ESD-TR-64-663

PROCEDURAL CONSTRAINT AND TASK PERFORMANCE

November 1964

Thornton B. Roby
Susan Goldberg

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

Project 7682
Task 768203

(Prepared under Contract No. AF19(628)2450 by Tufts University, Medford, Mass.)

ESD-TR-64-663

PROCEDURAL CONSTRAINT AND TASK PERFORMANCE

November 1964

Thornton B. Roby
Susan Goldberg

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

Project 7682
Task 768203

(Prepared under Contract No. AF19(628)2450 by Tufts University, Medford, Mass.)

FOREWORD

This research was supported in part by Decision Sciences Laboratory under Contract No. 19(628) - 2450. Exploratory studies were supported by a consulting contract with the Systems Laboratory of the Rand Corporation.

The assistance of Miss Nancy Sizer, Dr. Teresa Carterette and Miss Jean McMahon is gratefully acknowledged.

ABSTRACT

Persons or groups assigned to certain tasks are typically required to follow institutionally originated rules of action or constraints that limit the range of their task behavior. Ordinarily these procedural rules are based on general experience with the task situation and are designed to guard against serious errors: however they have the secondary effect of reducing the potential for superior enterprise or discretion on the part of the performing agent. The question of practical importance concerns the specific conditions that militate in favor of either increased or decreased superordinate control.

The present investigation is to develop a laboratory methodology for studying this problem. The general task condition used was an abstract maze in which subjects had to select a path between designated points. An attempt was made to produce experimental analogues of "visibility," or task information accessible to the subject, and environmental "bias," or general favorability for exploratory behavior.

Three formal studies are reported. They indicate the relevance of the experimental factors, but the results are too inconsistent across studies to be definitive. Based on these results, certain modifications are suggested for future research.

PUBLICATION REVIEW AND APPROVAL

This Technical Report has been reviewed and is approved.

Donald W. Connolly
DONALD W. CONNOLLY
Act'g Chief, Decision Techniques Division
Decision Sciences Laboratory

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

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TABLES

PROCEDURAL CONSTRAINT AND TASK PERFORMANCE

Introduction

The series of studies reported here constitutes an attempt to investigate, in a closely controlled laboratory setting, several very general aspects of the conditions governing an organism's behavior and his associated performance in a specified task environment. One of these conditions is the option, freedom of choice, or latitude, the organism has to modify task behavior in response to information or to whim. The other important condition is task visibility, the nature and quality of the information received by the organism concerning the task situation.

The real life counterparts of these factors may take a variety of forms. Option may be determined by external injunction or by internal compunction. Constraints upon option may be explicit or diffuse, and they may be expressed as negative prohibitions or as positive obligations. A recent theoretical paper[1], however, argues that a uniform conceptual framework may be applied to all instances of behavioral constraint. The particular form of constraint exercised in these studies is external and prohibitive, and is embodied in certain explicit task instructions.

Visibility, in real life, may be a product of direct on-the-spot information, of more subtle orienting cues, or of conceptual or sensory aids. As these connotations imply, visibility is defined by the interaction between the organism and his environment, conditions that afforded optimal visibility

---

[1]Roby, T. B. Behavioral Freedom and Constraint. J. Psychol. Studies (in press).

to a trained woodsman might leave a tenderfoot completely without guidance. Here again, however, the construct can probably be quantified in any given situation.

The principal hypothesis that has given structure to these studies may be phrased in common sense terms: it is that option is an asset to performance precisely to the extent that the organism has the visibility to use it effectively, and, conversely, that visibility can be employed only if the organism has sufficient option to exploit it. Latitude to modify procedures in performing a task is of little avail, and may be hazardous, if there is not enough information accessible in the task situation; and information without option may be no more than a source of frustration.

The practical or social importance of the hypothesized functional relation stems from the fact that in many real life situations there is a choice between supplying an agent with extensive information and task expertise on the one hand, or "programming" him with precise, detailed, instructions on the other hand. The relative economy and effectiveness of these two policies, or of compromise policies, undoubtedly depends upon specific properties of the task environment and of the agent.

From an experimental standpoint, then, the interesting question is not so much the truth or falsehood of the basic hypothesis as the determination of task conditions under which the implied relationship holds. That is, it is certainly possible to "rig" a task situation under which the increasing utility of option with increased visibility would be nothing more than a trivial demonstration. The methodological problem is to construct a task that is rich enough to permit a wide range of behavior yet austere enough so that the essential task conditions can be controlled or measured. The following section describes a promising, but far from complete, development along this line.

Experiment 1

The task was an abstract maze presented as a geographical area in which cities were labeled by nonsense syllables. The subject was given a starting point and a destination which could be reached in a fixed number of one-step moves and was to try to complete his trip as rapidly as possible. One of the main characteristics of the map was that the availability of moves from one city to the next varied for different cities so that the speed with which the subject could progress was determined in part by the choice of path. An example of the maze is shown in Fig. 1. The start of the trip was the extreme left hand corner (labeled fim) and the destination was the extreme right hand corner (jep). There were three airlines servicing the area. These were indicated by the three different colors and differed in the frequency with which they offered flights.

Option was varied by controlling the route S could follow by limiting his use of the airlines. As can be seen on the map, the blue line (E) offered three flights a day, the red line (N) offered two flights daily, and the grey line (T) offered one flight daily. Under the low option condition, 0_1, subjects could use only the blue line; under the medium option conditions, 0_2, they could use both the blue and the red line and under high option, 0_3, they could use all three. It should be noted that increased option conditions are inclusive; that is, under each higher option condition all the choices of the lower option conditions are available plus some new ones. Thus 0_2 enables the subject to do anything that he could do in 0_1 plus the new choices on the red line. 0_3 permits the subject to use all the flights available in 0_1 and 0_2 plus those on the grey line.

The immediate advantage of the higher option conditions is however, offset by the fact that the low frequency flights lead to cities that are difficult to get out of. Thus it may happen that an S who, by choice or instruction, passes up a low frequency flight and waits for a high frequency flight will make more rapid progress in the long run. The S's opportunity to assess the comparative prospects associated with these alternative decisions was in part a function of the existing visibility conditions next described.

During the experiment, the subject saw the available flights on a memory drum apparatus with a variable aperture. This consisted of an Esterline-Angus recorder placed behind a black screen with a rectangular aperture. Three different templates were used to cover different sized portions of the aperture and this determined the visibility conditions. Under the lowest visibility condition, V_1, S could see five flights at a time; under the medium visibility, V_2, he could see ten flights; and under high visibility he could see twenty flights. The tape ran at the maximum chart speed under which 37 new items passed a given point each minute. Subjects were allowed to choose flights only as long as they were visible. Hence, under low visibility for example, S could see an item five time units before his last opportunity to choose it. The tape contained four different randomizations of all the possible flights for a given map and each randomization was considered one "day". The only restriction on these randomizations was that no item could be repeated within a block of 10. The listing viewed by the subject included a flight number, the two cities which were connected, and the airline letter. When a subject chose a particular flight, he read this information to the experimenter, who recorded it.

The design was a latin square in which each subject had all nine combinations of option and visibility (Table 1). There were three different maps, all having the same structure and differing in the particular set of attached nonsense syllables and in the item orders on the tape. Each subject used the same map for all three of his exposures to a given option condition. Preliminary studies had indicated that learning effects were not likely to prejudice measures of performance.

