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Two experiments were performed to investigate how a stimulus (a film with scenes either in or out of order) in combination with a task (recalling facts or generating hypotheses about the film) affect whether or not a person responds to the stimulus with more than one discrete answer or thought (subjective response uncertainty). Specifically, this stimulus-task interaction was studied as it aroused either relevant uncertainty (thoughts about the stimulus related to the task) or irrelevant uncertainty (thoughts about the stimulus unrelated to the task because of something confusing or distracting in the stimulus). Both experiments, in which subjects (teacher-trainees and college freshmen) were randomly assigned to conditions determined by a factorial design of one or two films and the two film structures and tasks mentioned above, were used to test the hypothesis that relevant uncertainty (and, consequently, information search) would be maximized when the stimulus suggested many responses of the kind required by the task. Support for the hypothesis was found in that subjects generated significantly more hypotheses for unstructured films than for structured films (because a randomized order of scenes suggests more hypotheses) and recalled significantly more facts for one of the structured films (because the latter offer an associative basis for memory and do not divert attention from the task). The stimulus-task interaction paradigm needs to be expanded to examine problem-solving tasks and related questions, such as how problem solvers learn to generate relevant uncertainty in situations "designed" to arouse irrelevant uncertainty. (LP)

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RELEVANT SUBJECTIVE RESPONSE UNCERTAINTY AS A FUNCTION OF STIMULUS-TASK INTERACTION

Gavriel Salomon[1] and Joan E. Sieber[2]

An important aspect of problem solving and judgment is the ability to generate subjective response uncertainty, that is, two or more mutually exclusive response tendencies to the same stimulus. These response tendencies may be of various kinds such as beliefs about the nature of the problem, solution hypotheses, procedural approaches, factual observations, or free associations. The kind of response uncertainty which aids judgment depends, of course, on the nature of the problem and the way in which it is being solved. Much of the literature on problem solving may be construed as showing that the kind of response uncertainty required depends on the definition of the problem. However, we have no systematic knowledge of how persons learn to generate the relevant kind of subjective response uncertainty or of the role of situational cues in eliciting relevant uncertainty.

Within the context of this general question, the present experiment was performed to clarify the notion of relevant versus irrelevant subjective response uncertainty and to discover whether certain stimulus properties of problems can influence the task-relevance of the uncertainty they engender.

Subjective response uncertainty (H*) is defined by analogy to the information-theory definition of message uncertainty. Thus,

$$H^* = -\sum_{i=1}^{n} p_i^* \log_2 p_i^* ,$$

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where there is a set of n-alternative responses in an individual's response hierarchy, and p_i equals the probability or relative strength of his belief that the i^{th} response is appropriate (Berlyne, 1957). Subjective response uncertainty (H*) is a function of the number and relative strength of the mutually exclusive response tendencies which a stimulus evokes within an individual, whereas message uncertainty is a function of the number of stimulus events which could occur, and their actual probability of occurrence. When the likelihood of possible alternatives is accurately perceived, H* is linearly related to message uncertainty in choice situations involving up to approximately seven possible alternatives, beyond which H* approaches asymptote (Driscoll & Lanzetta, 1965). This asymptote is considered indicative of the natural limits on the amount of information which individuals can consider at a time (human channel capacity); beyond the limit of channel capacity, information cannot be maintained in short-term memory unless it is "chunked" or organized mnemonically (Miller, 1956). At a later point in the discussion, we will show how this limitation may be one reason why the generation of irrelevant subjective response uncertainty decreases the amount of relevant subjective response uncertainty that is generated.

Subjective response uncertainty is a fundamental variable in judgmental processes, since it implies awareness of alternative responses. It is not surprising, therefore, that individual differences in level of subjective response uncertainty are positively related to individual differences in level of predecision information search (Sieber & Lanzetta, 1964, 1966), or that groups of characteristically high-uncertainty persons generate more varied sets of responses than groups of characteristically low-uncertainty persons (Karlins, 1967).

Individual differences in characteristic level of subjective response uncertainty are experimentally modifiable. By the use of learning paradigms such as imitation (modeling) and operant conditioning, persons can be taught to increase the number of relevant responses they can make to a given stimulus (Maltzman, 1960). For example, a subject may be taught to increase the number of solutions to problems he can generate. Or, he may be taught to increase the number of stimulus attributes he can discern and then to infer relevant solutions or explanations on the basis of these attributes. Persons who have received such training increase their level of predecision information search

(Sieber & Lanzetta, 1966; Salomon, 1968), and groups of such subjects generate more diverse lists of responses (Salomon, 1968).

