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64. *Note.* After submission of this manuscript, two items have come to our attention that provide confirmative evidence that a chemical homology exists between the regions v and v' of heavy γ- and light κ-chains (Fig. 9). Hood *et al.* (*62*), by Edman degradations from the NH_2-terminals of seven human Bence Jones κ-chains, have shown that, in confirmation of the work of Hilschmann and Craig (*37*) and Titani *et al.* (*38*), the NH_2-terminal sequence of any one chain is constant but can vary from one chain to another. However, the number of variations at any one position along the chain appears to be limited; shown below are the variations so far found (numerals indicate positions):

1	2	3	4	5	6
Asp,Glu	Ilu	Gln,Val	Val,Met,Leu	Thr	Gln

Porter and Press (*63*) have recently shown that the NH_2-terminal tripeptide of one particular myeloma heavy-γ-chain was PCA-Val-Thr, where PCA is pyrrolidonecarboxylic acid, arising presumably from the cyclization of glutamine. It is of considerable interest that the tripeptide Gln-Val-Thr has its counterpart, therefore, in a possible κ-chain sequence at positions 3, 4, and 5 from the NH_2-terminal.
65. Studies reported in this article have been supported by NSF grant GB-1251 and PHS grant AI-06659.

Curiosity and Exploration

Animals spend much of their time seeking stimuli whose significance raises problems for psychology.

D. E. Berlyne

Higher animals spend a substantial portion of their time and energy on activities to which terms like *curiosity* and *play* seem applicable (*1, 2*). An even more conspicuous part of human behavior, especially in highly organized societies, is classifiable as "recreation," "entertainment," "art," or "science." In all of these activities, sense organs are brought into contact with biologically neutral or "indifferent" stimulus patterns—that is, with objects or events that do not seem to be inherently beneficial or noxious. Stimulus patterns encountered in this way are sometimes used to guide subsequent action aimed at achieving some immediate practical advantage. An animal looking and sniffing around may stumble upon a clue to the whereabouts of food. A scientist's discovery may contribute to public amenity and to his own enrichment or fame. Much of the time, however, organisms do nothing in particular about the stimulus patterns that they pursue with such avidity. They appear to seek them "for their own sake."

Until about 15 years ago these forms of behavior were overlooked in the theoretical and experimental literature, except for a few scattered investigations. Recently they have been winning more and more interest among psychologists. They constitute what is generally known in Western countries as "exploratory behavior" and, in Eastern Europe, as "orientational-investigatory activity."

Early demonstrations of the prevalence and strength of these activities in higher animals were rather embarrassing to then current motivation theories. Animals are, of course, most likely to explore and play when they have no emergencies to deal with, but there are times when these behaviors will even override what one would expect to be more urgent considerations. A hungry rat may spend time investi-

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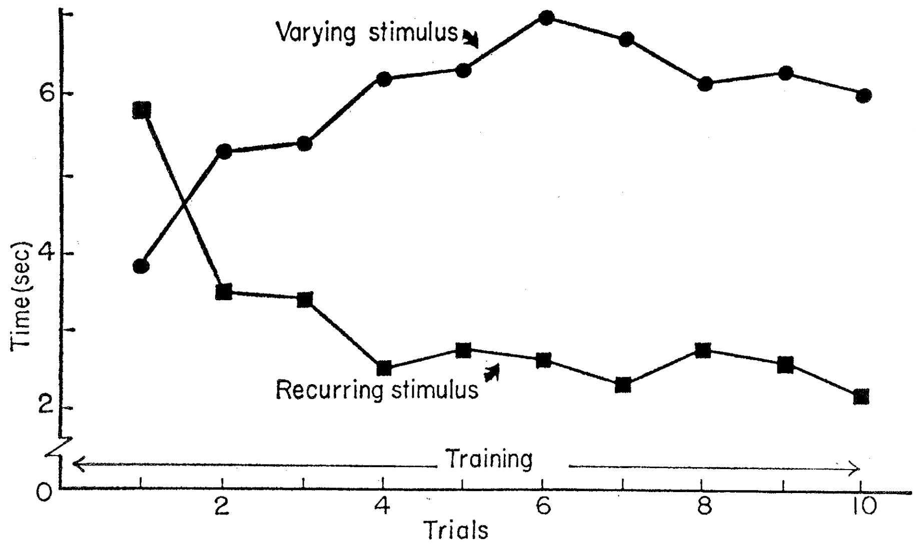

Fig. 1. Mean time spent by subjects fixating a novel (varying) and a familiar (recurring) pattern when the two were presented side by side for ten 10-second trials with 20-second intertrial intervals. [Adapted from Berlyne (*14*)]

gating a novel feature of the environment before settling down to eat (*3*). A bird may approach a strange and potentially threatening object at the risk of its life (*4*). Even human beings are reported to have played the lyre while Rome was burning and to have insisted on completing a game of bowls after an invading armada had been sighted.

Under the influence of Darwin's evolutionary theory and later of Cannon's concept of homeostasis, it had come to be widely believed during the 1930's and 1940's that the motivation of behavior is bound up with clear-cut prerequisites of survival, such as eating, drinking, procreating, and avoiding bodily injury. Behavior is set in motion, it was thought, either by biological dangers or by events associated (through contiguity or through similarity) with biological dangers. Similarly, the goals for which animals and human beings strive were commonly assumed to have inherent or learned connections with biological gratification or relief. These assumptions, in different forms, were shared by the early neobehaviorists, physiological psychologists, and psychoanalysts.