At the start of the experimental session, E read the directions to S who followed them on an instruction sheet. A practice problem under 0_2V_2, preceded the experiment proper. At the start of each trial S was given the map with the nonsense syllables and the three airlines in color, and told which airlines he could use. He was not given the flight frequencies for the various airlines. E recorded the actual choices and length of time required for each trip.

The subjects were female Tufts summer school students who were paid at an hourly rate for their participation. The experiment took approximately 2 hours.

Results

The basic performance score used was number of flights exposed to the subject from the time he started each maze until he reached the destination. Since the experiment utilized a constant presentation speed, this measure is directly related to the amount of time required to traverse the maze. These scores were found to be approximately normally distributed and were subjected to analysis of variance. The results are shown in Table 2. Subjects, maps and experimental conditions were significant. The order of presentation was not significant, supporting the earlier observation that learning effects are minimal in this task. Visibility was highly significant ($p < .01$) and the conditions were ordered as expected. The means were 274.6 for V_1, 258.0 for V_2 and 201.0 for V_3 (Table 3). The critical difference for a one-tailed test at the .01 level is 61.5 which is exceeded by $V_1 - V_3$. Option was significant at the .05 level. It was predicted that performance would improve as option was increased. Thus the mean number of exposures for the option conditions should be ordered $0_1 > 0_2 > 0_3$. This prediction was confirmed with the means being 258.7 for 0_1, 247.0 for 0_2, and 227.9 for 0_3 (Table 3). The critical difference for a one-tailed test at the .05 level is 29.1 in this case and this was exceeded by $0_1 - 0_3$. As with visibility it is again the difference between the two extreme conditions which contributes most heavily to the effect. The interaction for option and visibility, which was significant at the .05 level, is illustrated graphically in Fig. 2. Performance scores for the visibility condition are relatively close together under the low option condition and diverge considerably under the high option condition. The most marked improvement with increased option occurs under the high visibility condition. These results support the notion of a positive interaction between option and visibility.

Because the effect of option was only marginally significant and visibility and the option x visibility interaction was significant it seemed possible that the option effect was largely a by-product of the interaction with visibility. It was observed that subjects tended to be rather cautious in their choices of connections so that the new opportunities in the higher option conditions were used only rarely. While variability of path as measured by the mean uncertainty in bits did increase as option increased (.57 for 0_1, .97 for 0_2, and 1.20 for 0_3) it was felt that the procedure of increasing option by adding less desirable alternatives was probably depressing the effect of option. If this is true a more clearly independent option effect should emerge in a task where the additional choices of the higher option conditions presented more useful alternatives to the subjects. It was with this in mind that the task for the second experiment was developed.

Experiment 2

The results of the first study, and particularly those on option, also pointed up an ambiguity in the initial hypothesis. Constraints, as imposed by some superordinate agency, are not usually neutral with respect to task performance. They are typically intended to improve performance of the task agent above what might be expected from uninstructed performance.

In practice such constraints or standardized procedures may be misguided. This will be true, for example, whenever the constraining rules which must be applied to a variety of circumstances, fail to take unique or special circumstances into account. It is, of course, just these conditions that emphasize the importance of visibility.

In this study, constraints which improve performance over chance are said to have a favorable bias. Constraints which depress performance (whether intentionally or otherwise) are biased unfavorably and those which do not affect performance are neutral.

Taking the effect of constraint bias into account, a more detailed hypothesis emerges, as shown in Fig. 3. The three independent variables are Option (0_1, 0_3) visibility (V_1, V_3) and bias (E_1, E_3). Four hypothetical performance lines are generated by the latter two. Comparing first the two lines for low visibility, it is assumed that the highly constrained performance is more affected by constraint bias: negative bias with low option produces the poorest performance, and there is an equal degree of improvement for a favorable bias. The constraint biases become less influential as constraints are reduced (at 0_3) and converge on chance performance (assuming very low visibility).

For high visibility, with unfavorable constraint, S should do better than for low visibility, but not much better because of the imposed restraint. As option increases, this improvement over low visibility performance increases. High visibility also should improve performance over low visibility at positive bias, but not as much (presumably there will be a "ceiling" effect). As option increases, however, high visibility Ss should improve as contrasted with low visibility Ss who will continue to perform at chance.

For the high visibility condition, as for low visibility, bias conditions converge at high option, but move towards a higher asymptote, which is presumably optimal for the task.

In order to test these predictions, the present experiment thus undertook to vary systematically the direction as well as the degree of constraint.

The task design for this experiment resembled that for experiment 1 in using an abstract maze with a series of points labeled by nonsense syllables. The task was again presented to the subject as a trip through a geographical area in one-step flights. The structure of the map itself was changed. The basic maze for this experiment consisted of a starting point and a destination separated by two sets of twelve points lying on parallel lines. (Fig. 4) On the top line, each city had four outgoing flights each day. On the bottom line, each city had two outgoing flights each day. When a subject is attempting to minimize his waiting time, a connection which takes him to a point on the top line may be considered a "good" connection since he is likely to make his next connection more rapidly from the top line than from the bottom line. On the other hand trying to get an outgoing flight from a city on the bottom row is likely to take more time and connections leading to cities in the bottom row may be considered "bad" connections.

The map shown in Fig. 4 is considered to represent a neutral environment since each point within the maze has an equal number of good and bad outgoing connections. In other words for any given point, the probability of getting a good connection is the equal to the probability of getting a bad connection. When the probability of getting a good connection exceeds the probability of getting a bad connection, the constraint is defined as positively biased or favorable: when the probability of making a bad connection is greater than that of making a good connection, the constraint is defined as unfavorable.

To obtain the mazes actually used in the experiment, certain connections were restricted from use. The number of prohibited connections in a given maze determined the option condition. The kind of connections which were prohibited determined environmental bias. The method for eliminating connections was as follows:

Considering the top row of points as "good" cities, and the bottom row as "bad" cities, there are four specific types of connections, those which connect two good cities (GG), those which connect a good city to a bad city (GB), those which connect a bad city to a good one (BG) and those which connect two bad cities (BB). In order to reduce the interaction between constraints at neighboring junctures, constraints were applied only at alternate junctures. This left 12 GG connections, 12 GB connections, 6 BG connections and 6 BB connections available for manipulation. The number and kind of connection deleted for each option-bias condition are shown in Table 4. Because the subjects had to be allowed at least one path out of each point, it was impossible to structure the option conditions so as to maintain the inclusion property; that is, the property that constraints at the low option condition included the constraints at the higher option condition. Each option condition always occurred on the same map, that is with the same set of syllables and the same order of item listings. The available flights were displayed as before with the same three visibility conditions, V_1 exposing five flights, V_2 exposing ten flights, and V_3 exposing twenty flights. The lists for the tapes were prepared by randomizing the list of 72 connections with the restriction that any connection which occurred twice must occur once in each half of the list. Two different randomizations were prepared for each map and these were repeated five times each on the tape. The apparatus used in Study 1 was modified by the addition of a stop-start toggle switch which Ss could use to obtain longer scanning times. It was hoped that this would yield a time measure which was somewhat independent of the number of items exposed.

