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ABSTRACT

The purposes of this study are: (1) to attempt to show the weakness of the theory of a two-stage process of attending, i.e. having both separate and ordered focusing and elaborating aspects; and (2) to offer an alternative approach whereby both focusing and elaborating are under the service of cognitive variables. The discussion covers the issue of the definition of a "new" stimulus event, the inherent difficulties in a simple matching process, and presents an alternative model for attending to stimulus events. An experiment is presented which demonstrates an Orienting Reflex (OR) hierarchy comparable to hierarchies of concept formation attainment in the same age child. Specifically, a redundant visual signal is followed by four variations of that signal; changes in color, size, number, and rotation. The results, accounting for both discriminability and intrinsic value demonstrate a hierarchy of stimulus salience. This hierarchy of color, size, number, and rotation is consistent with concept formation acquisition and these results are used to argue for the proposed model of attending which emphasizes the need to consider cognitive principles in understanding an OR. (Author/AJ)

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# THE MEANING OF AN ORIENTING RESPONSE:
## A STUDY IN THE HIERARCHICAL ORDER OF ATTENDING

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# THE MEANING OF AN ORIENTING RESPONSE: A STUDY IN THE HIERARCHICAL ORDER OF ATTENDING[1]

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The orienting reflex, first introduced into modern psychology by Pavlov in 1910 (Pavlov, 1949) and made popular more recently by Sokolov (1963), has been defined in the broad sense as a "series of reactions bringing the [organism] into contact with the objects and tuning the analyzers of the [organism] so that perception of the stimulus takes place in the most favorable conditions." According to these theorists the orienting reflex differs from other behaviors, such as exploratory behavior, in that it is not involved in the elaboration or perception of the stimulus but only in the tuning or focusing of the organism's analyzers to be able to perceive or elaborate. Thus, the orienting reflex occurs temporally prior to any behavior associated with elaboration. It is possible, therefore, for an organism to exhibit an orienting reflex and no further elaboration or perception, but it is not possible to elaborate without first having exhibited an orienting reflex. The definition of which responses constitute an orienting reflex and which constitute elaboration is still being investigated using heart rate deceleration, vasodilation and constriction, respiration, GSR, activity, orientation of the receptor, and many other responses as indices of an orienting reflex.[2]

Another characteristic of this tuning process or reflex is its habituation when a stimulus event is repeated, and its reappearance when a new event is presented. Sokolov (1963) has offered a theory for explaining this reflex in terms of a matching procedure whereby a new event is matched against an internal representation (called a neuronal model) within the organism.

Mismatch produces excitation and an orienting reflex, while match produces inhibition and an absence of the reflex.

In the following discussion, issues will be raised which bring into question the notion that focusing the analyzers precedes elaboration or perception of the stimulus event. This notion will be questioned by attempting to demonstrate the inadequacy of discussing only the sensory qualities of stimulus events as well as the inability of a simple matching process to elicit an orienting reflex. An argument will be made for a process which includes both focusing and elaborating in the production of an orienting reflex. Moreover, this process utilizes a cognitive approach whereby such factors as plans, response sets, maturational readiness and mental structure may all be actively involved in the process of orienting to stimulus events.

While it is appealing to theorize about a two-stage process of attending, having both separate and ordered focusing and elaborating aspects, the following discussion will attempt to show the weakness of this theory and at the same time offer an alternative approach whereby both focusing and elaborating are under the service of cognitive variables. To accomplish this it is first necessary to discuss (1) the issue of the definition of a "new" stimulus event, (2) the inherent difficulties in a simple matching process and, finally, (3) an alternative model for attending to stimulus events. Once having shown that what has been considered to be an OR varies as a function of some cognitive principle(s), an experiment will be presented which demonstrates an OR hierarchy comparable to hierarchies of concept formation attainment in the same age child. This will be used as further proof of the control of cognition on the OR.

(1) Problems in defining a "new" stimulus event

Excluding the small amount of experimental data on intensity variation (Bernstein, 1967; Dodd & Lewis 1969; Zimny & Schwabe, 1966), little empirical evidence exists regarding the parameters defining the new stimulus event and their effect on the orienting reflex (OR).[3]

The first issue in the discussion of an orienting response as suggested by Sokolov (1963) is the nature and definition of the external event and its correspondence to an internal representation.[4] For example, an organism has seen a repeated presentation of a box from one angle and thus has built up an internal representation of the box. If now the same box is presented from a slightly different angle, will an orienting reflex occur? In a broad sense, does any change represent a "new" box and produce an orienting reflex, and will this OR be as great as the OR associated with an entirely different, "new" event? Intuitively, this seems highly unlikely. If it were the case, organisms would constantly show OR's or equal OR's to every alteration and slight change in the same event--clearly an inefficient process. What probably occurs outside the controlled setting of the laboratory is that the organism sees the box from a variety of angles and constructs an internal representation of the box which is a composite of his total experience with it. This total experience includes more than mere sensation, that is, it may include some type of cognitive manipulation. The subject's experience may thus be an idealization of the box--something greater than all his sensory experiences. In this way he is able to maintain invariance of the object over many different alterations of view.

In light of the preceding discussion, it seems clear that some changes are less important than others. Indeed, some changes are not changes in the stimulus itself--for example, various views of the same animal do not constitute a different ideated stimulus or animal, but only an altered sensation (Gibson, 1960). This consistency across some sensory changes is an important developmental principle. Older organisms are more able to hold object constancy over sensory change than are younger ones. In fact, constancy, regardless of sensory change, is essential to Piaget's notions of knowledge and his system of epistemology (Elkind, 1967; Kohlberg, 1966; Piaget, 1968).

This strongly suggests that the nature of change and therefore the nature of the stimulus event is also influenced by the developing mental structure of the organism and is capable of altering over time. These facts would argue for a hierarchical ordering in terms of what constitutes a stimulus change for the organism.

(2) Problems in a matching process

Another reason for considering a hierarchical ordering of OR's is the time the organism requires to search for internal representations that match external events. It is obvious that if all representations had to be scanned in order to find a match, the orienting reflex would be a slow response indeed and not at all the rapid phenomenon we observe. It is necessary, therefore, that some additional processes facilitating the search procedure be hypothesized. This further suggests that cognitive internal representations, composites of specific stimulus events, may be employed. These representations may produce or facilitate simultaneous scanning of multidimensional models. Moreover, branching procedures, where certain aspects of an external event can be monitored first, are possible. Such a branching procedure would reduce the number of representations scanned and therefore reduce the time required for the matching process and resulting orienting reflex. In either case, various aspects of an external event would have greater or lesser importance in terms of matching to the representation

The preceding discussion has raised some issues involved both in defining a "new" event and in the matching process and has suggested that some type of hierarchy of either perceiving, searching or processing external events with internal representations is present in the organism. The need for some type of hierarchy of OR becomes even clearer when signal stimuli--as opposed to non-signal stimuli--are discussed. While the nature of the matching procedure and problems previously discussed can be applied to non-signal stimuli, what follows is most appropriate to signal stimuli.

### (3) Hierarchical ordering of signal events

While Sokolov (1963) discusses the disappearance of the OR to a CS during conditioning, there is little evidence that once conditioning has been established, a CS will not then elicit an OR. The following are examples of CS which could elicit differential OR's.

Response set, expectations and anticipations. If signal stimuli or events, like non-signal events, still need to be matched in order for an OR to occur, a process which may reduce some of the time and effort in the search for match may make use of previously constructed plans or strategies. That is, the organism constructs these plans or strategies for attending prior to the presentation of the sensory event itself. Such examples are to be found in the literature under such terms as expectations, anticipation or response set. By the use of such procedures, an organism-determined continuum could be constructed along which the internal representations are placed. Thus, search procedures move along this predetermined continuum and the organism has to match the external event against only a selected few internal representations. An example of this selective OR as a function of some plan or strategy is best provided by the mother who sleeps through a loud noise caused by traffic, but awakes to her baby's cry, a sound of equal or lesser intensity.