As knowledge accumulated about the conditions that govern exploratory behavior and about how quickly it appears after birth, it seemed less and less likely that this behavior could be a derivative of hunger, thirst, sexual appetite, pain, fear of pain, and the like, or that stimuli sought through exploration are welcomed because they have previously accompanied satisfaction of these drives. The facts about exploratory behavior were especially hard to reconcile with the view once offered by Freud (*5*) and later espoused by neobehaviorists (*6*) that behavior is essentially directed toward minimizing stimulation and excitation, a view that anybody who has had to handle a child "with nothing to do" must have been tempted to question.

Being now compelled to recognize that higher animals put a great deal of effort into securing access to stimuli with no manifest ecological importance, we can discern two groups of reasons why this phenomenon may make biological sense. First, we know that spontaneous activity is constantly present within the central nervous system and that, during waking hours, the sense organs are ceaselessly bombarded with stimuli, all of which initiate excitatory processes within the brain. We also know that the brain is a highly intricate organ in which many processes can be initiated simultaneously and can interact to their mutual impediment. The only way in which the brain can perform its prime function of selecting adaptive responses is to allow one process to advance and complete itself while competing processes are held in check. To determine which process shall be granted priority, the brain depends on information about conditions inside and outside the organism, some of which enters through sense organs and some of which is stored after having been deposited by previous learning or by natural selection. The required information will often be lacking, in which case the brain will be unable to arbitrate between, or reconcile, the discrepant demands that are made on it. Reciprocal interference between processes going on within it and—if the organism is beset by an urgent call for action—conflict among incompatible response-tendencies may eliminate the effectiveness of behavior. So, in such cases, it is clearly useful for an organism to secure access to stimulus patterns that contain the information from lack of which it is suffering.

The second group of reasons is quite different. It seems that the central nervous system of a higher animal is designed to cope with environments that produce a certain rate of influx of stimulation, information, and challenge to its capacities. It will naturally not perform at its best in an environment that overstresses or overloads it, but we also have evidence that prolonged subjection to an inordinately monotonous or unstimulating environment is detrimental to a variety of psychological functions (*7, 8*). How much excitement or challenge is optimal will fluctuate quite widely with personality, culture, psychophysiological state, and recent or remote experience. But we can understand why organisms may seek out stimulation that taxes the nervous system to the right extent, when naturally occurring stimuli are either too easy or too difficult to assimilate.

With accumulating research, there have been more and more indications that exploratory responses can be of two distinct classes, corresponding to these two distinct biological needs. On the one hand, when an animal is disturbed by a lack of information, and thus left a prey to uncertainty and conflict, it is likely to resort to what we may call *specific* exploratory responses. These supply or intensify stimulation from particular sources—sources that can supply the precise information that the animal misses. The condition of discomfort, due to inadequacy of information, that motivates specific exploration is what we call "curiosity." In other circumstances, an animal seeks out stimulation, regardless of source or content, that offers something like an optimum amount of novelty, surprisingness, complexity, change, or variety. For this kind of behavior the term *diversive* exploration has been proposed. It is not preceded by receipt of partial information about the stimulus patterns at which it is aimed and thus seems to be motivated by factors quite different from curiosity.

Specific Exploration

One of the earliest discoveries coming out of Pavlov's work on "higher nervous activity" was the phenomenon that he called the "orientational" or "investigatory" reflex (*9*). A dog would respond to any unusual or unexpected happening by desisting from whatever activity it might otherwise have been engaged in and turning its eyes, head, and trunk toward the source of stimulation. This was an unconditioned or innate reflex, and yet it was subject to many of the processes to which conditioned reflexes are subject, including extinction and disinhibition. If the stimulus evoking it were repeated at short intervals, the orientational response would gradually disappear. It would come back if the stimulus recurred, say, a day later, but, after several recoveries and extinctions the power of a particular stimulus to evoke the response might be permanently weakened (*1*, chap. 4). It was thus shown that novelty, especially short-term novelty, is a potent factor governing this reaction.

The influence of novelty was amply confirmed when specific exploratory behavior began to be studied in the West. It was found, for example, that a rat is more likely to walk up to and sniff at an object that it has not seen before than one to which it has been exposed during the last few minutes (*10*). When a rat is confined in a novel environment, the amount of wandering about that it does and the frequency with which it approaches a particular feature of the environment decline with time—that is, as the stimulus patterns that are present lose their novelty (*11*, *12*). When the animal is put back into the situation after spending some time away from it, exploration will revive, but the revival will become less and less marked if the repeated exposures extend over several days.

Apart from the influence of novelty, the strength and direction of exploratory responses in animals have been shown to depend on stimulus properties of the kind usually denoted by words like *complexity*. More vigorous and prolonged exploration will generally be attracted by objects that of-