For the purpose of such training, these authors have used complex, unstructured or ambiguous stimuli because they increase the number of response tendencies which may be aroused. Using a related but somewhat different approach, Smedslund (1961) and Bruner (1966) have also used uncertainty-arousing stimuli along with experimental procedures designed to evoke conflicting predictions in order to teach children to generate superordinate concepts which "explain" the apparent conflicts or paradoxes in the stimuli.

Given the fact that subjective response uncertainty plays a fundamental role in judgmental processes and is modifiable, some fruitful research problems can obviously be identified concerning the relationship between stimulus properties, training procedures, and the way they can be used to facilitate productive thinking by arousing uncertainty. Hence, one might envision various combinations of learning paradigms, tasks, and uncertainty-arousing stimulus arrays being used to modify cognitive styles and abilities. Studies such as we have cited suggest that stimuli having any kind of uncertainty-arousing properties may usefully be employed in such experiments. However, the main purpose of this paper is to present arguments and data which qualify this generalization. Our major propositions are that (a) uncertainty may be relevant or irrelevant to the intellectual task at hand, and (b) sources of irrelevant uncertainty may interfere with the process of generating relevant uncertainty.

First, let us examine what is meant by relevant and irrelevant uncertainty. Suppose that a reader is required to respond to the meaning of a text consisting of randomly ordered sentences. He would probably think of several interpretations of the text without knowing which one conveyed the intended meaning. However, since producing alternative interpretations is relevant to the task of determining meaning, the reader may be said to be in a state of relevant uncertainty. Now, if the reader's task had been to proofread the text for spelling errors, such a set of randomly ordered sentences containing no unusual or misspelled words would have caused no relevant uncertainty since sentence order is ordinarily irrelevant to spelling. It would have aroused irrelevant uncertainty, however, if the reader had noticed and puzzled over the random order of sentences. Of course, a task may arouse both relevant and irrelevant uncertainty. For example, if our hypothetical proofreader were a very poor speller, and if he were required to check the spelling of the text, he would probably consider both the various possible spellings of certain words and the various possible meanings of the text. In this case, the irrelevant uncertainty about meaning would interfere with the uncertainty he should experience regarding spelling.

Consider now our proposal that irrelevant uncertainty may interfere with the generation and use of relevant uncertainty. This proposition is based on three principles. First, stimuli which suggest various mutually exclusive responses tend to attract attention, irrespective of their task relevance (Hebb, 1955; Berlyne, 1960). Second, attention is selective. Responding to one uncertainty-arousing aspect of a stimulus (e.g., the order of sentences) interferes with responding to another potential source of uncertainty (e.g., the dubious spelling of certain words). And third, as mentioned earlier, individuals cannot hold more than about seven pieces of information in short-term memory without a mnemonic aid (Miller, 1956).

If uncertainty may be relevant or irrelevant to the task at hand, and if sources of irrelevant uncertainty may interfere with the generation and use of relevant uncertainty, then relevant uncertainty should be maximized when the stimulus suggests many responses of the kind required and does not suggest many responses of another kind. This hypothesis was tested in the present studies.

In Experiment I, two sets of task instructions, two different films, and two levels of film structure for each film were employed in a factorial design as shown in Table 1A. In one version of the films the scenes remained sequenced as originally produced. The other version consisted of a randomly ordered sequence of the same scenes. Half of the subjects were required to report details observed in one of the structured films and to generate hypotheses about the plot of the unstructured version of the other film. The rest of the subjects were required to report details observed in the unstructured film, and to generate hypotheses about the plot of the structured film. No subject was exposed to the same film, the same kind of structure, or the same task twice. It was predicted that the unstructured versions of film would elicit

TABLE 1

A. The Four Conditions of Film, Film Structure and Instruction Combination to which Subjects were Assigned in Experiment 1.

	First Film			Second Film		
Condition	Instruction	Structure	Film	Instruction	Structure	Film
1	CA[a]	U	God's Man	HG[b]	S	Day of a Painter
2	CA	S	God's Man	HG	U	Day of a Painter
3	CA	U	Day of a Painter	HG	S	God's Man
4	CA	S	Day of a Painter	HG	U	God's Man

B. The Four Conditions of Instruction and Film Structure Combination to which Subjects were Assigned in Experiment II.

Condition	Instruction	Structure	Film
1	CA	S	God's Man
2	CA	U	God's Man
3	HG	S	God's Man
4	HG	U	God's Man

[a] CA = Cue Attendance

[b] HG = Hypothesis Generation

comparatively more relevant uncertainty, and consequently more information search when subjects were required to generate story plots, since the unstructured version suggested many plots. Greater relevant uncertainty and information search were also predicted in conditions requiring the recall of detail in structured films, since the latter suggest one rather simple and obvious plot which detracts little from the task of noticing stimulus detail and offers a meaningful associative structure to facilitate memory (Miller, 1956; Miller, Galanter & Pribram, 1960). However, since the opposite combinations of stimuli and tasks do not facilitate the kind of uncertainty which they require subjects to generate, it was predicted that they would evoke comparately less relevant uncertainty. Experiment I tested the predicted stimulus-task interaction effects on generation of relevant uncertainty.

