percent top quality items, tomato paste and tomato ketchup are made. Only shipments having 90 percent or more top quality items go into the Grade A canned tomatoes. For each shipment you will be informed of the company policy to use. In Table 1 are listed the 3 company policies you will use today.

Table 1

Company policies used in the experiment

1.	[.00 - .50]	[.50 - 1.00]			
	a	b			
2.	[.00 - .33]	[.33 - .67]	[.67 - 1.00]		
	a	b	c		
3.	[.00 - .20]	[.20 - .40]	[.40 - .60]	[.60 - .80]	[.80 - 1.00]
	a	b	c	d	e

[3] The Ss were selected from this pool in order to obtain as much data on the same Ss as possible to permit an anticipated large-scale investigation of individual differences in decision making.

If you were using policy 1, for example, and thought that the shipment had fewer than 50 percent top quality items you would grade it "a". After you grade a shipment, it is immediately processed and the actual proportion of top quality items is determined. If the shipment was graded correctly you are paid a bonus of 15 cents. However, each item that you have inspected will cost you 1/5 of a cent. This method of payment has been devised by the company because the more money you make, the more the company makes. Thus the company wants you to try to make as much money as possible.

"In order to aid you in your work, the company keeps a past record of the proportions of top quality items found in the past 300 shipments of each of the commodities with which you will be working. For each of the commodities you will inspect today, this past record will be available." The remainder of the instructions was concerned with procedural details.

Procedure and Apparatus

The S entered the experimental room which houses a Royal McBee LGP-30 digital computer. He read the instructions and sat down facing a Friden Flexowriter connected to the computer. The experimenter (E) started the program, which was stored internally, and the computer printed out the following:

```
The following is the record for the past 300 shipments
of the commodity with which you will now be working:

.00-.10      xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.10-.20      xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.20-.30      xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.30-.40      xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.40-.50      xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.50-.60      xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.60-.70      xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.70-.80      xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.80-.90      xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.90-1.00     xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
For the following shipments:
Inspection is sequential.
For the following shipments:
Company policy requires that you choose one of these intervals
[.00 - .50]      [.50 - 1.00]
     a                b
For the following shipments:
A correct choice is worth          .1500
An incorrect choice costs          .0000
Each piece inspected costs         .0020
```

(The rectangular prior distribution was presented first to one-half of the Ss. The other half first encountered the skewed prior-frequency distribution below.

The following is the record for the past 300 shipments
of the commodity with which you will now be working:

.00-.10
.10-.20
.20-.30 xxx
.30-.40 xxxxxxxxxxxx
.40-.50 xxxxxxxxxxxxxxxxxxxxxxxxxxxx
.50-.60 xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.60-.70 xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.70-.80 xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.80-.90 xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
.90-1.00xxxxxxxxxxx

All other information was identical.)

This information was interpreted for S to make certain that he understood the task. S was then shown that by pressing the "start compute" button on the typewriter, the computer would print either a "1" indicating that the item inspected was "top quality" or a "0" indicating that it was not. After the "1" or "0" was printed, a number was printed which represented the proportion of "top quality" items in the total sample taken to that point. When S was ready to stop sampling and to make a terminal decision he simply typed the letter corresponding to the interval he wished to choose and pressed the "start compute" button. The machine immediately printed the actual proportion for that shipment, .1500 or .0000, (depending on whether S was correct or incorrect), $-.02 \cdot n$ (minus the cost of the sample), and lastly S' s total earnings up to that point in the experiment. A trial ended with a terminal decision.

In addition to storing data and conducting the experiment, the computer, using a random number generator, selected values for p, the true proportion for each trial. These values were selected with probabilities specified by Beta density functions in which $f(p) = B(\alpha, \beta)^{-1} p^{\alpha-1} (1-p)^{\beta-1}$. For the rectangular prior distribution $\alpha = 1$, $\beta = 1$, while $\alpha = 6$, $\beta = 3$ for the skewed distribution. Once the value of p was selected, the computer generated a "1" with probability p and "0" with probability 1-p each time S requested another observation.