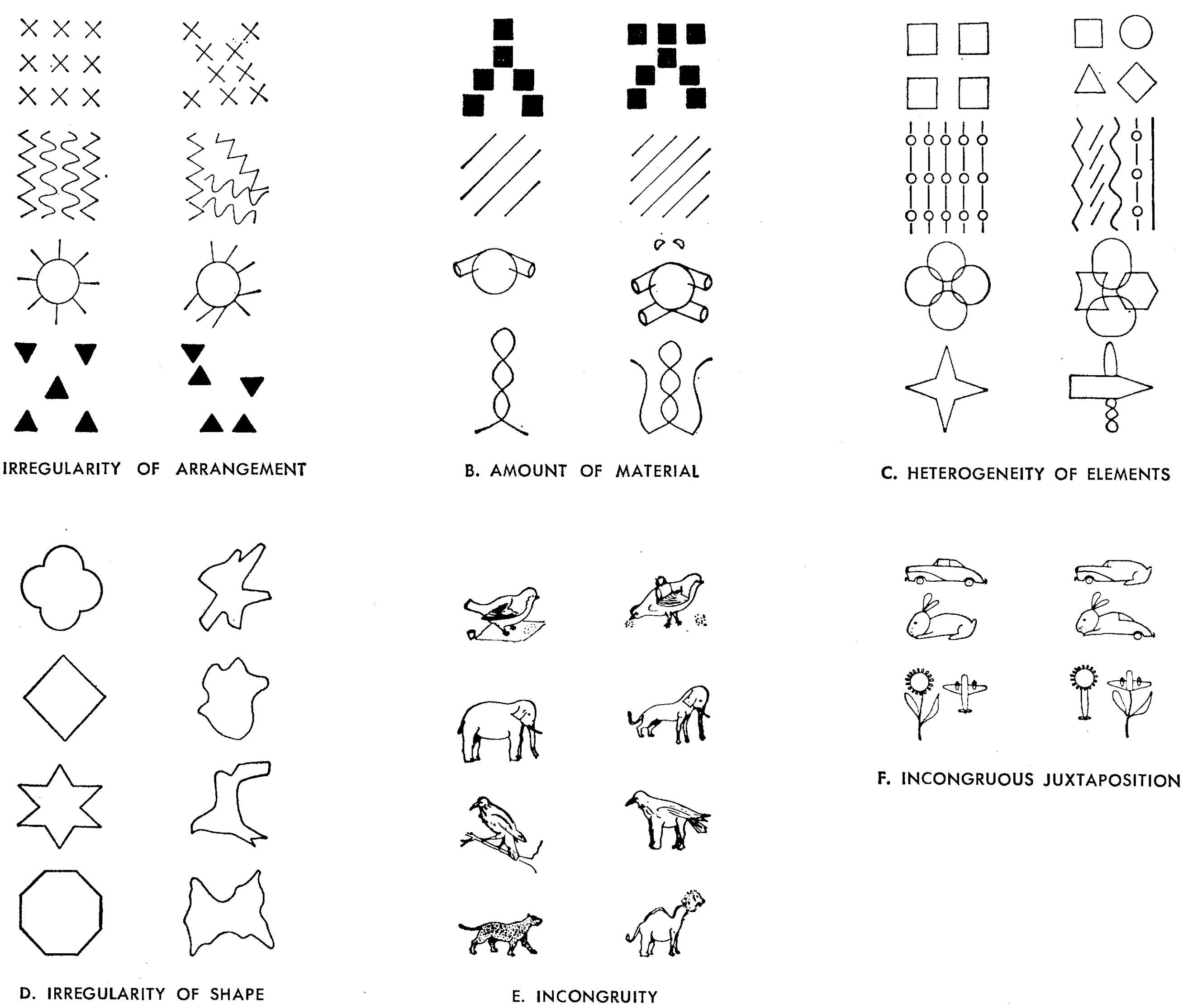

Fig. 2. Visual patterns, representing various "complexity" and "incongruity" variables, used in experiments on exploratory and related behavior in human adults. [From Berlyne (*16*); some of the same patterns were used in experiments reported in *14*, *15*, *17*, *18*, *30*, *31*, and *39–41*]

fer more varied or more irregular stimulation (*12, 13*).

Similar variables have been found to govern specific exploration in the human adult. We have used a number of techniques to compare the power of different visual patterns to attract and sustain inspection when subjects are given no special reason to attend to them. We have allowed subjects access to a switch controlling a tachistoscope, by means of which they could give themselves as many successive brief (0.14-second) glimpses of a pattern as they wished before calling for the next pattern (*14*). We have presented successions of patterns in an automatic projector, letting subjects look at each pattern for as long as they wished before pressing the button that replaced it with the next one (*15*). We have presented patterns side by side on a screen and measured how much time the subject spent fixating each of them; this measurement was made either by having eye movements observed by an experimenter who did not know which patterns were being exposed (*16*) or by recording them with an eye-movement camera (*17*). The influence of novelty is shown by one experiment (*16*) in which we showed a series of pairs of animal pictures, the picture on one side (the left and the right sides for equal numbers of subjects) being the same on every trial and the picture on the other side being changed from one trial to the next. Observation of eye movements (see Fig. 1) revealed that, as trials succeeded one another, the subjects spent a lower and lower proportion of the time inspecting the recurrent pattern and more and more time looking at the changing patterns.

All the techniques just mentioned have been used to study effects on exploration time of several stimulus properties that, although distinct, exemplify the kind of variable we mean when we use words like *complexity*, *irregularity*, or *incongruity*. In each of the pairs of patterns shown in Fig. 2, the member on the right is the more "complex" or "irregular" one, but the actual property that distinguishes it from its neighbor varies from one category of pairs to another. We have regularly found that the subject spends more time looking at the "more complex" than at the "less complex" pattern of a pair. Since all these patterns are relatively simple, we have more recently added the patterns of Fig. 3 (*15, 17, 18*). These likewise comprise categories rep-