Motivational and state differences. Signal stimuli or events may vary in the magnitude of the elicited OR because of differences in motivational content. That is, some events have previously been associated with a rewarding condition. For example, a dinner bell would produce a greater OR than a bell of equal intensity but of different pitch. Obviously, the difference could be explained in terms of differential reward value associated with the dinner bell. Moreover, this example points out that an OR elicited by a signal stimulus may vary as a function of the organism's state. Thus, when hunger is decreased or increased, the dinner bell may elicit less or more of an OR.

Biological variables. Still another reason for differential OR's to various signal events may be biological. The perceiving of a target stimulus for an innate releasing mechanism (IRM) (Tinbergen, 1951) might produce a greater OR than an event of equal or greater complexity but unrelated to the IRM. Alternatively, the physiological structure of the organism must be considered. Color events, for example, would produce no OR in early human experience in that the retinal cones are still relatively poorly defined. However, in the older infant and young child, color stimulus events might become more relevant and therefore elicit an OR.

Change in mental structure. A final factor that might affect differential degrees of OR's is the change in mental structure as a function of maturational processes and in maturational processes and experiential interactions. Implied for this factor is that mental structures, independent of such peripheral variables as sensory maturation, have altered and thus produce differential OR's. The development or change in detecting salient environmental dimensions (often referred to as concepts) such as color, size, shape, etc., could provide an example here.

Thus, for both signal and non-signal stimulus events, hierarchies of OR magnitude, independent of intensity variations and dependent to some degree on the salience of the environmental change, seem reasonable to assume. This should not be surprising, for it would be naive to assume that all discriminable events would produce equivalent OR's. In a recent review of the Russian literature on the OR, Razran (1961) has presented experimental data indicating differential OR's to different stimulus events. Examples of stimulus events which produce strong OR's are: rustling sound for hares; the sight of a cat for owls; the odor of rosemary and hunter's decoy sounds for ducks; the sound of wood splintering for beavers; and the sound of waves splashing for fish. While not ignoring the possibility of natural reinforcement, Razran believes that "the consistency of the results and the fact that young animals were used in some cases point to congenital ecological differences" (p. 115). Hierarchical orderings in the strength of stimulus events in animals has been shown.

If OR hierarchies exist, it must then follow that both focusing and some type of elaboration must be involved in producing an OR. That is, as soon as some stimulus events elicit an OR and others do not, a process other than focusing or tuning the analyzers must necessarily be considered. Razran (1961) in his review further states "yet there is little doubt that if any such pattern is accorded cognitive status [elaboration], the OR pattern is surely the most likely candidate." After stating several reasons for this belief, he concludes that it is a "preparatory and controlling mechanism of what is to come" (p. 119).

Because of our view that the OR must be considered both as a tuning and elaborating process, an alternative model shall be suggested. However, for the moment let us conclude that for an OR to take place, external stimulus events are both focused and elaborated upon as a function of some cognitive process involving more than the sensory experience of the stimulus and related to the cognitive salience to the organism. The rules of this cognitive salience, still undefined, then become the concern of the experimenter. By uncovering OR hierarchies, one hopes to be able to discern both the rules governing the occurrence of an OR and the process by which external events and internal representations or rules of meaning are considered.

Before discussing a general model of hierarchical attending, it is important to note that in Sokolov's neuronal model theory, mismatch between external non-signal events and internal representations elicits an OR, whereas for signal events it is the match between external and internal representations which elicits an OR. A simple mismatching theory appears to become strained in explaining this difference.

## General Model of Hierarchical Attending

An attempt to incorporate the above mentioned considerations into a model of attending follows. Alternative models have been presented, however most fail to consider the need for including cognitive rules acting upon external events. In a recent attempt to construct a model of attention and memory, Norman (1968) deals with one aspect of these cognitive rules. Figure 1 presents a diagram outlining the type of model necessary to account for some of the problems encountered earlier.

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Insert Figure 1 about here

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In the figure the energy qualities of the stimulus event, or the change in energy qualities caused by an event, are the initiators of the attentional process. These changes produce a general state of arousal or alerting. Its function is to change the organism from a totally unprepared, undifferentiated state into a state from which differentiated and organized behavior--either internal as in thoughts, etc., or external as in some motor response--can result. Concomitant with this alerting phase is the start of the analyzer tuning, stimulated by the energy change itself. This alerting-arousing function may be subcortical, located at the reticular level and occurring in short time spans.

At the next point in the information processing it is necessary to introduce the first type of elaboration operation because its outcome will determine whether the organism focuses on the stimulus event. This first elaboration operation could be either cortical or subcortical and may be in the service of any number of cognitive principles. Such cognitive principles might consist of certain expectation or rules, innate releasing mechanisms, or specific mental structures. Moreover, these principles may be programmed by the subject for specific events (as in the example of the mother programming herself to wake only when the infant cries), or be a more general, longer lasting program (such as response set in a learning problem). Two outcomes of this first elaboration are possible. In some cases, the elaboration will determine that the alerting event is unimportant and no further tuning or focusing will occur. On the other hand, the operation may indicate that the information is relevant to some cognitive princple and it therefore becomes necessary to completely tune and/or focus the analyzers for the next operation. One might picture the function of this first elaboration as the initial cognitive attempt of the organism to monitor the relevance of the information. In some sense, it could be considered a screen omitting from consideration only those sensory events that are irrelevant to the various cognitive principles.[5] It is important to note that the consideration of this initial elaboration makes no statement as to matching or mismatching the external event to any internal representation. Both processes may be involved and may depend on the nature of the external event and the particular cognitive principle involved. Thus, for signaled events, a matching process may be important while for non-signaled events, mismatching would represent the significant operation.

If the information is unimportant, inhibition occurs, alerting ceases and the analyzers stop focusing and turn to alternative events. Relevant information (always defined by the organism's cognitive principles) cause excitation and the full tuning of the analyzers so that a second state of elaboration, exploration and processing may occur. Typically, it is at this point, that is, the point of the signal to proceed tuning, that what has been called an OR becomes visible. Thus, at each of these operations general information (meaningless information) is becoming either differentiated and acted upon (becoming meaningful) or rejected, depending on the nature of the various cognitive principles.

After full tuning of the analyzers (OR), the second elaboration operation is performed. Again this elaboration operation is in the service of cognitive principles, for example, the reduction of stimulus uncertainty (Lewis & Goldberg, 1969; Pribram, 1967). It might be necessary, given that the information supplied by the analyzers is not sufficient to satisfy the cognitive principles at work during the second elaboration state, to refocus or utilize an alternative set of analyzers and then reconsider the elaboration step. Thus, some type of oscillation might take place until the particular cognitive principle was satisfied.

The model proposes two levels of sensory analyzers and two levels of elaboration, all in the service of a set of cognitive principles. This model differs from most attentional models in that it contains a feedback loop. Because of this feature it resembles Miller, Galanter and Pribram's TOTE system (1960). That is, an OR can be considered to be a tune-elaborate-tune-exit system. While certainly not answering many of the important questions (the nature of the various cognitive principles, for example), the model does account for the need to hypothesize both a tuning and elaborating process in the initial attentional interaction. Perhaps the model is best viewed not as containing a separate operation for each step, but rather some type of interactive process whereby both functions occur together, each necessary for the other. Thus, tuning and elaborating in a type of oscillating fashion move the stimulus event from a general energy statement to a highly differentiated information statement sufficient for the organism to act upon.