The Ss were 18 undergraduates at Tufts University who had volunteered as experimental subjects at the beginning of the fall semester. They were paid at an hourly rate for participation in the experiment. The session began with a practice trip under 0_2V_2. Subjects then proceeded through a predetermined sequence of nine trips under each combination of option and visibility. For any given subject all nine trips were under the same bias condition. A session lasted between 1 1/2 and 2 1/2 hours depending on how rapidly S worked through the mazes.

The design (shown in Table 5) is Lindquist's type VI with Option and Visibility as within-subject variables and bias as a between-subjects variable.

During the experiment E recorded the time in minutes for each trip, the actual connections taken, and the last exposed item from which the number of items exposed was later computed. Very few subjects made use of the stop switch and none used it extensively so that the time scores were not independent of number of items exposed. Hence the latter was used for all analyses and the time scores were not analysed.

The analysis of variance of number of items exposed is shown in Table 6. Only subjects, and the main effects of option and visibility are significant, both at the .01 level. It was expected that increasing option would improve performance and the mean number of exposures for the three option conditions would be ordered $0_1 > 0_2 > 0_3$. The actual means were 351.5, 359.9 and 241.0 for 0_1, 0_2, and 0_3 respectively. The critical difference at the .01 level for a one-tailed test is 55.7. This difference is exceeded by 0_1-0_3 and 0_2-0_3, but the difference between 0_1 and 0_2 is not significant. The mean number of exposures for the visibility conditions was expected to decrease as visibility increased so that $V_1 > V_2 > V_3$. The actual means were 375.4, 323.8 and 253.2 for V_1, V_2, and V_3 respectively. The differences were again compared with the critical difference of 55.7: V_1-V_3 and V_2-V_3 are significant while V_1-V_2 falls just short of the critical difference.

While the effect of bias conditions was not significant, the trends were puzzling. It was expected that the number of exposures would increase as the constraint became less favorable. The favorable condition, E_3 required fewer exposures than the unfavorable condition E_1 but the neutral condition E_2 yielded lower scores than E_3. This inversion holds up over 0_2, 0_3, V_2, and V_3 while the ordering over bias conditions is as expected for 0_1 and V_1. This suggests that constraint bias might interact with both option and visibility if it were manipulated in a way that did not confound it with subject differences.

The fact that there was no interaction between option and visibility was also puzzling, partly because such an interaction is predicted by the theoretical framework and partly because option and visibility did interact in the previous experiment. In an attempt to account for these results, it was decided to examine more closely the actual patterns of choice behavior. A tabulation was made of the frequency with which each of the four kinds of connections was chosen under each level of the main conditions. Over all conditions there were 855 GG choices, 450 choices of both GB and BG, and 351 BB choices. It should be noted that the number of GB choices must equal the number of BG choices as a function of the structure of the maze and that this is not a behavioral phenomenon.[1] While GG was chosen about twice as often as any of the others, the large number of choices of GB and BB connections indicates that the design of the maze did present less desirable alternatives which were useful to subjects. This form of the distribution remained essentially the same over all levels of the main variables (with minor exceptions in the case of 0_1 and E_2). Thus, none of the main variables actually changed the pattern of choices.

One factor which seemed to be a possible source of artifacts was the order in which items turned up on the lists. The effect of lists as an experimental variable cannot be determined accurately since lists were confounded with option conditions in the design. As a crude estimate of the influence of

---

[1]Since the number of choices entering a point must equal the number leaving a point BB+GB = BB+BG and BG+GG = GB+GG, hence BG $\doteq$ GB.

lists, each map was traversed once under each condition using the arbitrary rule of always taking the first relevant connection. The number of exposures required to complete the maze in this fashion may be seen in Table 7. Visibility scores are as expected. 0_2 tended to require more exposures than 0_1. This finding is consistent with the subject data and suggests that this effect in the subject data is an artifact of list order. The scores for bias conditions show E_2 to be the worst and E_1 the best condition (unlike the empirical results). Thus, the imposed constraint bias conditions were not likely to have the effect that was intended in constructing the task.

These observations pointed up the need to use a larger number of lists and randomizations in the next experiment.

Experiment 3

The main changes introduced in the third experiment involved an increase in the number of maps and randomizations, the manipulation of environment as a within subjects variable and some changes designed to make the option conditions inclusive and more widely separated.

The structure of the maze remained the same but the number of connections was doubled at each point. Restrictions were applied as before and the number and kind of restrictions for each condition may be seen in Table 8. The pattern of restriction for 0_2 and 0_3 is identical to that of the previous experiment. For 0_1, the total number of restrictions was increased. This was an attempt to increase the difference between 0_1 and 0_2 which was nonsignificant in the previous experiment. The larger number of connections also made it possible to choose the restrictions so that within any environmental condition the option conditions were inclusive. This is, under 0_2 the subject had available all the connections he had in 0_1 plus some new ones, and under 0_3 he had all those connections available under 0_1 and 0_2 plus some new ones.

These restrictions were displayed to subjects on the tape using letter codes as shown below:

0_3	E_3	A
	E_2	B
	E_1	C
0_2	E_3	AD
	E_2	BE
	E_1	CF
0_3	E_3	ADG
	E_2	BEH
	E_1	CFJ

There were nine different sets of nonsense syllables attached to the maze, three being the same as those used in experiment 2. Thus there were actually nine distinct maps. For each map the order in which connections appeared on the tape was determined by randomizing the total list of connections so that each connection appeared an equal number of times in each half. Three such randomizations were prepared for each map. After the first few pilot sessions it became evident that 3 days of connections would not enable all the subjects to finish the maze. A fourth day was added to each of the tapes by repeating the first randomization.

The physical setup was identical to that of the earlier experiment. Subject sat in front of the table with the black screen. The Esterline-Angus was placed behind the screen so that the tape could be viewed through the aperture which was varied in size by use of the same three templates. The chart was again run at maximum speed and the subject had a stop-start toggle switch available for use.

Twenty-seven subjects served in the experiment. The majority were Tufts University summer school students. Six students going to high school or prep school were included and these were distributed equally over experimental conditions. Other subjects included non-Tufts undergraduates, graduate students and graduate students' wives. All were between the ages of 16 and 25. Subjects were seen individually and were paid at an hourly rate for participating.

Each subject took nine "trips," one under each option environment condition, using each map once. For any given subject, all nine trips occurred under the same visibility. Visibility was selected as the between subjects variable because it seemed the one least likely to be affected by individual differences. As a rule, the length of the session varied according to the visibility condition under which it was run with V_1 taking about 2 1/2 hours, V_2 taking about 2 hours and V_3 taking about 1 1/2 hours. Because of the time differences the subjects as numbered in the design (Table 9) were run in random order with the restriction that a set of three different visibilities had to be completed before any visibility condition could be repeated.*

The overall design is again similar to Lindquist's Type VI with option and environment as within subject variables and visibility as a between subject variable. The assignment of maps on a within subjects variables was superimposed upon the original type VI design. The design and order of conditions may be found in Table 9. It should be noted that option-environment combinations are balanced over maps and order positions and maps are balanced over option-environment and order but not over combinations of option, environment and order.

Results

The measure of performance was the number of flights exposed to the subject from start to finish of each trip. Little use was made of the start-stop switch so that the time measure was not independent. The results were subjected to analysis of variance first according to Lindquist's Type VI design with separate error terms for the various interactions and then introducing the factors of maps, orders, and trials and using a residual error term.