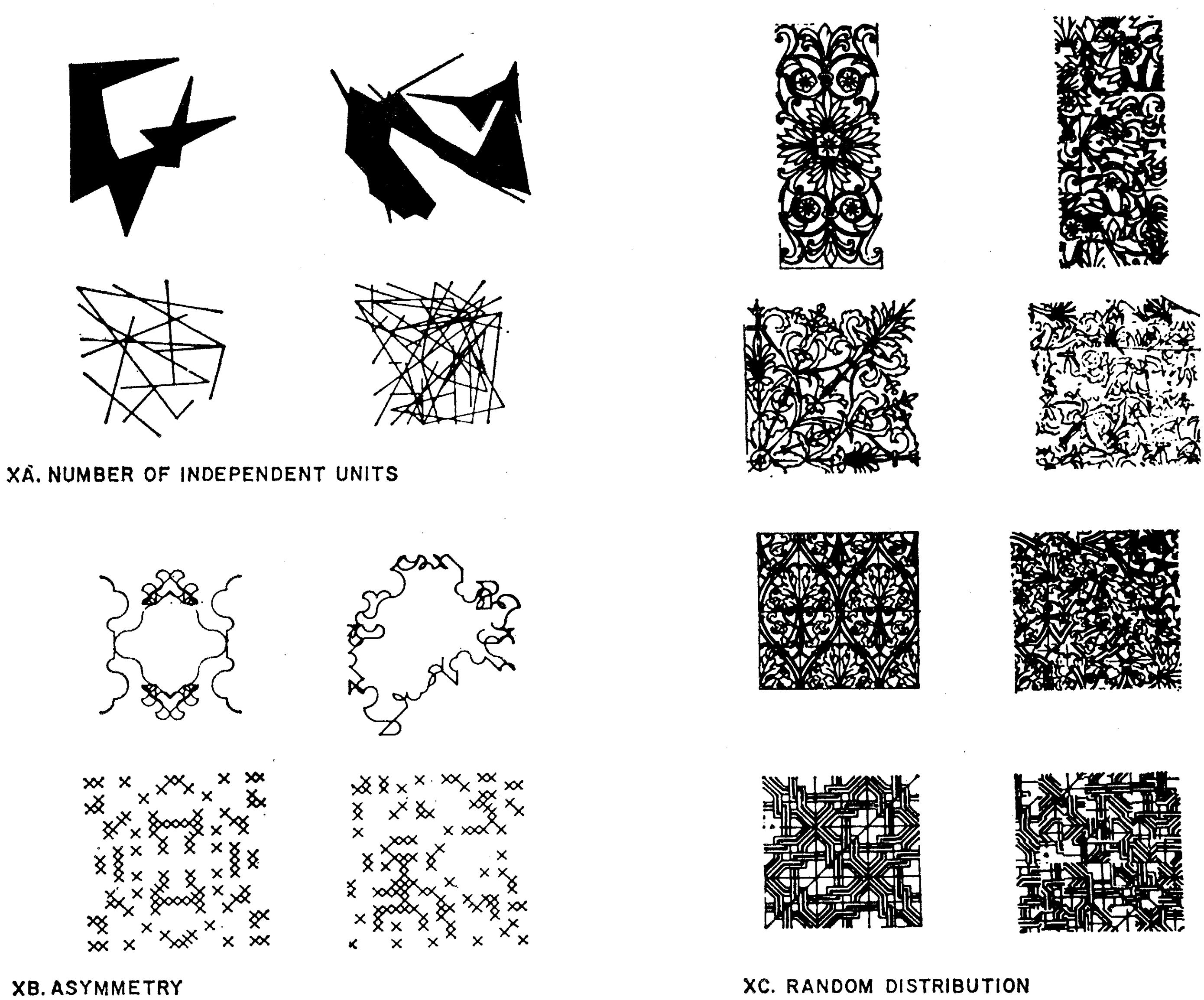

Fig. 3. Visual patterns, representing various "complexity" variables, of a higher order of complexity than those of Fig. 2. [These patterns were first published in Berlyne and Lawrence (*15*), but some have been used for experiments reported in *17, 18, 30, 31*, and *39–41*]

resenting different "complexity" variables, but all of them contain notably more elements than the patterns in categories *A* through *D* of Fig. 2 and thus allow us to probe the upper reaches of the dimensions underlying judgments of "complexity." It has been demonstrated that the material in categories *XA* through *XC* (Fig. 3) is rated significantly more "complex" by adult subjects than the material in categories *A* through *D* (*17*). Experiments incorporating categories *XA* through *XC* have indicated that exploration time reaches a peak and declines as complexity becomes extreme. The point at which the peak is reached seems, however, to vary quite widely from individual to individual and from population to population.

An experiment (*19*) was carried out with 3- to 9-month-old babies, after casual observation of one infant suggested a strong predilection for looking at newsprint, maps, and the like. Spock (*20*) advises, in fact, that babies enjoy watching leaves and shadows. In the experiment, pairs of adjacent patterns were brought simultaneously down into the field of vision, and it was found that patterns B3 and D3 of Fig. 4 were more likely than others in the same series to attract the subject's gaze first. These patterns seem to be more "complex" than the others in the sense that they possess more internal contour. There seemed to be some inconsistency between this result and Hershenson's finding (*21*) that newborn infants are inclined to spend more time looking at a 2 by 2 checkerboard than at a 4 by 4 or 12 by 12 checkerboard—that is, more time looking at the least complex stimulus pattern.