We have argued for the possibility, indeed the necessity, of considering sensory and cognitive experiences together as inseparable. That is, experience, even sensory experience, has a cognitive component and cannot be considered alone. This being so, then by the manipulation of various stimulus events, it may be possible to explore the mental structure of the organism by determining stimulus salience hierarchies. Moreover, by observation of the change in these hierarchies, a developmental course in these saliences may be determined.

## General Model for Investigating OR Hierarchies

Having argued for the possibility and necessity of an OR hierarchy, it is now necessary to explore a general method for empirically demonstrating their existence and systematic study.

A very useful paradigm for investigating the hierarchical nature of the OR is to present an event $(S_1)$ repeatedly for n trials and then to present some alteration $(S_2)$ on trial n + 1 . One would predict response decrement over the n trials having the form of a negative exponential function $Y = A + Be^{-Cx}$ (Lewis & Goldberg, 1969; Lewis, Goldberg, & Rausch, 1967; Thompson & Spencer, 1966). The presentation of $S_2$ on trial n + 1 should result in response recovery. This response decrement and recovery is one characteristic of an OR (Sokolov, 1963). In order to demonstrate that recovery is not a function of receptor or organism fatigue, it is necessary that $S_2$ be less intense than $S_1$ (Engen, Lipsitt, & Kaye, 1965). Moreover, in order to demonstrate a hierarchy of OR's, it is necessary to demonstrate that various alterations, $S_{2a}$, $S_{2b}$......$S_{2j}$, are equal in intensity and are equally discriminable from $S_1$ . Figure 2 presents a schematic representation of a hierarchy of $S_2$'s under this type of experimental paradigm. In this figure, responses such as orientation of the receptor (fixation of the eyes upon the stimulus event) are presented along the X axis, while trials and stimulus events are presented along the Y axis.

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Insert Figure 2 about here

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It is critical, at this point, to consider the issue of which responses constitute an orienting response and which responses constitute some other response, such as an exploratory response (ER). The preceding discussion has attempted to deal with this problem, in part, by eliminating the need to consider these processes as two separate or distinct operations. Clearly, the discussion of these two processes implies a time dimension with an orienting response preceding an exploratory response and having a shorter time duration. This distinction becomes confused when we consider that such indicative orienting responses as heart rate change and vasodilation or constriction are measured in terms of seconds rather than milliseconds. That is, at what point, in a several second response such as heart rate deceleration, does the subject go from an orienting to an exploratory response and how can these be separated? Thus, fast responses are not necessary to distinguish an orienting from an exploratory behavior. The speed of the occurrence of the response is not critical to the definition. It then follows that many responses can be considered to be orienting responses. Recently we (Lewis & Goldberg, 1969) have demonstrated that a young child's heart rate deceleration, fixation time, smiling and pointing all are highly correlated and all habituate to repeated presentation. All showed response recovery to a less intense altered event, satisfying the criteria of an OR.

The problem of orienting response measurement is interwoven with the preceding discussion of two distinct operations. If we avoid this type of model, the measurement problem becomes relatively easy. Acceptance of a model having separate OR and ER phases presents serious measurement problems, especially with measures that have slow response time.

## Experimental Data

In the following exposition this model has been used to investigate OR hierarchies. The demonstration of their existence across four stimulus event dimensions and the relating of this hierarchy to other cognitive operations are both presented in the service of proving that cognitive principles are involved in the OR. Moreover, these principles may be better understood by the systematic examination of these hierarchies.

## Method

### Subjects

Twenty-four Caucasian children, 12 girls and 12 boys, each approximately 44 months old (± 3 months), were used as subjects. The sample was slightly skewed toward the higher socioeconomic levels.

### Procedure

Experimental procedures identical to those described by Lewis (Dodd & Lewis, 1969; Lewis & Goldberg 1969; Lewis et al., 1967) were employed. Each subject was seated at a table in a small room. An adult female sat to the rear and side of the subject and visual stimuli were presented by rear-screen projection approximately 2 1/2 feet from the subject's head and at the subject's eye level.

Four different sets of stimulus events were used, each set consisting of the same six presentations of a chromatic picture of random straight lines ($S_1$) and a seventh trial of one of four alterations of the stimulus event ($S_2$). The $S_2$'s were (1) achromatic lines (BW); (2) lines one-half the length of those in $S_1$(1/2L); (3) one-half the number of lines as in $S_1$(1/2N); and (4) $S_1$ rotated $180^\circ$, or upside-down (UD). These $S_2$'s as well as $S_1$ are presented in Figure 3.

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Insert Figure 3 about here

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The subjects viewed each of the four sets, two at one experimental session, and two at a second session which averaged 16 days later but was not less than 7 days later. During each session a filler set was presented between the two experimental sets. The filler set, always the same, consisted of six presentations of a chromatic picture followed by a seventh trial in black and white. Four different orders of presentation of the experimental films were used to eliminate order effects, but the filler set always appeared between the first and second experimental sets for that session. The various orders of presentation of the sets are shown in Table 1.

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Insert Table 1 about here

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Each presentation was 30 seconds long with a 30-second intertrial interval. Fixation, smiling and surprise were recorded throughout the stimulus presentations.

In order to determine whether the $S_2$'s were discriminable from the $S_1$, a sorting task was presented to each subject immediately following each film. In this task, the subject was asked to help the experimenter sort 30 cards into two piles, 15 of $S_1$ and the appropriate $S_2$. These 30 cards were presented in random order. As the experimenter presented the task, the following instructions were given:

> Now we have a game to play. I want you to help me put these cards into two piles. See this picture (E points)? It goes in this box because it looks just like this picture (E puts the card in the box). Now, look at this picture. This one goes in this box because it looks just like this picture. Now, it's your turn. Look at these pictures which are standing up. Put this one (E hands the card to S) in the box in front of the picture that looks just like it. Now put this one (E hands the second card to S) in the box in front of the picture that looks just like it.

The criterion for evidence of discrimination was determined by using the normal approximation to the binomial distribution $\underline{Z} = \frac{(x \pm .5) - 1/2N}{1/2N}$ and was set at 20 correct responses out of 30 possibilities.

Measurement Procedures

As in the earlier work, orientation of the head and eyes toward the screen, now referred to as fixation time, was recorded by two observers who were unaware of which stimulus event was being presented Two additional observers recorded smiling and surprise. The depression or release of a key by the observers activated an event recorder and recorded the occurrence of the behavior. An automatic timer recorded stimulus onset and offset. Interscorer reliability for amount of fixation was .91 and ranged from .68 to .98 for the behavior data.

Response decrement was evaluated on the basis of a best-fit regression curve computed over all six trials (see Lewis & Goldberg, 1969). The data used to generate this curve were the combined data for the four separate presentations of $S_1$ series. The curve based on 4 points per 24 subjects for each of the six trials resulted in a most stable response function.

Response recovery was evaluated on the basis of a comparison of the observed response on trial 7 with that predicted by the regression function. In order to compare the various $S_2$'s , trial 7 minus the mean value at trial 6 was used. These differences were computed for each subject for each $S_2$ , always using that subject's mean response on trial 6. In effect, each subject served as his own control, with behavior on trial 7 evaluated on the basis of parameters of previous behavior by the same subject.

## Results

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Insert Figure 4 and Table 2 about here

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Fixation time. Response decrement was evaluated on the basis of a curvilinear regression curve fitted to the combined data for the four presentations of the $S_1$ series. The best fit curve was a negative exponential function of the form $Y = A + Be^{-Cx}$. Table 2a presents the raw data for each set as well as the combined data, while Figure 4 presents the best fit regression curve for the combined data[6] ($Y = 11.13 + 11.79e^{-.5x}$ ; $\underline{F} = 86.00$, $\underline{p} < .001$).