Design

Company policy 1 (Table 1) was used only for 3 practice trials. Thereafter only policies 2 and 3 were used. Each subject had 8 trials with each of the 4 combinations of prior distribution and company policy giving a total of 32 trials. (The computer was programmed to automatically inform S after every 8 trials when a change in the decision context was required. The new information was typed out each time a change occurred.) For the first 16 trials S used one prior distribution. The other was used for the last 16 trials. Under this restriction there are 8 different sequences of the 4 experimental conditions. These sequences with the number of Ss in each are given in Table 2.

Table 2

Sequences of experimental treatments with the number of Ss in each. "F" designates the flat prior distribution, "S" designates the skewed one.

Group	First Prior	Company Policies		Second Prior	Company Policies		n
1	F	3	2	S	3	2	6
2	"	3	2	"	2	3	7
3	"	2	3	"	3	2	8
4	"	2	3	"	2	3	6
5	S	3	2	F	3	2	7
6	"	3	2	"	2	3	7
7	"	2	3	"	3	2	7
8	"	2	3	"	2	3	6

The Ss were randomly assigned to the sequences.

Results

For each S the total number of observations taken prior to decision under each treatment was recorded. To allow for the evaluation of subject by treatment interactions, this total was split into the total for even numbered trials and the total for odd numbered trials. In order to obviate the assumption of equal variance-covariance matrices for different sequences of treatments, separate analyses were conducted for the Ss in each of the 8 conditions.

The F-ratios with their respective degrees of freedom for the 8 groups for all effects of interest are presented in Table 3. The largest and most consistent source of variance in

Table 3

F-ratios and degrees of freedom for experimental effects for 8 different groups

Source	Groups 1	2	3	4	5	6	7	8
Subjects	31.91** 5/24	81.47** 6/28	64.59** 7/32	48.87** 5/24	163.36** 6/28	113.39** 6/28	123.72** 6/28	38.33** 5/24
Company policy (cp)	9.08** 1/15	6.62* 1/18	5.19* 1/21	--	4.22 1/18	10.85** 1/18	11.15** 1/18	10.49** 1/15
Prior distribution (Pr)	--	11.28** 1/18	14.72** 1/21	1.79 1/15	1.10 1/18	3.67 1/18	7.20*	--
CP x Pr	2.14 1/15	1.11 1/18	--	--	--	4.21 1/18	--	1.19 1/15
Subject x treatment	2.05 15/24	7.16** 18/28	6.32** 21/32	4.03** 15/24	3.11** 18/28	4.37** 18/28	4.40** 18/28	5.58** 15/24

$*\ p < .05$
$**\ p < .01$

these analyses results from individual differences between Ss in the number of observations taken prior to decision. The extent to which individual differences were present is suggested by the fact that lowest average number of observations per trial for any S was .25, the largest was 22.59, while the mean for all Ss was 9.09.

In all but 2 of the 8 groups, the company policy contributed a significant source of variation. In every group more observations were taken with the 5 alternative policy than with the 3 alternative one. Averaging over all groups, the mean number of predecision observations with the 3 alternative case is 8.23 while that for the 5 alternative scheme is 10.16.

The prior information (the prior frequency distributions) contributed a significant source of variation in only three of the 8 groups. The apparent unreliability of these results is enhanced by the fact that in Groups 2 and 3 Ss took more observations under the skewed prior distribution, while in Group 7 Ss took more observations under the flat prior. This contradiction is readily explained. In all groups, one prior was used for the first 16 trials and the other was used for the last 16 trials. Differences between prior distributions in terms of their effects on the number of observations taken prior to decision are therefore confounded with any systematic trends, e.g., learning or adaptation effects, which might operate simply as a function of time in the task. Just such a systematic effect does appear to be responsible for the differences between prior distributions. First, in every group, more observations were taken in the last 16 trials than in the first 16. Second, the difference between the mean number of observations for the first 16 trials and that for the last 16 trials does not depend on which of the prior distributions is presented first. The relevant means are presented in Table 4.

Table 4

Mean number of predecision observations in the first and last 16 trials when the rectangular prior distribution is first and the skewed prior second, and vice versa.

	First 16 trials	Second 16 trials
Rectangular first	8.41	10.08
Skewed first	8.53	9.79

The F ratios in Table 3 indicate that while the interaction between company policy and prior distribution is non-significant in every group, the interaction between Ss and the 4 treatment combinations is significant in all but one group. Thus it seems that Ss not only differ in terms of the total number of predecision observations taken, but also in terms of their reactions to each experimental condition.