---

*Because of an error found in the tapes subjects 16 and 2 as originally run were rejected and replaced by two new subjects. These two occur last for this reason and not as a consequence of the randomization procedure. This also accounts for some cases where the visibility sets are not complete in the order listed. The actual order in which subjects were run was 1, 3, 23, 18, 19, 11, 27, 6, 4, 14, 10, 20, 12, 21, 7, 26, 17, 13, 24, 9, 22, 5, 15, 8, 25, 16, and 2.

The two resulting tables are given in Tables 10 and 11. Subjects, visibility, and option are highly significant and the interaction between option and environment is marginally significant in both tables. In the second table, the only other variable of significance is maps which is significant with $p < .001$.

The significance of these findings can be further clarified by examining the means for various conditions. For visibility, the mean scores are 314.8, 289.9, and 197.2 for V_1, V_2, and V_3 respectively. The order $V_1 > V_2 > V_3$ is as expected. The differences $V_3 - V_1$ and $V_3 - V_2$ exceed the critical difference of 38.5 for a one-tailed test at the .001 level. For the option conditions the order $0_1 > 0_2 > 0_3$ is as expected with the means being 299.2, 254.0, and 248.7 for 0_1, 0_2, and 0_3 in the order. The critical difference of 38.5 is exceeded by the differences $0_2 - 0_1$ and $0_3 - 0_1$.

The interaction between option and bias is illustrated graphically in Fig. 5. Option conditions are most widely separated under E_1 and least divergent under E_3. From the Table (12) of mean differences, it can be seen that the differences $0_1E_1 - 0_2E_1$, $0_1E_1 - E_3E_1$ and $0_1E_2 - 0_2E_2$ are significant. None of the differences between option conditions are significant under E_3. Hence, increasing option appears to improve performance significantly with an unfavorable bias, while it makes little difference in a favorable bias. In Fig. 5 it should also be noted that it is only under the lowest option condition 0_1 that performance improves consistently as the constraint bias becomes more favorable. From Table 12 it can be seen that the difference $0_1E_1 - 0_1E_3$ is significant. This is the only statistically significant difference between bias conditions within an option condition. Bias effects within 0_2 and 0_3 do not show any consistent trends and there are no significant differences for bias conditions within 0_2 or 0_3. Thus bias differences affect performance most where the subject's range of choices is most restricted. It might be said that under low option the subject is at the mercy of the constraint bias. When it is favorable, he does well and when it is unfavorable he does poorly. Under less restrictive conditions performance is relatively independent of the bias.

Since differences between maps do not reflect any particular dimensional criterion, the significance of maps as a factor cannot be meaningfully interpreted. The finding that map differences are significant serves to point up again the fact that random fluctuations in item order influence performance.

Discussion

Neither the results from experiment 2 nor experiment 3 seem to fit the pattern that was expected from the theoretical considerations described above. Moreover, there are marked discrepancies between the relative performance values obtained in those two experiments. Some of these discrepancies can be explained by differences in procedure but, taken as a whole, they indicate that further experimentation along this particular line probably ran a continual risk of interpretative error because of sampling anomoly or experimental artifact. It seemed advisable, therefore, to attempt to summarize the implications of these studies, such as they are, and to seek new approaches to a more sensitive test of the theoretical framework.

The visibility manipulation used in all these studies appears to be operationally meaningful and to give consistent results in the natural direction. Option has a more problematic effect but, even more surprising, the interaction between option and visibility is much less consistent than expected: it shows up clearly only in the first study. Constraint bias, finally, does not seem to have been varied adequately by the present experimental techniques. Only in the third study, under low visibility and option conditions, does it appear to have an appreciable effect on performance.

If this series of studies does not warrant any very far reaching substantive generalization, it does provide several important methodological lessons and suggestions. The general research tactic employed here was to study the performance of naive Ss in a highly artificial task environment. This still seems to represent a worthwhile approach but it probably needs modification in at least three respects.

First, it will be necessary to introduce a greater degree of discretionary choice on the part of S to increase the meaningfulness of choices in some sense. That is, S should be made aware of the comparative advantages and risks of the action alternatives that are available under various conditions. If possible, choices should probably be simultaneous rather than based on acceptance or refusal of single action alternatives in sequence.

A second desideratum in a task would be a more diagnostic form of process measure. The task used in these studies permitted a complete record of the sequence of 'flights' taken for each traversal of the maps. Yet these did not appear to relate very clearly to overall performance and did not seem to be consistently influenced by the experimental conditions. It may be necessary to supplement such objective data by some form of stimulated recall in order to find out what is really going on.

Finally, although it is inherent in the purpose of the task environment that it must contain some element of chance, greater care must be taken to insure that bad luck at one juncture, or even momentary poor judgment, does not permanently impair S's prospects for the entire task. That is, the task should be organized in such a way as to minimize the carry over effect of the performance outcome on successive subtasks.

Table 1

Design of Experiment 1

Trial

Ss	1	2	3	4	5	6	7	8	9
1	O_3V_1 I	O_2V_2 II	O_1V_3 III	O_2V_3 II	O_1V_1 III	O_3V_2 I	O_1V_2 III	O_3V_3 I	O_2V_1 II
2	O_2V_3 III	O_1V_1 I	O_3V_2 II	O_1V_2 I	O_3V_3 II	O_3V_1 III	O_3V_1 II	O_2V_2 III	O_1V_3 I
3	O_1V_2 II	O_3V_3 III	O_2V_1 I	O_3V_1 III	O_2V_2 I	O_1V_3 II	O_2V_3 I	O_1V_1 II	O_3V_2 III
4	O_1V_3 II	O_3V_1 III	O_2V_2 I	O_2V_2 III	O_2V_3 I	O_1V_1 II	O_2V_1 I	O_1V_2 II	O_3V_3 III
5	O_3V_2 I	O_2V_3 II	O_1V_1 III	O_2V_1 II	O_1V_2 III	O_3V_3 I	O_1V_3 III	O_3V_1 I	O_2V_2 II
6	O_2V_1 III	O_1V_2 I	O_3V_3 II	O_1V_3 I	O_3V_1 II	O_2V_2 III	O_3V_2 II	O_2V_3 III	O_1V_1 I
7	O_2V_2 III	O_1V_3 I	O_3V_1 II	O_1V_1 I	O_3V_2 II	O_2V_3 III	O_3V_3 II	O_2V_1 III	O_1V_2 I
8	O_1V_1 II	O_3V_2 III	O_2V_3 I	O_3V_3 III	O_2V_1 I	O_1V_2 II	O_2V_2 I	O_1V_3 II	O_3V_1 III
9	O_3V_3 I	O_2V_1 II	O_1V_2 III	O_2V_2 II	O_1V_3 III	O_3V_1 I	O_1V_1 III	O_3V_2 I	O_2V_3 II

Roman numerals refer to maps

Table 2

Analysis of Variance of Number of Items Exposed in Experiment 1

Source	SS	df	Ms	F
Subjects	41, 145. 6	8	5, 143. 2	2. 63*
Maps	94, 145. 6	2	47, 072. 8	24. 10**
Order	20, 130. 4	8	2, 516. 3	1. 28
Tasks	113, 924. 8	8	14, 240. 6	7. 29**
Options	13, 104. 2	2	6, 552. 1	3. 35*
Visibility	80, 428. 6	2	40, 214. 3	20. 59**
O x V	20, 392. 4	4	5, 098. 1	2. 61*
Error		54	1, 952. 7	