The discrepancy has since been resolved by Brennan, Ames, and Moore (*22*), who have shown that the preferred degree of complexity goes up with age: 8-week-olds prefer to look at a checkerboard of intermediate grain (8 by 8), whereas 20-week-olds prefer a 24 by 24 checkerboard to less complex ones. These investigators have also demonstrated that this development is not simply a matter of increasing visual acuity. Eight-week-olds can distinguish 24 by 24 checkerboards from gray rectangles. Other experiments have ascertained that novelty (*23*), surprisingness (a disparity between a stimulus event and expectation) (*24*), and regularity or irregularity of form (*25*) are other stimulus characteristics influencing infantile exploration.

In recent years, measurement of exploratory behavior has become a standard means of investigating not only motivational but also perceptual processes in subjects who are too young for traditional techniques, such as questioning and discrimination training. A difference in the power of two visual patterns to elicit exploration implies that the subject can tell them apart.

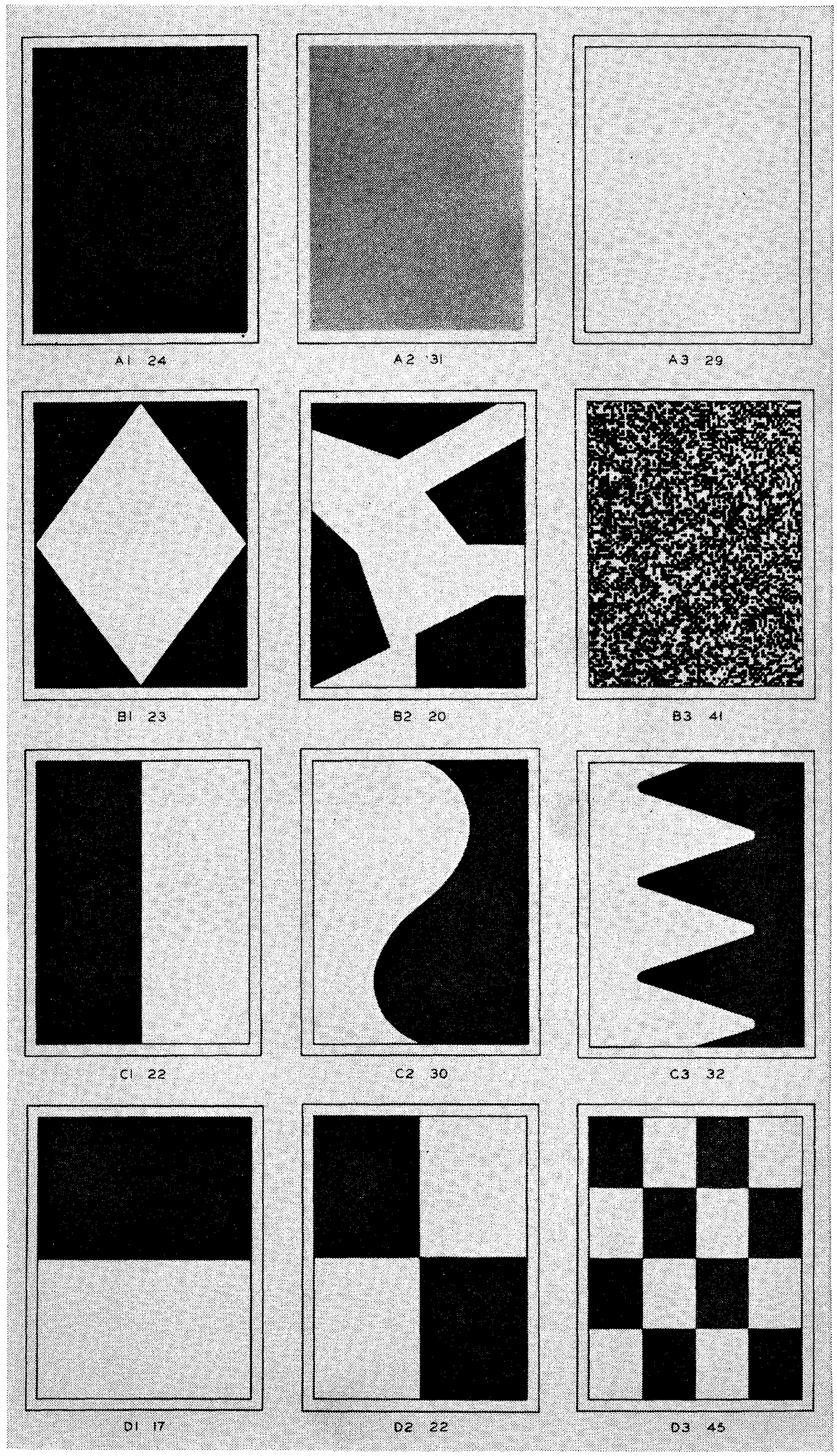

Fig. 4. Four sets of three visual patterns used in experiments with 3- to 9-month-old infants. The patterns of a set were presented in pairs, and the member of each pair that first attracted the subject's gaze was noted. The numeral under each pattern denotes the number of times out of 56 presentations (four with each of 14 subjects) that the pattern was fixated first.

Table 1. Mean numbers of responses in 15-minute session on training days.

Reinforcing stimulus	Methamphetamine	Placebo	Mean
Familiar	9.0	4.8	6.8
Novel	3.9	11.7	8.2
Mean	6.6	8.2	

By this means, it has become evident that some degree of visual form discrimination, presumably innate, exists before learning has had time to mould perception, a question that was formerly open to debate (*26*).

According to a theoretical view that suggests itself (*1, 27*), specific exploratory responses, whether unlearned or learned, are likely to result from an aversive condition or condition of heightened drive due to lack of information (subjective uncertainty). Such a condition, which may appropriately be called "perceptual curiosity," is apt to result from exposure to novel, surprising, highly complex, or ambiguous stimulus patterns.