Discussion

The significant S x treatment interactions found in this study are similar to subject interactions reported by Lanzetta and Kanareff (1962) and Irwin and Smith (1957). Such results may be viewed as being composed of at least two components: a) individual differences with respect to systematic changes over time, e.g., rate of learning, and b) individual differences in the extent to which Ss are sensitive to experimental treatments. The treatment means for some Ss vary much more (after being corrected for Subject and Treatment effects) than do those of other Ss. It would be of interest to the study of individual differences in decision making to study the relationship between personality variables and the variability of Ss corrected treatment means. One might speculate that such variability would correlate positively with other measures of sensitivity to the external environment.

It is somewhat of a puzzle that the prior frequency distributions did not have a major effect on the number of observations taken before decision. Certainly the skewed prior distribution provided less uncertainty about p than did the flat prior distribution. With the 3 alternative company policy, for example, the prior probability that the terminal acts will be correct under the skewed prior distribution are approximately .02, .46, and .52 for a, b, and c respectively. Under the flat distribution, all 3 acts are equally probable. The Ss did not appear to make use of this information in deciding how many observations to take. There are at least two possible explanations of this finding. First the result might reflect the general tendency of humans to use probabilistic information inefficiently. Edwards (1964) has found that Ss often fail to reach the degree of certainty in opinions which is justified by data. It is possible that Ss in this experiment did not consider the difference in the prior frequency distributions to be large enough to warrant their making adjustments to account for the difference. On the other hand, it is possible that Ss "should" have taken as much information under the skewed prior as with the rectangular one. (By "should" we mean that this result might be predicted by a "rational" theory of information seeking in decision making.) This possibility follows from the fact that the skewed prior distribution has a smaller variance than the rectangular distribution and, consequently, the probability of values of p close to 0 or 1 being selected is smaller with the skewed than with the rectangular prior. For example, the probability that p will be within .10 of either 0 or 1 is .20 under the rectangular prior and approximately .04 under the skewed prior. Thus homogeneous samples, i.e., samples composed entirely of 1's or 0's are more likely under the rectangular prior. As a general rule (which applies to the two company policies used in this experiment) one should stop sampling sooner if the obtained sample is homogeneous than if it is not. This possibility will be evaluated in detail when optimal information seeking strategies have been derived for this task.

It is reasonable to suppose that almost any "optimal" theory of sequential information seeking would predict that more observations should be taken using the 5 alternative company policy than with the 3 alternative one. The same is true of the results of the studies by Irwin and Smith (1956, 1957) and Becker (1958). At least in certain coarse aspects, therefore, these studies tend to support a "rational" theory of human decision making. At present, however, there is no formal theory which can be applied to the problem presented by the experimental task used in this study. As a result of this deficiency and of the encouraging results of studies by Wiesen and Shuford (1962) and Rapoport (1964), in predicting human behavior from Bayes strategies, an optimal Bayes model is currently being derived which will permit a more detailed investigation of the extent to which human information-seeking may be accounted for in terms of a "rational" theory of behavior.

Summary

An experiment was conducted by a digital computer in which 54 human Ss were faced with the task of sampling from an hypothetical binomial universe in which a proportion, p, of all observations were "top quality". Ss sampled the universe sequentially, stopping after

some number of observations had been made to make a terminal decision by selecting the one of the s mutually exclusive and exhaustive subsets of the unit interval which S believed contained p. The four experimental treatments were defined by the four combinations of the two decision partitions of the unit interval, one involving 3 possible terminal acts, the other having 5 alternatives, and the two prior frequency distributions, one a rectangular distribution over [0 - 1] , the other being negatively skewed. Analysis of variance of the number of predecision observations taken indicated a) significant individual differences; b) significant S by treatment interactions; c) differences attributable to the decision partitions with more observations being taken in the 5 act case than in the 3 act case; and d) no effect of prior frequency distributions, but a tendency to take more observations in the second 16 trials than in the first 16. It is planned to analyze these data from the point of view of optimal Bayesian information-seeking strategies.

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13. ABSTRACT

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