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Insert Table 3 about here

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Response recovery was shown to all four $S_2$'s and a hierarchical ordering of recovery was evident (see Fig. 4). For each $S_2$, the mean observed response on trial 7 was significantly different from that predicted by the regression function. The observed response on trial 7 represented distances of 15.80, 14.70, 10.60, and 5.19 standard deviations from the predicted point for the BW, 1/2L, 1/2N, and UD $S_2$'s ($\underline{p} < 1 \times 10^{-23}$ for the first three $S_2$'s, and $\underline{p} < 1 \times 10^{-7}$ for the last $S_2$, respectively[7]). An analysis of variance on the recovery scores revealed a significant $S_2$ effect ($\underline{F} = 7.26$, $\underline{p} < .001$). The $S_2$'s were then compared individually using the critical difference. Table 3 presents the mean recovery scores for each $S_2$ and the results of the individual comparisons.

Thus, the different $S_2$'s produced different degrees of recovery, the greatest recovery shown for the color change followed respectively by size, number and orientation changes.

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Insert Figure 5 about here

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Smiling. The smiling data (see Table 2b), like the fixation data, fit a regression curve of the negative exponential form. The regression curve[8] is shown in Figure 5, and the corresponding regression function is $Y = 0.40 + 4.43e^{-.5x}$ ($\underline{F} = 99.33$, $\underline{p} < .001$).

The smiling data showed response recovery to all four $S_2$'s , and as in the fixation data, a hierarchical ordering of recovery was evident (see Fig. 5). The observed response on trial 7 for the $S_2$'s represented standard deviations of 12.16 ($\underline{p} < 1 \times 10^{-23}$), 6.22 ($\underline{p} < 2.5 \times 10^{-10}$), 2.46 ($\underline{p} < .01$), and 2.84 ($\underline{p} < .003$) from the predicted points for the BW, 1/2L, 1/2N, and UD $S_2$'s , respectively. An analysis of variance on the recovery scores revealed a significant $S_2$ effect ($\underline{F} = 5.87$, $\underline{p} < .005$). Table 3b presents the results of comparisons of the individual $S_2$'s using the critical difference analysis.

Thus, the smiling response showed differential degrees of recovery to the four $S_2$'s . The greatest recovery was shown to the color change, followed respectively by size, rotation, and number. This order is similar to that for the fixation response, with only the relative positions of the number and rotation changes reversed.

Surprise. Fifteen instances of surprise were recorded for the four series; more subjects showed surprise on trial 7 than on any other trial. The recorded occurrence of surprise across series was 1, 2, 0, 1, 3, 2, and 6 on trials 1 through 7 respectively. There were no differences in surprise between $S_2$'s .

## Discriminability of the Stimuli

A possible explanation of the differential recovery to the $S_2$'s lies in the differential discriminability of the stimuli. That is, differential OR's might be produced as a function of discrimination. However, in any test of discriminability several vectors, not readily distinguished, may be at work. For example, the subject may not be able to show discrimination because of the inability of some receptor or because the stimulus quality does not stand out (is not salient). If told about the particular stimulus quality, the subject might then be able to discriminate. In general, one might consider the differences in these vectors comparable to that between physiology and attention in discrimination.

While it is difficult to separate these vectors, it was necessary to determine whether there were any gross differences in a simple test of discrimination. A sorting task was presented to each subject immediately following each series. The procedure is described in the methods section. In addition to the sorting task criteria, any spontaneous vocalizations by the child which clearly indicated that he distinguished between the $S_2$ and $S_1$ were also accepted as evidence of discrimination. Examples of acceptable vocalizations were: "They're all black and white!" (to BW); "They're little ones!" (to 1/2L); "They cut some out!" (to 1/2N); "It's upside-down!" (to UD); and, "What's the matter with these? They're taken off! But they're not taken off here!"

Using both sorting task and vocalization criteria, only the data for those subjects who showed discrimination were used in the following analysis. For each child, a mean regression curve was obtained for only those series in which discrimination was observed. This meant that for some subjects all four series were used to obtain a mean, while for others only one, two or three series were used. After computing each subject's individual data, a mean curve, over all subjects was obtained. Responses to the various violations were obtained in the same manner. Observation of both the fixation and smiling data for those who did and did not show discrimination on the sorting task revealed no significant difference between the groups. Thus, fixation and smiling time recovery to stimulus change were not affected by whether or not the subject showed discrimination between $S_1$ and the particular $S_2$. Exactly what this result means is unclear; however, it does suggest that a sorting task is a less sensitive measure of discriminability than is the OR paradigm.

The following results suggest that sensory inability to discriminate between the various $S_2$'s and $S_1$ was not responsible for the OR hierarchy.

For fixation time, the regression function for the composite data was $Y \doteq 11.36 + 9.71e^{-.5x}$ ($\underline{F} = 71.47$, $\underline{p} < .005$). Recovery was shown to all four $S_2$'s and, like the data for the entire sample, a hierarchical ordering of the $S_2$'s was evident. The observed mean TF on trial 7 for the BW, 1/2L, 1/2N, and UD $S_2$'s represented distances of 9.88 ($\underline{p} < 2.5 \times 10^{-23}$), 9.85 ($\underline{p} < 3.5 \times 10^{-23}$), 6.32 ($\underline{p} < 1.5 \times 10^{-10}$), and 1.75 ($\underline{p} < .04$) standard deviations from the point predicted by the regression function respectively. The mean recovery scores reflect a similar hierarchical order, and with discriminability controlled, remained the same as the sample as a whole.

Like fixation, the smiling data for the subsample were similar to the data for the entire sample. The best fit regression curve for the composite data over the first six trials was $Y = 0.35 + 4.10e^{-.5x}$ ($\underline{F} = 107.11$, $\underline{p} < .001$).

All four $S_2$'s showed recovery of the smiling response and the resultant hierarchical ordering of the $S_2$'s was again the same as that found for the entire sample. The observed response on trial 7 for the BW, 1/2L, 1/2N, and UD $S_2$'s, respectively, represented distances of 9.39 ($p < 3 \times 10^{-21}$), 6.21 ($p < 3 \times 10^{-10}$), 2.71 ($p < .003$), and 5.53 ($p < 2 \times 10^{-8}$) standard deviations from the predicted point. The mean recovery scores paralleled the standard deviation scores and maintained the hierarchical order of color, size, number and rotation.

In brief, the data for the subjects who met the discrimination criteria do not differ significantly from the data for the whole sample. Thus, the discriminability of the stimuli, as defined by the vocalization and sorting criteria, did not account for the differential recovery shown to the $S_2$'s .

Random Sequence Films

It might be argued that the intrinsic characteristics of the stimulus events themselves, independent of any change factor, would differ from the standard and from each other. In order to investigate this possibility, a succession of random sequence series including each of the $S_2$ stimuli and $S_1$ were presented to an independent sample of 15 children, 10 boys and 5 girls. Each stimulus was presented twice to each subject in random order. The order of presentation varied among the subjects.

The results of an analysis of variance on the fixation and smiling responses to the random sequence films yielded a nonsignificant stimulus effect for each of the responses (see Table 4). Apparently, there are no differences among the $S_2$ events nor between any of the $S_2$ and $S_1$ events due to intrinsic characteristics of the stimuli. Differences among $S_2$ must therefore be attributed to the effect of the presentation of a new stimulus ($S_2$) following repeated presentations of the standard ($S_1$) .