In Experiment II, two sets of task instructions, one film, and two levels of film structure were employed as shown in Table 1B. Subjects were required either to memorize film details or to formulate hypotheses about the film plot, but were not required to respond overtly. They were allowed to view the film as often as they wished. Experiment II tested the predicted stimulus-task interaction effects on information search.

Method

Experiment I

Subjects. The subjects were 120 college freshmen, 60 from a class in communication at Stanford University, and 60 from a class in introductory psychology at San Jose State College. Subjects participated without pay.

Materials. Two different films were employed to control for film-specific effects, Day of a Painter, produced by Little Movies, Inc., and God's Man by Shelly Fay. From each film, a three- to four-minute excerpt was chosen and two duplicated copies were made of each excerpt. For each film, one copy of the duplicated excerpt was separated at the original cuts and resequenced at random. Thus, two versions of each film were obtained, a structured (S) version in its original logical order, and an unstructured (U) version reordered at random and spliced.

Design and procedure. The subjects were randomly assigned to four groups of 30. Each group was assigned to one of the four conditions shown in Table 1A.

In the cue-attendance task, subjects were given written instructions to notice and write down as many facts and details of the film as possible, but not to write down any inferences or interpretations of the film. In the hypothesis generation task, subjects were given written instructions to formulate as many different explanations as possible concerning the main idea conveyed by the film. Subjects were given instructions, shown the first film, and given ten minutes to respond as instructed. Then the remaining instructions and film were presented and another ten minutes were allowed for responding.

Calculation of dependent measures. Three measures of uncertainty were calculated: (1) group-response uncertainty (H_g) which was used as an estimate of individual subjective response uncertainty (H*); (2) maximum response uncertainty (H_m) and (3) relative response uncertainty (R_H). The last two measures were adapted from Attneave's (1959) derivations from the information theory formula for uncertainty.

1. Group-response uncertainty (H_g) is a measure of the response variability produced by a group of respondents. To compute H_g, each response is assigned to one of several empirically derived response categories; the resulting response distribution is then transformed into a probability distribution. The probability of each category (p_i) is entered into the formula,

$$H_g = - \Sigma \; p_i \log_2 \frac{1}{p_i} ,$$

where p_i is the decimal value of the relative frequency of responses in category i. It can be seen that H increases as a function of the number of response categories and their nearness to equiprobability. This measure is based on three assumptions. First, it is assumed that subjects are drawn from a culturally homogeneous population. Second, for a given stimulus, the set of responses generated by the sample of subjects is assumed to approximate the set of response tendencies evoked in any individual drawn from that population. And third, it is assumed that the relative frequencies of the group-generated responses approximate the strength of each individual's respective response tendencies. Laffal (1955) and Driscoll, Tognoli and Lanzetta (1966) have shown that group response uncertainty (H_g) approximates the subjective response uncertainty (H*) of individuals drawn from the same population.

2. Maximum response uncertainty (H_m) is the amount of response uncertainty which a stimulus would arouse if all the obtained response categories were equiprobable and mutually exclusive.

$$H_m = \log_2 n \ ,$$

where n is the number of obtained response categories.

3. Relative response uncertainty (R_H) is the ratio of the amount of obtained uncertainty (H_g) to the hypothetical value of maximum uncertainty (H_m). Thus,

$$R_H = \frac{H_g}{H_m} \ .$$

R_H may be considered a measure of transformed information, leading to the computation of redundancy (C) in a distribution of group responses:

$$C = 1 - R_H \ .$$

Experiment II

Subjects. The subjects were 52 teacher trainees at Stanford University. Subjects participated without pay.

Materials. The stimulus materials used were the structured and unstructured versions of the film God's Man.

Design and procedure. The subjects were randomly assigned to the four task-structure conditions: CA-S, CA-U, HG-S and HG-U as shown in Table 1B. Ss were asked either to "memorize as many details in the film as possible" (CA), or "to formulate different hypotheses about what is shown in the film" (HG). In both cases, they were not required to respond overtly. However, they were told that they could view the film as many times as they wished.