*$p < .05$

**$p < .01$

Table 3

Condition Means for Number of Items Exposed in Experiment 1

	V_1	V_2	V_3	$\bar{X}$
0_1	284.0	273.0	219.1	258.7
0_2	265.8	246.7	228.7	247.0
0_3	273.9	254.4	155.2	227.9
$\bar{X}$	274.6	258.0	201.0	

Table 4

Number and Type of Restrictions for Option and Environment Conditions in Experiment 2

	Option								
	0_1			0_2			0_3		
Environment	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
Type of Conn.									
GG	8	6	4	6	4	2	4	2	0
GB	4	6	8	2	4	6	0	2	4
BG	4	3	2	3	2	1	2	1	0
BB	2	3	4	1	2	3	0	1	2
Total	18	18	18	12	12	12	6	6	6

Option 0_1 = Low

0_2 = Medium

0_3 = High

Environment E_1 = Unfavorable

E_2 = Neutral

E_3 = Favorable

Table 5

Design of Experiment 2

Subject No.	Trial No. 1	2	3	4	5	6	7	8	9
1(E_3) 10(E_2)	O_1V_1	O_2V_2	O_3V_3	O_2V_3	O_3V_1	O_1V_2	O_3V_2	O_1V_3	O_2V_1
2(E_2) 11(E_1)	O_2V_3	O_3V_1	O_1V_2	O_3V_2	O_1V_3	O_2V_1	O_1V_1	O_2V_2	O_3V_3
3(E_1) 12(E_3)	O_3V_2	O_1V_3	O_2V_1	O_1V_1	O_2V_2	O_3V_3	O_2V_3	O_3V_1	O_1V_2
4(E_3) 13(E_2)	O_2V_2	O_3V_3	O_1V_1	O_3V_1	O_1V_2	O_2V_3	O_1V_3	O_2V_1	O_3V_2
5(E_2) 14(E_1)	O_3V_1	O_1V_2	O_2V_3	O_1V_3	O_2V_1	O_3V_2	O_2V_2	O_3V_3	O_1V_1
6(E_1) 15(E_3)	O_1V_3	O_2V_1	O_3V_2	O_2V_2	O_3V_3	O_1V_1	O_3V_1	O_1V_2	O_2V_3
7(E_3) 16(E_2)	O_3V_3	O_1V_1	O_2V_2	O_1V_2	O_2V_3	O_3V_1	O_2V_1	O_3V_2	O_1V_3
8(E_2) 17(E_1)	O_1V_2	O_2V_3	O_3V_1	O_2V_1	O_3V_2	O_1V_3	O_3V_3	O_1V_1	O_2V_2
9(E_1) 18(E_3)	O_2V_1	O_3V_2	O_1V_3	O_3V_3	O_1V_1	O_2V_2	O_1V_2	O_2V_3	O_3V_1

Table 6

Analysis of Variance for
Number of Exposed Items in Experiment 2

Source	SS	df	Mean Sq.	F
Total	2,973,018.20	161	18,465.95	-----
Between Ss	687,904.64	17	40,464.97	2.55*
Bias Conditions	128,717.68	2	64,358.84	1.73
Replications	1,375.21	1	1,375.21	-----
Error Between	559,186.96	15	37,279.13	-----
Within Ss	2,285,113.56	144	15,868.84	
Option	475,167.64	2	237,583.82	22.09**
Visibility	406,260.23	2	203,130.12	19.41**
0 x V	61,079.99	4	15,270.00	1.85
0 x B	87,363.77	4	21,840.94	2.03
V x B	17,967.87	4	4,491.97	
0 x V x B	105,118.01	8	13,139.75	1.59
$Error_W$	1,132,156.05	120	9,434.63	
$Error_1$	322,623.48	30	10,754.12	
$Error_2$	313,930.13	30	10,464.33	
$Error_3$	495,602.44	60	8,260.04	

*$p < .05$

**$p < .01$

0 and 0 x B are tested against $Error_1$, V and V x B against $Error_2$, 0 x V and 0 x V x B against $Error_3$. B is tested against Error Between.

Table 7

Number of Items Exposed
in Experiment 2
(Taking the First Relevant Connection)

		V_1	V_2	V_3	$\sum$
	O_1	211	310	122	643
E_3	O_2	273	115	115	949
	O_3	229	108	153	490
		1,001	691	390	2,082
	O_1	394	454	266	1,114
E_2	O_2	273	273	114	660
	O_3	230	108	86	424
		897	835	466	2,198
	O_1	266	211	211	688
E_1	O_2	561	273	129	963
	O_3	153	108	86	347
		980	592	426	1,998

Table 8

Number and Type of Restrictions
for 0 and E Conditions in Experiment 3

	Option								
	0_1			0_2			0_3		
Environment / Type of Conn.	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
GG	12	8	4	6	4	2	0	2	4
GB	4	8	12	2	4	6	4	2	0
BC	6	4	2	3	2	1	0	1	2
BB	2	4	6	1	2	3	2	1	0
Total	24	24	24	12	12	12	6	6	6

Table 9

Option and Visibility Design for Experiment 3

Subject Nos. V_1 V_2 V_3	Trial No. 1	2	3	4	5	6	7	8	9
1 2 3	$\underline{1}\,O_1E_1$	$\underline{2}\,O_2E_2$	$\underline{3}\,O_3E_3$	$\underline{4}\,O_2E_3$	$\underline{5}\,O_3E_1$	$\underline{6}\,O_1E_2$	$\underline{7}\,O_3E_2$	$\underline{8}\,O_1E_3$	$\underline{9}\,O_2E_1$
4 5 6	$\underline{3}\,O_2E_2$	$\underline{4}\,O_3E_3$	$\underline{5}\,O_2E_3$	$\underline{6}\,O_3E_1$	$\underline{7}\,O_1E_2$	$\underline{8}\,O_3E_2$	$\underline{9}\,O_1E_3$	$\underline{1}\,O_2E_1$	$\underline{2}\,O_1E_1$
7 8 9	$\underline{5}\,O_3E_3$	$\underline{6}\,O_2E_3$	$\underline{7}\,O_3E_1$	$\underline{8}\,O_1E_2$	$\underline{9}\,O_3E_2$	$\underline{1}\,O_1E_3$	$\underline{2}\,O_2E_1$	$\underline{3}\,O_1E_1$	$\underline{4}\,O_2E_2$
10 11 12	$\underline{7}\,O_2E_3$	$\underline{8}\,O_3E_1$	$\underline{9}\,O_1E_2$	$\underline{1}\,O_3E_2$	$\underline{2}\,O_1E_3$	$\underline{3}\,O_2E_1$	$\underline{4}\,O_1E_1$	$\underline{5}\,O_2E_2$	$\underline{6}\,O_3E_3$
13 14 15	$\underline{9}\,O_3E_1$	$\underline{1}\,O_1E_3$	$\underline{2}\,O_3E_2$	$\underline{3}\,O_1E_3$	$\underline{4}\,O_2E_1$	$\underline{5}\,O_1E_1$	$\underline{6}\,O_2E_2$	$\underline{7}\,O_3E_3$	$\underline{8}\,O_2E_3$
16 17 18	$\underline{2}\,O_1E_2$	$\underline{3}\,O_3E_2$	$\underline{4}\,O_1E_3$	$\underline{5}\,O_2E_1$	$\underline{6}\,O_1E_1$	$\underline{7}\,O_2E_2$	$\underline{8}\,O_3E_3$	$\underline{9}\,O_2E_3$	$\underline{1}\,O_3E_1$
19 20 21	$\underline{4}\,O_3E_2$	$\underline{5}\,O_1E_3$	$\underline{6}\,O_2E_1$	$\underline{7}\,O_1E_1$	$\underline{8}\,O_2E_2$	$\underline{9}\,O_3E_3$	$\underline{1}\,O_2E_3$	$\underline{2}\,O_3E_1$	$\underline{3}\,O_1E_2$
22 23 24	$\underline{6}\,O_1E_3$	$\underline{7}\,O_2E_1$	$\underline{8}\,O_1E_1$	$\underline{9}\,O_2E_2$	$\underline{1}\,O_3E_3$	$\underline{2}\,O_2E_3$	$\underline{3}\,O_3E_1$	$\underline{4}\,O_1E_2$	$\underline{5}\,O_3E_2$
25 26 27	$\underline{8}\,O_2E_1$	$\underline{9}\,O_1E_1$	$\underline{1}\,O_2E_2$	$\underline{2}\,O_3E_3$	$\underline{3}\,O_2E_3$	$\underline{4}\,O_3E_1$	$\underline{5}\,O_1E_2$	$\underline{6}\,O_3E_2$	$\underline{7}\,O_1E_3$