At present, my associates and I are engaged in experiments designed to test the hypothesis that subjective uncertainty is aversive—that its termination will reinforce an instrumental response. Presentation of blurred pictures is our means of inducing uncertainty. Our preliminary results have provided some tentative confirmation for our expectations. The replacement of a blurred picture by a clear version of the same picture seems, in at least some circumstances, to be a more effective reward or reinforcer (as shown by the rate at which a key is pressed to secure it) than the replacement of a blurred picture by an unrelated clear picture or by another blurred picture. Furthermore, we have some hint that a clear picture is most rewarding when it replaces a picture with an intermediate degree of blurredness. This seems to be a degree at which some differentiation is beginning to emerge but no objects or detail can be recognized, so that there is maximum scope for competing hypotheses.

Collative Variables

The widespread attention that exploration and related forms of behavior are now receiving, after decades of relative neglect, seems justified when one considers the prevalence of such behavior in higher animal species. As psychologists are coming to recognize more and more, exploratory responses are indispensable adjuncts of many vital activities. When unlearned behavior patterns or discrimination learning have invested an external stimulus object with a special significance, an animal must initiate a segment of behavior by bringing its receptors into contact with the crucial cues that indicate what action is likely to have beneficial consequences. How sense organs are oriented must profoundly affect the form in which a stimulus pattern is perceived and represented in memory. But, as often happens with a new area of investigation, the examination of exploratory behavior has raised questions of a much wider import and reopened some fundamental theoretical questions that at one time seemed settled.

What is explored, and how vigorously, depends on many factors inside and outside the organism. Properties of external stimuli with which psychologists have long been concerned have an undeniably potent influence. They include psychophysical properties, closely dependent on specific physicochemical variables (for example, brightness, loudness, color), and ecological properties, dependent on association with noxious events or visceral gratifications. It was, however, not long before experiments on curiosity and specific exploration had demonstrated the psychological importance of a third group of stimulus properties, which evidently outweighed the others in controlling this kind of behavior.

These are the properties for which I have suggested the term *collative* (*1, 27*), since they depend on comparison or collation of stimulus elements, whether they be elements appearing simultaneously in different sectors of a stimulus field or elements that have been perceived at different times. They comprise the properties that we designate by words like *novelty, surprisingness, incongruity, complexity, variability,* and *puzzlingness.* Just as the psychophysical properties are derived from distributions of energy and the ecological properties connect stimuli with the factors that govern natural selection, thus making contact with the two great unifying concepts of 19th-century science, the collative properties have close connections with information, the unifying concept responsible for some revolutionary developments in 20th-century science.

The technical language of information theory does not suffice for an adequate description of the collative variables, but its concepts can help a great deal in specifying and measuring them. Provided that certain assumptions are fulfilled, how "novel," "surprising," "regular," or "orderly" a structure is, how numerous its elements are, and how interdependent, determine its information content, uncertainty (from an external observer's point of view) regarding an organism's reaction to it, and the organism's degree of subjective uncertainty regarding what will happen next or regarding the nature of elements that have not yet been inspected.

What all the collative variables have in common to give them the motivational effects that they apparently share is an interesting but still debatable question. One hypothesis for which supporting arguments can be found (*1, 27*) is that these effects all depend on *conflict* between incompatible neural, and ultimately motor, reactions that are simultaneously mobilized.

The motivational effects of collative stimulus properties are by no means confined to occasioning and directing exploratory responses. They include the factors making for "good" or "bad" form, which were shown by the Gestalt psychologists to govern many perceptual phenomena. They include the factors constituting "form," "composition," or "structure" in the visual and performing arts, in literature, in music, and in humor.

Instead of eliciting exploration—which means approach and sustained contact—novel, surprising, and strange objects may provoke terror and flight (*28*). Approach (for the sake of obtaining additional information or perhaps simply for the sake of relief through habituation) and escape are, after all, alternative ways of alleviating a disturbance due to a conflict-inducing sight or sound. Which will prevail seems to depend on many things, including how disturbing the stimulus pattern is, how agitated or relaxed a subject is, and what personality traits he possesses. Forms of behavior that apparently represent vacillation between curiosity and fear in the face of something unusual have frequently been observed in animals and in human beings. Whether something is experienced as pleasurable, annoying, or vapid often turns in an extremely subtle way on how much novelty, variety, or unpredictability it affords. This is true even when some extrinsic source of motivation is at work, as in the culinary and erotic domains.

Arousal

Still further ramifications come into view as we pursue the relations between exploratory behavior and arousal (*1, 27*). The concept of "arousal level" is an outgrowth of several developments in neurophysiology and psychology that have occurred during the last 15 years or so. It connotes a psychophysiological dimension, indicative of how "wide-awake," "alert," or "excited" an organism is at a particular time. Fluctuations in arousal are reflected by changes in the electrical activity of the brain, in electrical and thermal properties of the skin, in muscular tension, in the circulatory system, in the respiratory system, and in the diameter of the pupil, all of which can be recorded and precisely measured. A great deal has been learned, and more is coming to light, about the neural processes on which arousal depends, involving interactions among the brain-stem reticular formation, the hypothalamus, the diffuse thalamic system, and the cerebral cortex.