Calculation of the dependent measure. The measure used here was the number of times each subject asked to view the film.

Results

Experiment I

Group response uncertainty (H_g), maximum uncertainty (H_m), relative uncertainty (R_H), and redundancy (C) for each task-structure combination of each film are presented in Tables 2 and 3.

TABLE 2

Uncertainty Coefficients Computed for Each Task-Structure Combination of the Film God's Man .

	Structured	Unstructured
Hypothesis Generation	H_g = 3.30	H_g = 4.86
	H_m = 5.67	H_m = 4.90
	R_H = .58	R_H = .992
	C = .42	C = .008
Cue Attendance	H_g = 5.58	H_g = 5.19
	H_m = 9.02	H_m = 8.99
	R_H = .62	R_H = .577
	C = .38	C = .423

TABLE 3

Uncertainty Coefficients Computed for Each Task-Structure Combination of the Film Day of a Painter.

	Structured	Unstructured
Hypothesis Generation	H_g = 2.43	H_g = 3.50
	H_m = 5.61	H_m = 5.64
	R_H = .44	R_H = .62
	C = .56	C = .38
Cue Attendance	H_g = 5.13	H_g = 4.53
	H_m = 8.78	H_m = 9.38
	R_H = .58	R_H = .48
	C = .42	C = .52

As shown in Table 2, the unstructured version of God's Man with hypothesis generation task requirements evoked a higher H_g than the structured version. Since the number of different hypotheses produced by the two groups of subjects was nearly identical, R_H was also higher for the unstructured version. A t-test of proportions (Downie & Heath, 1965), used to compare the R_H of the structured and unstructured versions of God's Man yielded a $t = 3.59$, d.f. $= 79$ (based on the number of responses), $p < .01$. Obviously, the redundancy (C) of the unstructured version was less than that of the structured version. This is in accord with expectations, since a completely randomized order of film scenes permits more freedom for interpretation than a logically ordered sequence, given the task to generate interpretations.

Similar results were obtained using the second film, Day of a Painter. As shown in Table 3, a large difference was obtained in the H_g and R_H coefficients between the structured and unstructured versions. A t-test of proportions comparing the R_H coefficients yielded a $t = 1.98$, d.f. $= 98$, $p < .05$.

Turning now to the cue-attendance tasks, we see in Tables 2 and 3 that the results are reversed, as predicted; the structured versions of both films elicited the greater values of H_g and R_H. The structured version of God's Man elicited an insignificantly greater R_H than the unstructured version ($t = 1.4$, d.f. $= 00$, $p < .16$), but this difference was significant ($t = 3.36$, d.f. $= 00$, $p < .01$) when the film Day of a Painter (Table 3) was used.

Experiment II

Information search data for each task-structure combination are presented in Table 4.

To compare the mean number of requests to view the film within each response condition, a two-sample t-test was used. As shown in Table 4, relatively more information search was manifested under CA-S compared to CA-U condition ($t = 2.21$, d.f. $= 24$, $p < .05$). Under HG conditions the opposite result was obtained: more information search took place under HG-U than under HG-S ($t = 2.27$, d.f. $= 24$, $p < .05$).

TABLE 4

Mean Numbers of Voluntary Viewings of *God's Man* in Each of the Four Stimulus-Task Combinations.

Condition	Mean	t
CA-S	2.38	2.21*
CA-U	1.92	
HG-S	1.61	2.27*
HG-U	2.15	

NOTE: n = 26 in each comparison

*p <.05

Discussion

Measures of relative subjective response uncertainty (R_H), and information search proved sensitive to differences in task and stimulus variables as predicted. Support was obtained for the hypothesis that relevant uncertainty is maximized when the stimulus suggests many responses of the kind required and does not suggest other kinds of responses. Moreover, the similarity of results yielded by the two different sets of films used in Experiment I provides some assurance that this conclusion is generalizable. While these findings elucidate only a small part of the relationship between stimulus and task properties and the task relevance of the elicited uncertainty, they nevertheless permit us to draw some specific conclusions.

First, stimuli which consist of unusually juxtaposed cues for which there is no obvious singular explanation tend to hinder recall of stimulus detail. Perhaps this is because unstructured stimuli do not call attention to specific details, offer little meaningful associative basis for memory, and sidetrack attention to the task of inferring explanations, which may crowd out temporarily remembered details. Logically structured stimuli, on the other hand, do not divert attention from subtle details and offer a meaningful associative basis for remembering what was observed.