Underscored numbers indicate maps

03 (high)	F (E_3)	A
	N (E_2)	B
	U (E_1)	C
02 (med.)	F (E_3)	A D
	N (E_2)	B E
	U (E_1)	C F
01 (low)	F (E_3)	A D G
	N (E_2)	B E H
	U (E_1)	C F J

Table 10

Analysis of Variance 1
Option and Visibility for Experiment 3

Source	Ss	df	$\bar{x}$ Sq	F	P
Between Ss	945, 158. 22	26	36, 352. 24	7. 11	$\angle .001$
Visibility	621, 748. 47	2	310, 874. 24	23. 07	$\angle .001$
$Error_b$	323, 409. 75	24	13, 475. 41	---	---
Within Ss	1, 104, 430. 45	216	5, 113. 10		
Option	125, 083. 13	2	62, 541. 56	11. 31	$\angle .001$
Environment	3, 845. 99	2	1, 922. 00	---	---
OE	40, 918. 21	4	10, 229. 55	2. 79	$\angle .05$
OV	26, 394. 25	4	6, 586. 06	1. 19	---
VE	14, 576. 65	4	3, 644. 16	---	---
OVE	35, 635. 74	8	4, 454. 46	1. 22	---
Total $Error_W$	858, 026. 48	184	4, 663. 19	---	---
$Error_{W1}$	265, 424. 40	48	5, 529. 67	---	---
$Error_{W2}$	270, 354. 47	48	5, 632. 38	---	---
$Error_{W3}$	322, 247. 61	88	3, 661. 90	---	---

Table 11

Analysis of Variance 2
Including Maps, Trials, Order for Experiment 3

Source	Ss	df	Sq	F	p
Between Ss	945,158.22	26	36,352.24	7.11	$<.001$
Visibility	621,748.47	2	310,874.24	29.26	$<.001$
Order	153,451.97	8	19,181.50	1.81	---
Residual Between	169,957.78	16	10,622.36		
Within Ss	1,104,430.45	216	5,113.10		
Option	125,083.13	2	62,541.56	15.58	$<.001$
Environment	3,845.99	2	1,922.00	----	----
O x E	40,918.21	4	10,229.55	2.54	$<.05$
O x V	26,344.25	4	6,586.06	1.64	----
E x V	14,576.65	4	3,644.16	----	----
O x V x E	35,635.74	8	4,454.46	1.11	----
Maps	105,165.18	8	13,145.64	3.28	$<.001$
Trials	43,801.78	8	5,475.22	1.36	----
Residual	709,059.65	176	4,011.70		

Table 12

Differences Between Means
Option x Environment - $p < .05$

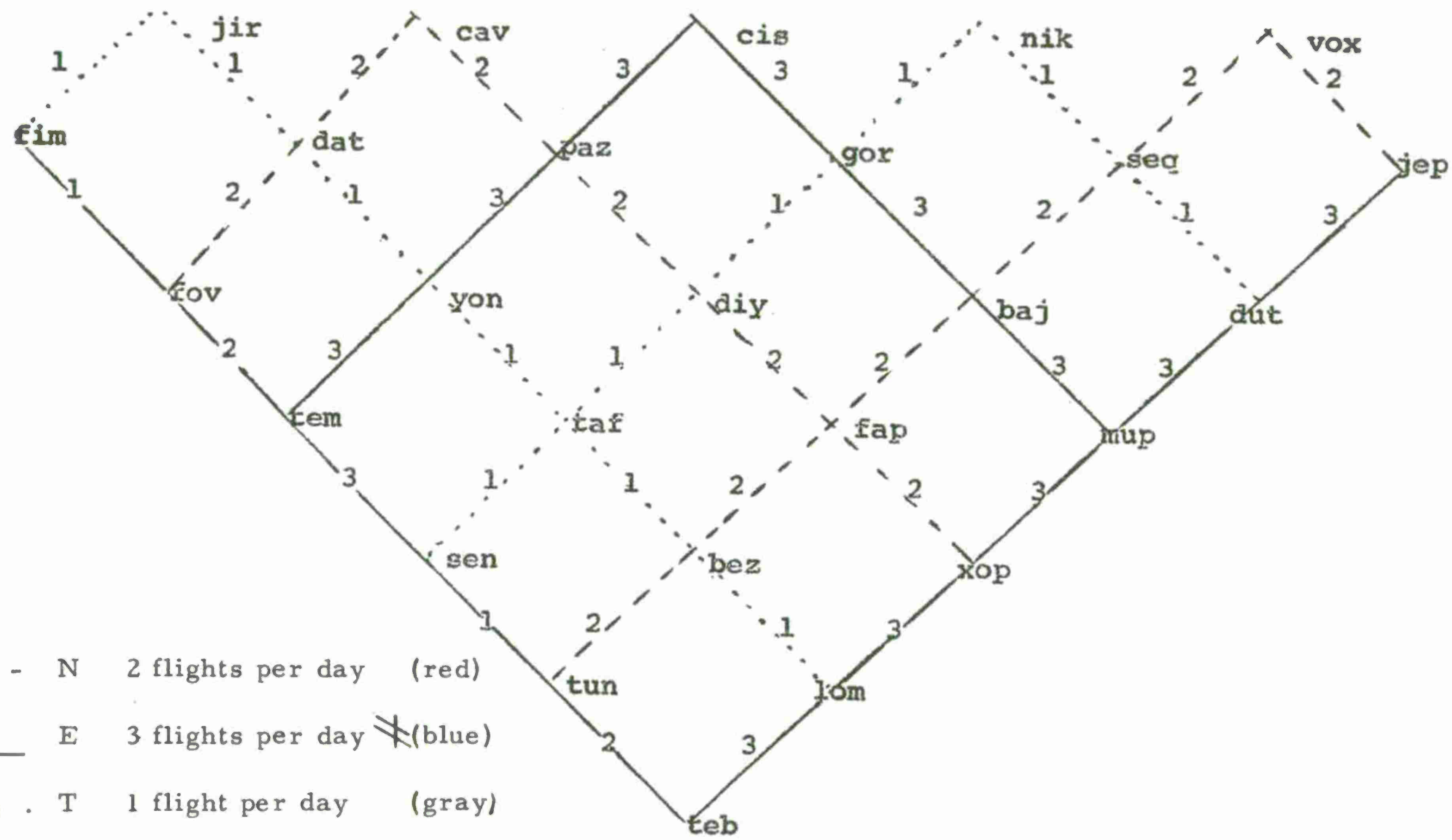
OE**	12	13	21	22	23	31	32	33
11	20.2	43.9*	70.8*	73.6*	55.5*	84.7*	54.3*	76.9*
12	----	23.7	50.6*	53.4	35.3	64.5*	34.1	56.7*
13	----	----	26.9	29.7	11.6	40.8*	10.4	33.0
21	----	----	----	2.8	-15.3	13.9	-16.5	6.1
22	----	----	----	----	-18.1	11.1	-19.3	3.3
23	----	----	----	----	----	29.2	- 1.2	21.4
31	----	----	----	----	----	----	22.6	-7.8
32	----	----	----	----	----	----	----	22.6
33	----	----	----	----	----	----	----	----