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Insert Table 4 about here

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## Discussion

The decrement data for both the fixation and smiling responses confirm the earlier results reported by Lewis, Goldberg and Rausch (1967) and Lewis and Goldberg (1969). These data indicate that response decrement as a function of stimulus repetition follows the form of a negative exponential curve. Growing experimental evidence (Lewis, 1967; Razran, 1961) indicates that the rate of this decrement is related to cognitive variables. Stimulus change following stimulus repetition produces an orienting reflex, and the magnitude of the OR varies with the nature of the stimulus change. It is to be noted that three of the stimulus changes in this experiment were less intense (contained fewer of such variables as number, length or color), while the fourth--orientation--was equally as intense as the repeated event. The increase in response strength (OR) was thus attributable not to overriding a fatigued receptor but to the stimulus change. Moreover, the differences in the OR's associated with the various stimulus changes were neither a function of some intrinsic quality of the events nor of their differential discriminability.

Both the fixation and smiling data indicate a hierarchical ordering of attentive behavior.

The hierarchical ordering of OR intensity was such that color changes produced the greatest OR, while size, number and orientation followed in that order. If this ordering is related to the salience of the stimulus change, as a function, for example, of the child's mental structure, other data reporting on stimulus salience should provide parallel results. The data on this problem is sparse, however. Rice (1930) in a study of concept formation in young children found that the orientation of plane figures on a page is not a relevant perceptual factor until 5 or 6 years of age. The least OR in this experiment was produced by orientation changes. Brian and Goodenough (1929) found that in a study of form and color concepts, color is predominant at three years of age. More recently Lee (1965) presented children with six different concepts in what she called a concept identification task. Of these, the results for the color, size, and number concepts are most relevant here. Lee found that the children in her youngest age group (average age 46 months) showed significant differences in the mean number of errors made in solving each of the concepts. Her results indicated that the color concept was the most easily formed, followed by size and number. The results, then, indicate a hierarchy of concept attainment for young children. Moreover, the order of concept attainment and the intensity of the OR as a function of stimulus change as found in this study are identical. Thus, the hierarchical nature of the OR to stimulus change corresponds to that found using other measures of mental structure.

It would be unrealistic to assume, however, that this hierarchy remains stable throughout childhood. As development progresses, different aspects of the child's surroundings become relevant to him, and corresponding changes occur in his mental structure and in his stimulus-change-salience hierarchy. Indeed, several studies have demonstrated that the hierarchy of concept formation changes as a function of age. Brian and Goodenough (1929) found that form is used as the basis for matching until three years of age. A preference for color appears at three years and remains until six years, at which time form again becomes predominant in adulthood. Lee (1965) also found that at 46 months, fewer errors are made in the formation of color concepts than in form concepts, while at almost six years, the reverse is true. Kagan and Lemkin (1961) found similar results using a sample of children almost six years of age, and Suchman and Trabasso (1966) reported that these preferences are stable despite changes in hue, saturation and figure contour. It would appear, therefore, that there are hierarchies of OR's to various stimulus events and that these hierarchies are related to mental structure as measured in such tasks as concept formation. Moreover, there is every reason to believe that these hierarchies are not fixed, but vary as a function of the altering mental structure.[9]

The present paper has attempted to argue persuasively for the position that there are important cognitive components to the OR. We have shown that there are OR hierarchies and that these are related to other cognitive tasks such as concept formation acquisition. While the cognitive principles governing these hierarchies are yet unknown, it is our belief that the mapping of these hierarchies will aid in their discovery and will, at the same time, enable us to uncover the process whereby the organism processes or defines incoming events.

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## Footnotes

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[2] This issue of response measurement has important implications and will be reopened in subsequent discussions.

[3] It must be noted that while the term "reflex" is being used throughout this paper, it is not the intention of the author to restrict the term to its exact meaning, but rather to use it in a more general sense of "response." By this manner we may avoid the many difficulties inherent in the term "reflex."

[4] This issue, i.e., the meaning and concept of a stimulus, is, unfortunately, sadly neglected but is a most important problem. For a lucid discussion of this issue, the reader is referred to Gibson's 1960 paper.

[5] It is recognized that there are some classes of sensory events which impose themselves regardless of the desire or intent of the organism.

[6] The data were combined over the 4 series in order to provide a more stable curve, both for the exploration of response decrement and for comparison of the various $S_2$ changes. This procedure seems justified first by observation of the data of Table 2a. There was little difference in the shape of the various sets. An analysis of variance was computed on trials 1 through 6 using a treatments-by-treatments-by-subjects design (see Bruning & Kintz, 1968). As expected, the results revealed no series effect ($F = 0.18$) and a significant trial effect ($F = 17.96$, $p < .001$). The analysis also

revealed a significant series by trial interaction effect ($F = 1.85$, $p < .05$). Investigation of the interaction was made by comparing the critical difference with the within-trial differences in means over all the series (see Lindquist, 1953). Four of the resulting 36 comparisons were significant and these were all on the early trials: three on trial 2 and one on trial 3. However, out of 36 comparisons, two significant results can be expected by chance alone. Further, since the interaction was evident only in the early trials, it is clear that the latter half of the trials were basically the same across series. In addition, because the interest of this experiment is focused on the overall response decrement rather than on individual trials, an analysis of variance was computed on the decrement scores (trial 1-6/1) across series. No series effect was found ($F = 0.67$). The combination of the data across series thus seems justified.

[7] One-tailed probabilities were used for all recovery measures because earlier studies by Lewis et al. (1967, 1969) provided a strong basis for the prediction of the direction of the response on trial 7 in relation to trial 6.

[8] Like the fixation data, the smiling data showed no significant difference over the four repeated sets (see Table 2b). An analysis of variance over trials 1 through 6 showed no series effect ($F = 0.04$), a significant trial effect ($F - 15.07$, $p < .001$), and no interaction effect ($F = 0.64$). An analysis of the decrement scores also showed no series effect ($F = 0.84$).

[9] It should not escape the reader that a method for demonstrating stimulus event salience has been suggested. Moreover, this method requires

no verbal instructions and is applicable for all age groups, even the very young infant. Changes in the hierarchical ordering of stimulus salience can be obtained and important developmental consequences mapped.

Table 1

Order of Set Presentation

| First Session | Second Session | Number of Subjects |
|---|---|---|
| BW, Filler, 1/2L | 1/2N, Filler, UD | 6 |
| 1/2N, Filler, BW | UD, Filler, 1/2L | 6 |
| UD, Filler, 1/2N | 1/2L, Filler, BW | 6 |
| 1/2L, Filler, UD | B/W Filler, 1/2N | 6 |

## Table 2

Means by Trial for Each Set for (a) Fixation, (b) Smiling,

### (a) Fixation (TF)

Trial

| | $S_1$ | | | | | | $S_2$ |
|---|---|---|---|---|---|---|---|
| Set | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| BW | 18.65 | 12.52 | 14.13 | 12.69 | 11.22 | 12.85 | 22.54 |
| 1/2L | 19.76 | 14.23 | 14.24 | 12.76 | 12.04 | 10.40 | 21.77 |
| 1/2N | 17.73 | 19.13 | 12.09 | 14.03 | 12.71 | 12.69 | 18.90 |
| UD | 17.00 | 14.96 | 16.29 | 11.69 | 13.29 | 9.19 | 15.11 |
| Mean Score | 18.28 | 15.21 | 14.19 | 12.79 | 12.31 | 11.28 | |

### (b) Smiling Time

| | $S_1$ | | | | | | $S_2$ |
|---|---|---|---|---|---|---|---|
| BW | 3.96 | 1.75 | 1.50 | 0.61 | 0.55 | 0.73 | 5.03 |
| 1/2L | 2.75 | 2.21 | 1.35 | 1.47 | 1.08 | 0.50 | 2.83 |
| 1/2N | 2.99 | 1.20 | 2.02 | 0.79 | 1.09 | 0.79 | 1.44 |
| UD | 3.10 | 1.93 | 1.26 | 0.60 | 0.91 | 0.35 | 1.58 |
| Mean Score | 3.20 | 1.77 | 1.53 | 0.87 | 0.91 | 0.59 | |