Second, it follows that unstructured stimuli are also likely to hinder any hypothesis-generation processes which involve acquisition and memory of factual details in which subtle logical contradictions or surprising implications are to be noted. The confusion engendered by a disorganized account of events would probably interfere with perception of these subtler uncertainties.

And third, concerning hypotheses which are not based on subtle, logical transformation of remembered factual detail, unstructured stimuli are likely to suggest more hypotheses than structured or logically ordered stimuli.

It is obvious that problem solvers can proceed most insightfully with tasks which are arranged to elicit relevant uncertainty. Unfortunately, this tenet cannot be applied without knowing what kinds of uncertainty are relevant to the processes of solving given types of problems and what stimulus characteristics arouse relevant and not irrelevant uncertainty. And, except for intuitive knowledge, we understand little about what comprises relevant uncertainty and how it may be aroused in given types of problem-solving tasks. Of the many possible task and stimulus dimensions, we have studied only two. However, the stimulus-task interaction paradigm of this study could be used to examine the range of uncertainty-eliciting properties within various stimulus dimensions in relation to kinds of tasks. For example, stimuli may be varied in length of presentation, number and kind of modalities to which they are directed, or degree of familiarity to the observer. Tasks might include finding contradictions, estimating probabilities, or finding implied conjunctive or disjunctive statements. An experiment need not be limited, of course, to the study of a 2 x 2 task- and stimulus-interaction, but may be extended factorially to many stimulus-task relationships.

Thus far we have limited our attention to the simple task of following instructions such as "give all of the hypotheses you can concerning the plot of this movie and decide which hypothesis is the most reasonable." We have ignored problem solving, which usually consists of a situation and a more or less clearly defined goal and requires the problem solver to select or discover the rule(s) or task(s) by which to arrive at the goal. Learning to solve problems, then, involves learning to discern and carry out relevant tasks. In many cases, the tasks within problems involve generating and reducing (relevant) uncertainty, e.g., noticing many details and deciding which ones suggest possible procedures, or considering possible procedures and selecting the most appropriate.

Returning now to the more general questions of how problem solvers learn to generate the relevant kind of uncertainty and the role of situational cues in eliciting relevant uncertainty, we note that there are many ways in which parts of this question may be examined within a stimulus-task interaction paradigm. For example, problems may be task-analyzed to determine the kinds of uncertainty which are relevant to finding a solution and then classified according to their kinds of relevant uncertainty. Then one may ask concerning this array of problems, what kinds of stimuli are most conducive to eliciting relevant uncertainty when the uncertainty-generating task alone is presented, when the problem alone is presented, or when the problem is given along with task hints. Recalling Gagné's (1965) concept of learning hierarchies, one may ask whether various kinds of prior task learning enable persons to make better use of stimulus cues in order to discover and generate relevant uncertainty.

We have focused thus far on the problem of maximizing relevant uncertainty by use of stimulus cues. A more interesting and practical question is how problem solvers learn to generate relevant uncertainty in situations which are "designed" to arouse irrelevant uncertainty. Obviously, problem solvers and decision makers usually find, rather than create, their problems. They are not free to select only those situations which elicit relevant uncertainty. Good problem solvers probably learn ways of attending only to relevant uncertainty. Such processes (if they exist) are not presently understood.

Investigation into these processes should be guided by a detailed characterization of stimulus and mediating-response variables such as task-stimulus interaction experiments are designed to yield. Again, problems would be classified according to their task-requirement and uncertainty-arousing properties. Given a problem designed to elicit irrelevant kinds of uncertainty, what kinds of learning will produce ability to generate relevant uncertainty? Several possibilities come to mind: (a) prior task-learning; (b) prior training on problems that require the same kinds of uncertainty and are designed to elicit relevant uncertainty, followed by more problems having the same requirements, but which are designed to elicit successively more irrelevant uncertainty; (c) transfer training in which prior task-learning or prior training on problems is done with a different kind of stimulus than is used in the criterion task, but the task is basically the same; (d) transfer training in which prior task-learning or prior training on problems is done with the same kind of stimulus as is used in the criterion task, but with a different task, and (e) other possible combinations of (a) through (d).

These techniques for studying problem solving in relation to such stimulus-problem characteristics offer interesting possibilities for developmental studies of problem-solving processes and for modifying cognitive processes and abilities. And, ultimately, they offer a methodology for designing an empirically derived series of instructional materials in which problems, varying in the degree of relevance of the uncertainty they are designed to arouse, are organized along with other kinds of training procedures so as to develop sophisticated problem-solving skills.

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