**First digit of each OE number gives Option condition; second digit gives Environmental condition. For example, "11" means 0_1E_1.

*$p < .05$

d = 38.85

Figure 1: An illustrative maze with identifying names and flight densities.



- - - - N 2 flights per day (red)

———— E 3 flights per day ╪ (blue)

. . . . T 1 flight per day (gray)

╪ except along lower left border

Figure 2

Interaction between Option and Visibility in Experiment 1

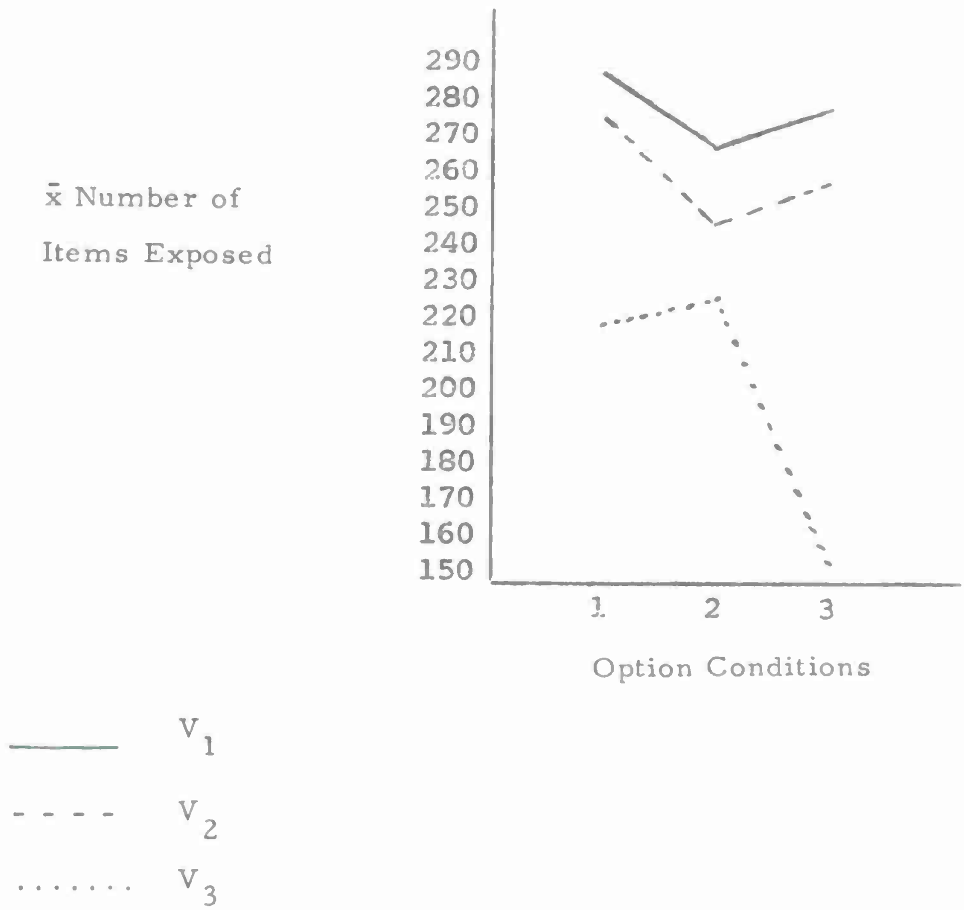


Figure 3

An Elaborated Hypothesis of the Option Visibility Relation

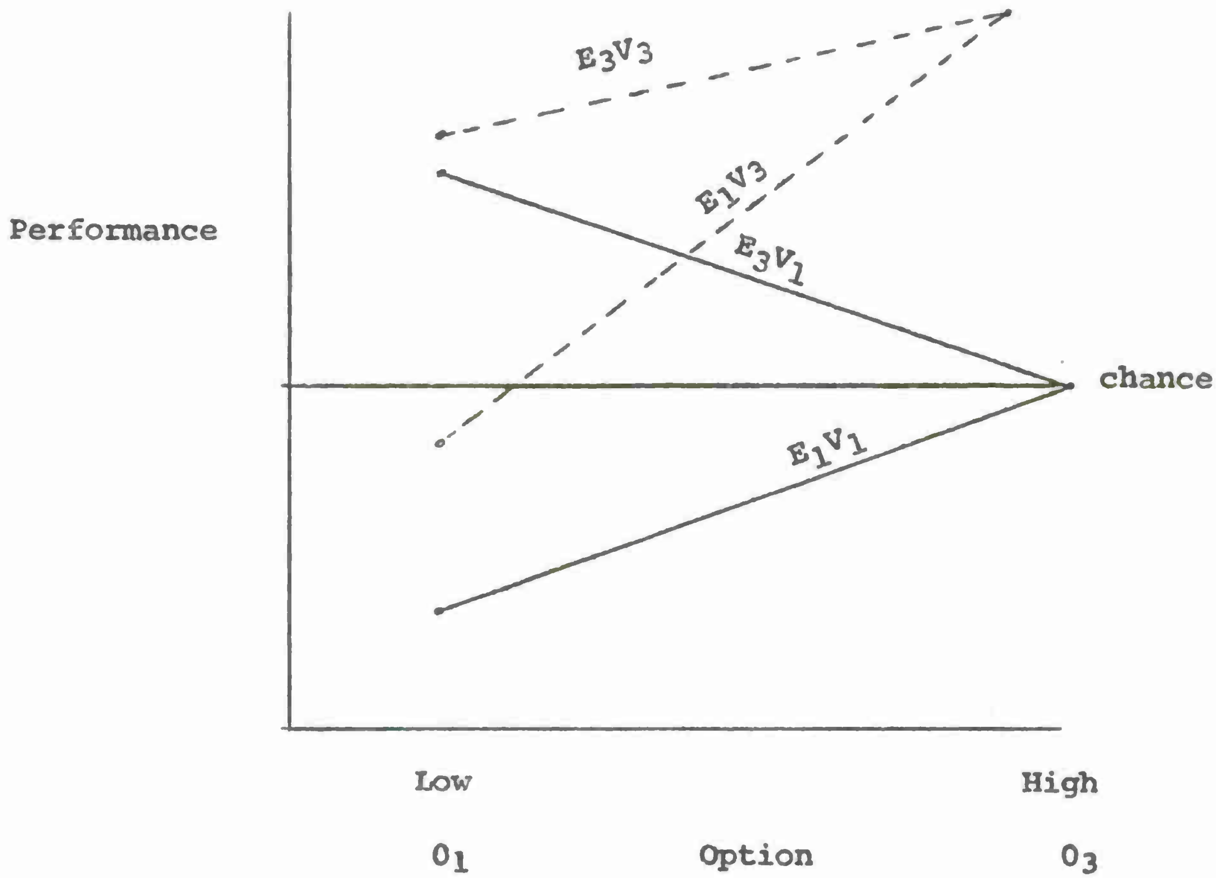


Figure 4

Schematic Diagram of Maze Used in Experiment 2

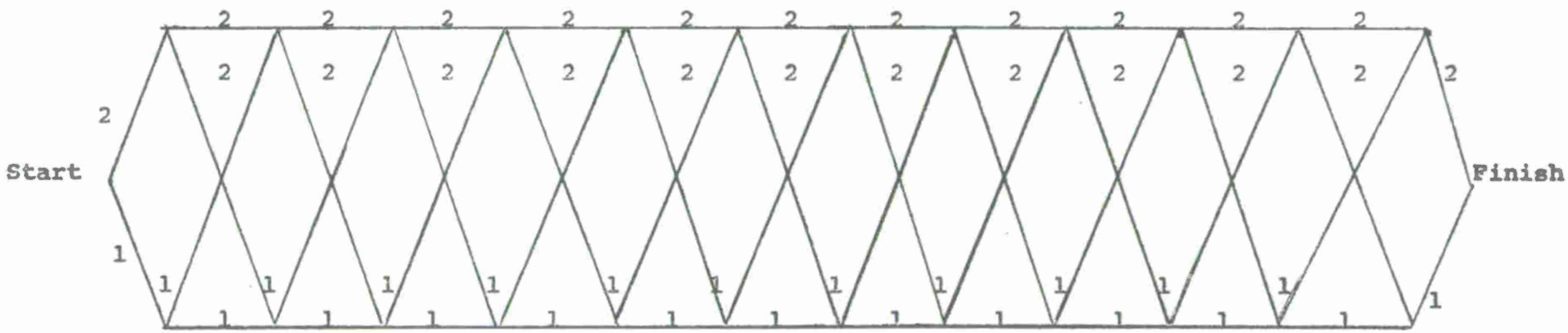
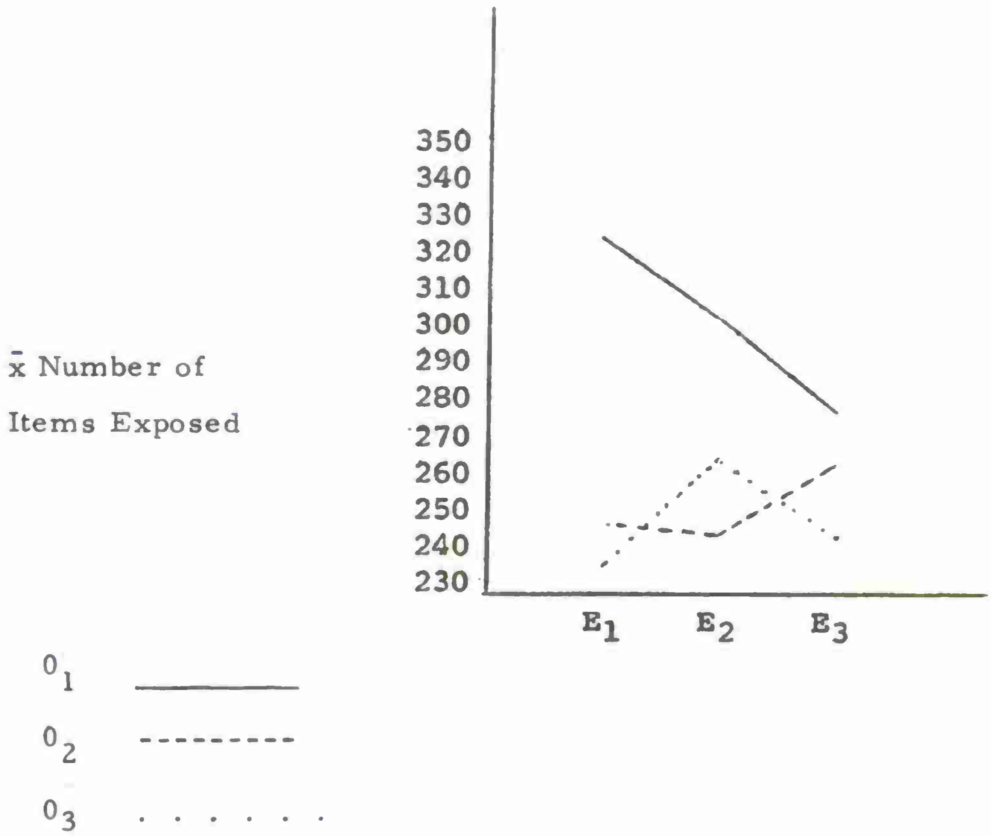


Figure 5

Experiment 3: Option x Environment



Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Tufts University, Medford, Massachusetts	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

PROCEDURAL CONSTRAINT AND TASK PERFORMANCE

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(Last name, first name, initial)*

Roby, Thornton B., Goldberg, Susan

6. REPORT DATE November 1964	7a. TOTAL NO. OF PAGES 35	7b. NO. OF REFS

8a. CONTRACT OR GRANT NO. AF19(628)2450 b. PROJECT NO. 7682 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) ESD-TR-64-663 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES

DDC release to OTS is authorized.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Electronic Systems Division L. G. Hanscom Field, Bedford, Mass.

13. ABSTRACT

Persons or groups assigned to certain tasks are typically required to follow institutionally originated rules of action or constraints that limit the range of their task behavior. Ordinarily these procedural rules are based on general experiences with the task situation and are designed to guard against serious errors: however they have the secondary effect of reducing the potential for superior enterprise or discretion on the part of the performing agent. The question or practical importance concerns the specific conditions that militate in favor of either increased or decreased superordinate control.

The present investigation is to develop a laboratory methodology for studying this problem. The general task condition used was an abstract maze in which subjects had to select a path between designated points. An attempt was made to produce experimental analogues of "visibility", or task information accessible to the subject, and environmental "bias", or general favorability for exploratory behavior.

Three formal studies are reported. They indicate the relevance of the experimental factors, but the results are too inconsistent across studies to be definitive. Based on these results, certain modifications are suggested for future research.

DD FORM 1 JAN 64 1473

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Behavior Decision Making Procedural Constraints Task Performance Tests						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.