## Table 3

## The Mean Recovery Scores (7-6 Trial Differences) for Each $S_2$ and the Significance of Differences Between Them for (a) Fixation and (b) Smiling

### (a) Fixation (TF)

| | $\bar{x}$ | 1/2L | 1/2N | UD |
|---|---|---|---|---|
| BW | 11.26 | 0.78 | 3.65* | 7.51** |
| 1/2L | 10.48 | -- | 2.87* | 6.73** |
| 1/2N | 7.61 | | -- | 3.86* |
| UD | 3.75 | | | -- |

### (b) Smiling

| | $\bar{x}$ | 1/2L | 1/2N | UD |
|---|---|---|---|---|
| BW | 4.44 | 2.19* | 3.58** | 3.41** |
| 1/2L | 2.25 | -- | 1.39 | 1.22 |
| 1/2N | 0.86 | | -- | 0.17 |
| UD | 1.03 | | | -- |

* $p < .05$

** $P < .001$

## Table 4

## Analysis of Variance on Fixation, and Smiling Responses to Random Sequence Films

| Measure | Source | SS | df | MS | F | P |
|---|---|---|---|---|---|---|
| Fixation | Total | 2561.18 | 74 | | | |
| | Subjects | 1736.99 | 14 | | | |
| | Treatments | 47.08 | 4 | 11.77 | 0.85 | NS |
| | Error | 777.11 | 56 | 13.88 | | |
| Smiling | Total | 553.45 | 74 | | | |
| | Subjects | 345.90 | 14 | | | |
| | Treatments | 28.60 | 4 | 7.15 | 2.23 | NS |
| | Error | 178.95 | 56 | 3.20 | | |

## Figure Captions

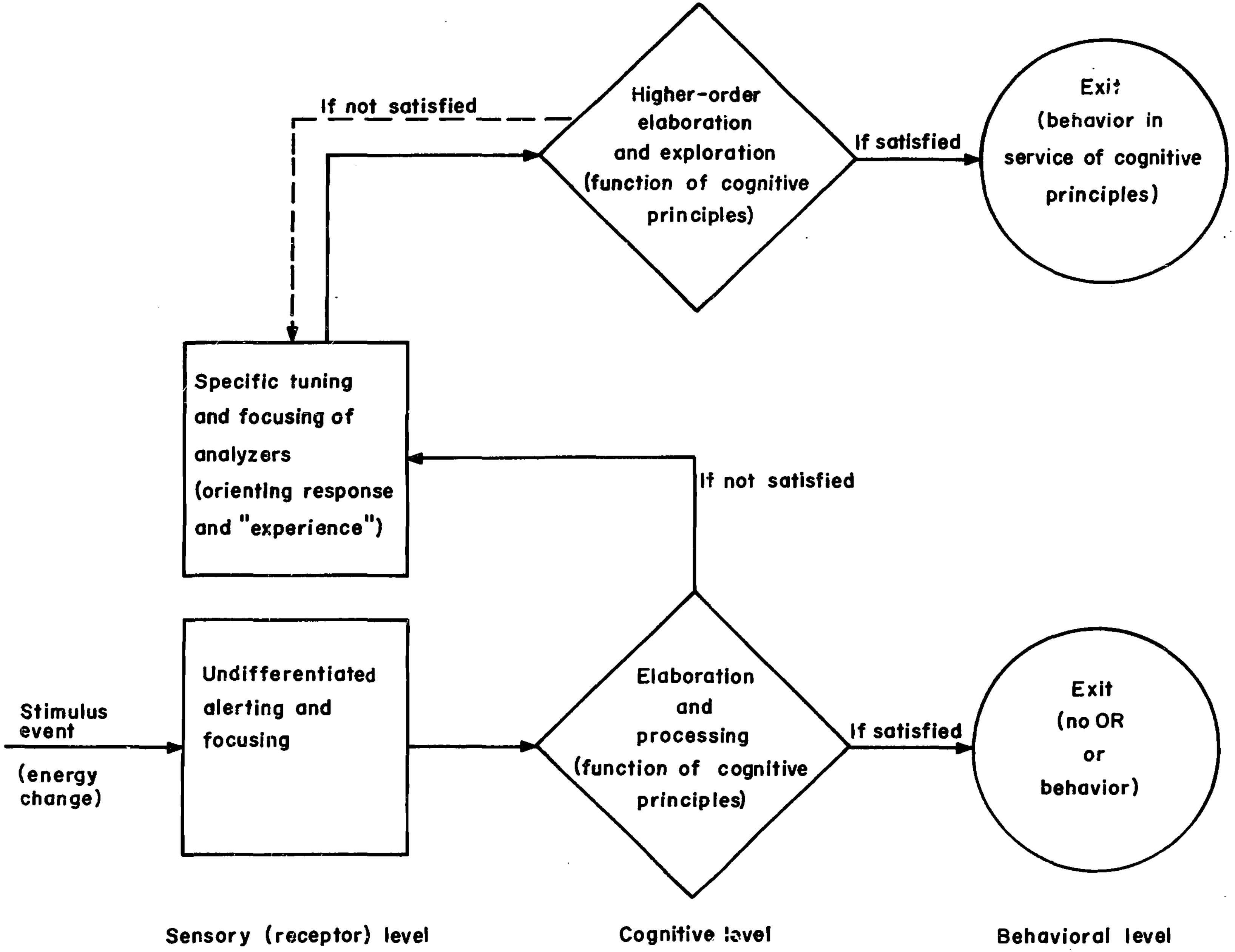
Fig. 1. A representation of the cognitive and sensory interaction involved in information processing.