Few, if any, motivational aspects of behavior have been untouched by fresh thinking inspired by the concept of "arousal." One particularly pregnant trend has been a progressive coalescence between the new concept of "arousal" and the concept of "drive," which has dominated discussion of motivation since the 1920's. If "arousal" can be identified with "drive" (and more refinement of both concepts is required before we can tell how far and in what sense it can be), the implications may be quite far-reaching. First, we shall have at our disposal more precise and direct techniques than we had before for measuring drive. Secondly, any factor that can be shown to raise or lower arousal will have to be included among the factors that induce and reduce drive, and thus among those that can motivate behavior and give rise to changes in behavior through learning.

The grounds for connecting exploratory responses with rises in arousal are twofold. First, a great deal of experimental work (largely, but not entirely, carried out in the U.S.S.R.) has shown at least some forms of exploratory behavior to be accompanied by pervasive psychophysiological changes, including several recognized indices of increased arousal (*29*). This work has led to a broadening of Pavlov's notion of an "orientational reflex" or orientation reaction. Pavlov used this term to denote the immediately visible bodily movements through which an animal focuses its sense organs on an unusual source of stimulation. It is now clear that these are accompanied by a whole network of processes, most of them not detectable without special amplifying and recording equipment, which seem to represent a mobilization of the animal's capacities to absorb information through its sense organs, process the information through its central nervous system, and act promptly and energetically.

Secondly, evidence is accumulating that the collative stimulus properties by which exploratory behavior is so profoundly influenced are capable of increasing arousal. Several experimenters have shown that a stimulus gradually loses its power to evoke an orientation reaction—that is, to raise arousal—as it loses its novelty through repetition (*1*, chap. 4). In our own research, my associates and I have been measuring the effects of various collative stimulus properties on the galvanic skin response (*15, 30*) (a transient increase in conductance or in potential difference between two points on the palms or soles) and on the duration of electroencephalographic desynchronization (*31*) (the replacement of alpha waves by an irregular, low-amplitude, predominantly high-frequency pattern, indicative of an alerted cerebral cortex) as indices of arousal or components of the orientation reaction. We have been able to show that the magnitude of the galvanic skin response declines not only as one visual pattern is repeatedly exposed but also as different patterns succeed one another.

We have found the intensity of the orientation reaction to increase with surprisingness (when surprising and nonsurprising stimuli are equated for novelty) and with the complexity and incongruity variables embodied in the patterns of Figs. 2 and 3. We have also demonstrated that the mean amplitude of the galvanic skin response increases with degree of conflict, which, as explained earlier, is suspected of being the common underlying factor responsible for the motivational effects of the collative variables. At present we are investigating electroencephalographic effects of various "complexity" variables descriptive of auditory stimuli. It has already become clear that white noise evokes longer desynchronization than equally loud sine-wave tones or combinations of two or three such tones.

Table 2. Mean numbers of responses in 15-minute session on test days.

Reinforcing stimulus	Methamphetamine	Placebo	Mean
Familiar	13.9	4.8	9.1
Novel	6.5	10.7	8.8
Mean	10.4	7.8	

Epistemic Curiosity

Specific exploratory responses in human beings are, as often as not, "epistemic" responses as well as exploratory responses. The use of this term is proposed in order to indicate that they are aimed not only at obtaining access to information-bearing stimulation, capable of dispelling the uncertainties of the moment, but also at acquiring knowledge—that is, information stored in the form of ideational structures and giving rise to internal symbolic responses that can guide behavior on future occasions. Bringing sense organs into contact with appropriate external events is, of course, not the only means of accumulating knowledge. Thinking can be another form of epistemic behavior (*32*).

Extending the notion of perceptual curiosity suggested by studies of specific exploration, we may suppose that epistemic behavior is motivated by "conceptual conflict," or conflict between mutually discrepant symbolic response-tendencies—thoughts, beliefs, attitudes, conceptions (*32, 33*). Conflicting elements or requirements often characterize the "problems" that start us off inquiring or experimenting or thinking (*32*, chap. 10). Several experimenters have recorded variations in arousal level while subjects are engaged in thinking, and these variations are influenced by degree of "difficulty," in senses that seem to involve degree of conceptual conflict (*32*, chap. 11).

Unfortunately, the motivational aspects of epistemic behavior and of thinking in particular are only just beginning to receive study. We have made some preliminary investigations of the determinants of "epistemic curiosity" (as we may call a motivational condition favoring epistemic behavior) by presenting human subjects with a series of questions and simply asking them to specify a certain number of questions whose answers they would most like to know (*34*).

In one such experiment, questions about invertebrate animals were used. According to verbal reports, the most curiosity was induced by questions about the more familiar animals, by questions that subjects found surprising, and by questions that attributed to species characteristics they seemed unlikely to possess. These findings confirmed predictions from hypotheses regarding conceptual conflict. It had been argued that more familiar concepts would produce greater conflict than less familiar ones, by producing more numerous and stronger divergent associations.

In two later experiments, subjects were presented with quotations, each followed by the names of two or three possible authors. Each author's name was coupled with a number, purporting to show how many teachers out of a group of 100, had guessed it to be the correct name. One experiment provided evidence that curiosity was greater when there were three than when there were two alternative authors, and another demonstrated the influence of the distribution of supposed teachers' guesses: the more even the distribution, the greater the curiosity. These two variables—number of alternatives and nearness to equiprobability—are identifiable as the two principal determinants of subjective uncertainty, just as uncertainty in the information-theoretic sense is an increasing function of the two corresponding variables. Conceptual conflict is assumed to increase with subjective uncertainty.