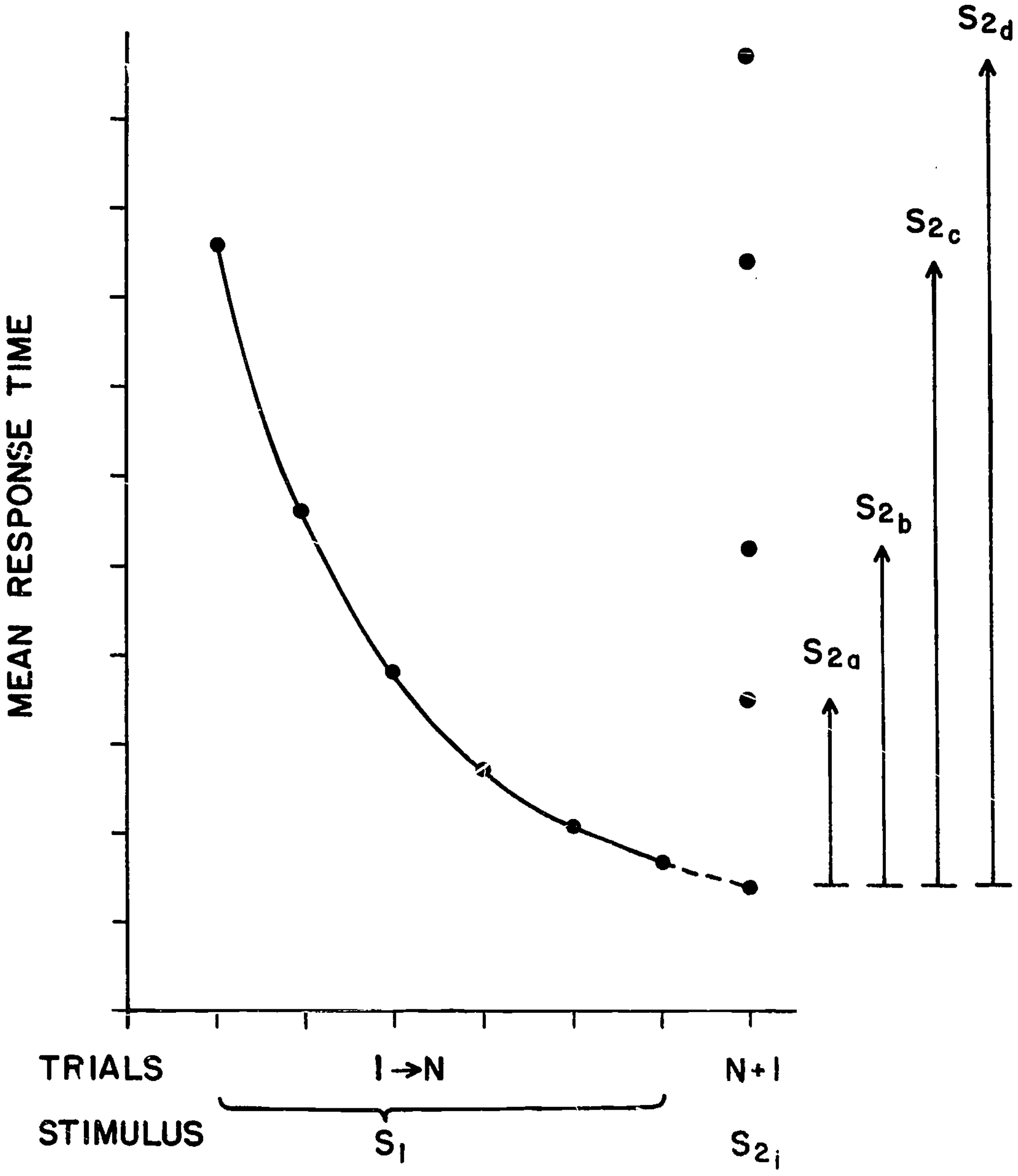
Fig. 2. A representation of an experimental paradigm for investigating OR hierarchies. $S_1$, the standard event, is presented for n trials while on trial n + 1 some variation of the standard, $S_{2_j}$, is presented. Response decrement showed result from repeated presentation of $S_1$ and response recovery to $S_{2_j}$.

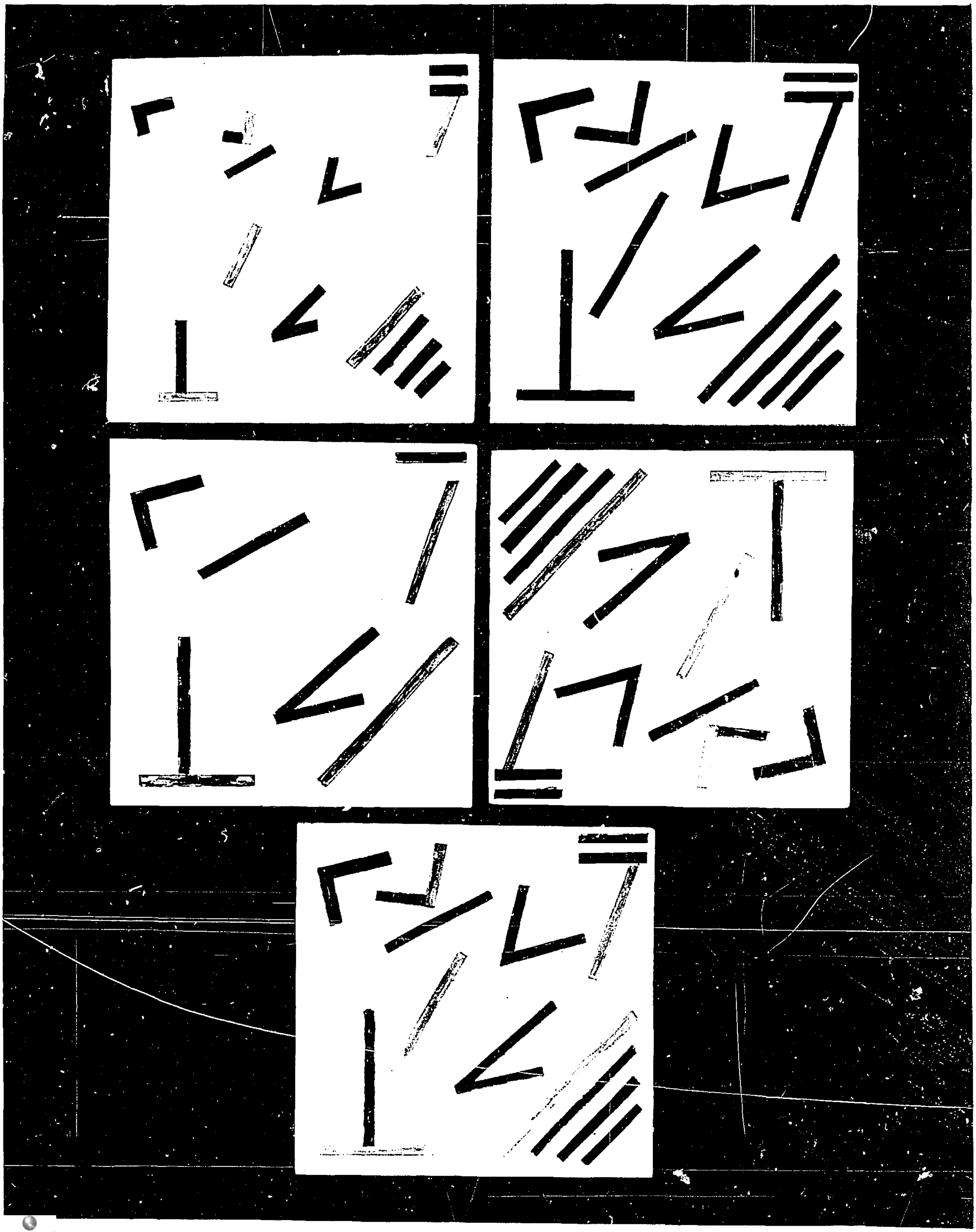
Fig. 3. Presents the standard stimulus event $S_1$ and the four variations $(S_2)$. The top center stimulus is the standard and is chromatic. The left middle stimulus is exactly the same as the standard except that it is rotated 180° (UD). The right middle stimulus has 1/2 the number of lines as the standard and is chromatic (1/2N). The lower left stimulus has the same number and size elements as the standard but is achromatic (BW). Finally the lower right stimulus has 1/2 the size stimulus elements as the standard and is chromatic (1/2L).

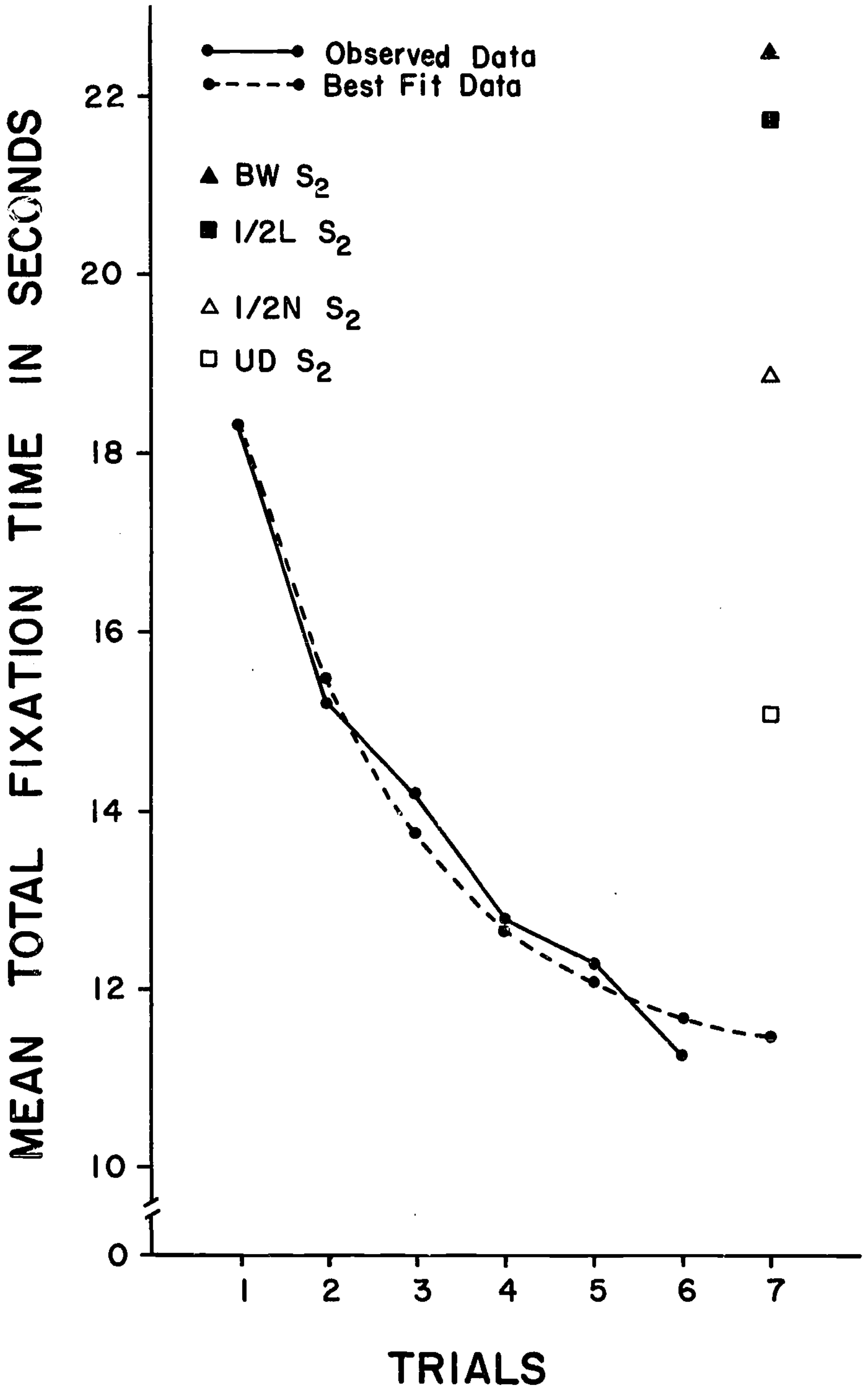
Fig. 4. Presents the fixation data for the $S_1$ and various $S_2$'s.

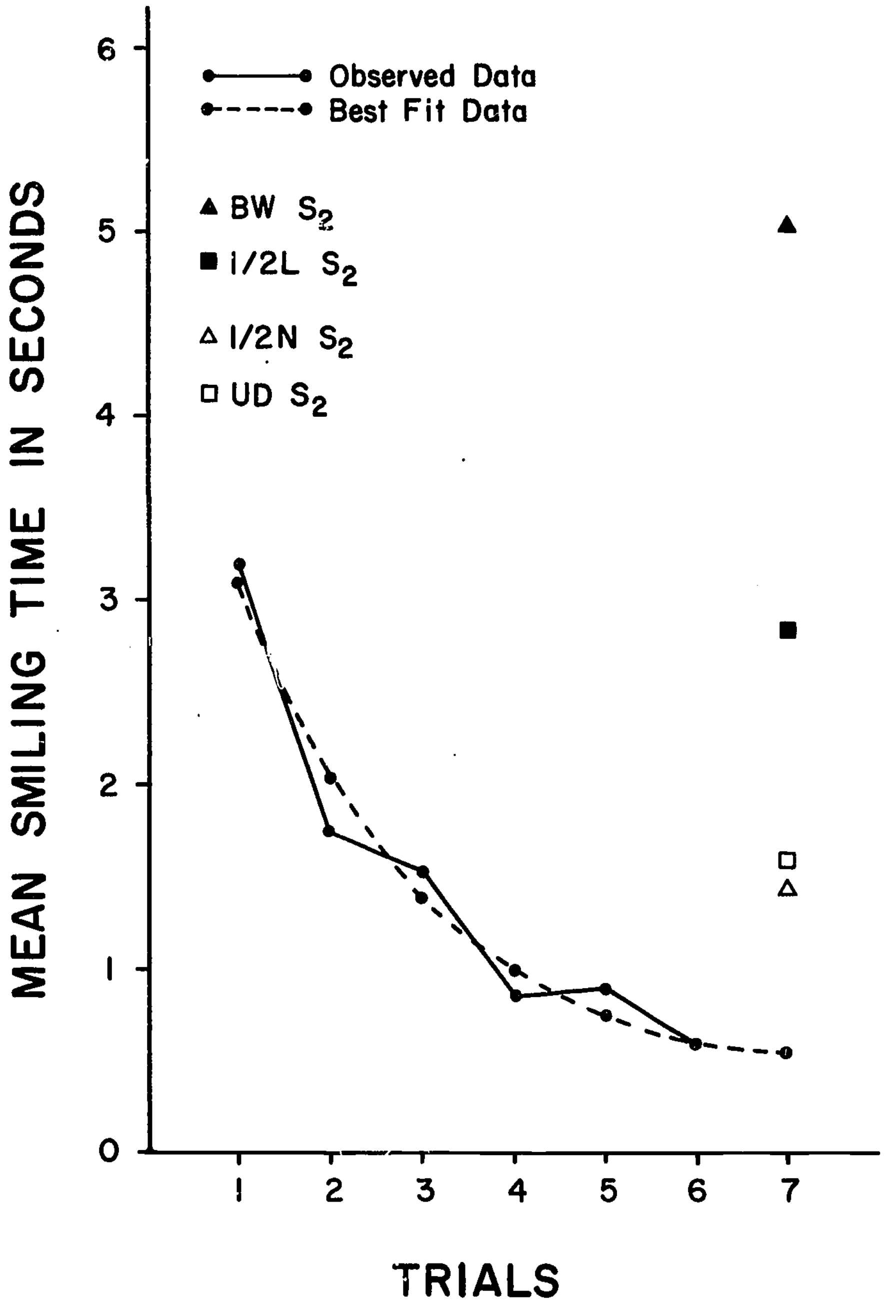
Fig. 5. Presents the smiling data for the $S_1$ and various $S_2$'s.


If not satisfied
Higher-order elaboration and exploration (function of cognitive principles)
If satisfied
Exit (behavior in service of cognitive principles)
Specific tuning and focusing of analyzers (orienting response and "experience")
If not satisfied
Stimulus event
(energy change)
Undifferentiated alerting and focusing
Elaboration and processing (function of cognitive principles)
If satisfied
Exit (no OR or behavior)
Sensory (receptor) level
Cognitive level
Behavioral level


MEAN RESPONSE TIME
TRIALS
1 → N
N+1
STIMULUS
S1
S2i
S2a
S2b
S2c
S2d




MEAN TOTAL FIXATION TIME IN SECONDS
22
20
18
16
14
12
10
0
1
2
3
4
5
6
7
TRIALS
Observed Data
Best Fit Data
▲ BW $S_2$
■ I/2L $S_2$
△ I/2N $S_2$
□ UD $S_2$


Observed Data
Best Fit Data
▲ BW $S_2$
■ 1/2L $S_2$
△ 1/2N $S_2$
□ UD $S_2$
MEAN SMILING TIME IN SECONDS
0
1
2
3
4
5
6
TRIALS
1
2
3
4
5
6
7