Experiments in which other techniques were used have also confirmed the importance of such factors for epistemic curiosity (*35*). Novelty, surprise, and incongruity make children ask more questions and affect the content of their questions. Several investigators have found adult subjects more likely to seek symbolically expressed information as uncertainty and the gains and losses at stake increase, although there are signs that information-seeking may decline as these variables assume very high values.

There have been many reports from animal studies of exploratory behavior that seems to be aimed not at obtaining stimulation from a specific object or event about which there is a specific uncertainty but, rather, at obtaining stimulation from any source that can afford an optimum dosage of novelty, complexity, and other collative properties. For example, rats will, all other things being equal, tend to enter a maze arm that differs from the one they entered on the preceding trial or that has undergone some change since they were last in the maze (*1*, chap. 6; *36*). Monkeys confined in a box will work hard, sometimes for as long as 19 hours at a stretch, at repeatedly opening a door so that they can see what is going on in the room outside (*37*). Human beings confined in a dark room with a minimum of stimulation will press buttons to make patterns of colored spots of light appear, preferring those sequences of pattern that offer the most variety and unpredictability (*38*). These and similar forms of behavior are classifiable, according to the proposed terminology, as "diversive" exploration, and it seems important to distinguish them at this stage of research from the specific exploratory responses that may be motivated by perceptual curiosity.

The advisability of drawing a distinction between specific and diversive exploration is supported by experiments with human subjects. When a subject is shown a pair of patterns from Figs. 2 or 3 and then asked to choose one of the two patterns for further viewing, which he is likely to choose depends on the duration of the initial exposure. If he has seen the two patterns briefly (for 1 second or less) before making his choice, he is more likely to want to see the *more* complex pattern again (*39*). Preliminary exposures of such brevity are presumably not long enough to allow him to see what the patterns are like and thus to relieve his curiosity. He chooses the more complex pattern, presumably because that is the one about which he has more residual curiosity. If, on the other hand, the preliminary exposures are long enough (3 seconds or more) to allow him to become adequately acquainted with the patterns, he is more likely to want another look at the *less* complex pattern (*17, 39, 40*). In this case, curiosity, having been largely eliminated by the initial exposures, must play a minor role. Factors akin to esthetic taste will presumably have more influence. Experiments in which verbal scaling techniques are used have, in fact, suggested that patterns attracting more specific exploration when perceptual curiosity is at work tend to be rated more "interesting," whereas patterns attracting more diversive exploration when a subject has no cause to wonder what a pattern is like tend to be rated more "pleasing" (*15, 17, 39, 41*).

There might seem to be a close affinity between specific exploration and activities such as science, philosophy, and mathematics, with diversive exploration more closely akin to entertainment and the arts. But this distinction is not absolute. The importance of pleasing structure in science, mathematics, and philosophy has been noted too often to be overlooked, while curiosity—wondering what will come next, trying to make sense of a work, and so on—certainly plays a part in esthetic appreciation.

Diversive exploratory behavior is likely to be especially strong after an animal or a human subject has spent some hours in an environment that is highly monotonous or devoid of stimulation (*38, 42*). The desperate craving of a bored person for a change of any kind is attested by everyday experience and by experiments on "sensory deprivation" (*7*).

One phenomenon that has been much investigated during the last 10 years and was particularly surprising when it was first discovered is the reward value that stimulus changes of no specific biological significance (for example, light coming on or becoming momentarily brighter, the sound of a buzzer or a click) can have, as shown by the power of such changes to reinforce a bar-pressing response in mice and rats (*43*).

Some recent experiments in which my associates and I sought factors governing diversive exploration (*44*) have confirmed the importance that the interaction between collative stimulus properties and arousal level has for this behavior also. The role of these variables in diversive exploration seems, however, to be somewhat different from their role in perceptual curiosity and specific exploration. Fortuitous circumstances compelled us to house some of the rats to be used for one experiment next to a room containing some extremely noisy print-out counters. A quiet room became available later, and the remaining animals were housed in it. The experiment lasted for 8 days. On odd-numbered days (training days), each subject was placed in a Skinner box for a 30-minute pretraining period, during which no bar was present in the box. The pretraining period was immediately followed by a 15-minute training session, during which two bars protruded from the rear wall, and every time either was pressed, the illumination became brighter for 1 second or a buzzer sounded for 1 second. On even-numbered days (test days) there was a 15-minute test session during which the bars were present but no light change or buzzer sound occurred when one of the bars was pressed.

It turned out that, in animals maintained in the noisy quarters, a familiar stimulus (one that was presented every minute during pretraining periods) had a greater reward value than a novel stimulus (one not presented during pretraining periods), as evidenced by the rate of bar-pressing during both training sessions and test sessions. In animals maintained in the quiet room, on the other hand, novel stimuli were more rewarding than familiar stimuli.

These unexpected findings could be explained by making three assumptions: (i) that the rats subjected to noise between experimental sessions had a higher arousal level than the rats maintained in the quiet room; (ii) that the reward value of a stimulus resulting from diversive exploration is an inverted U-shaped function of the degree to which the stimulus raises arousal; and (iii) that the extent to which a stimulus raises arousal increases with its novelty and with the subject's initial arousal level. This explanation was corroborated by a subsequent experiment, in which injections of methamphetamine were used to raise arousal and a change in illumination served as reward. It was found, in accordance with predictions, that the drugged animals performed more responses with a familiar reinforcing stimulus, whereas control animals injected with saline solution performed more responses with a novel reinforcing stimulus (see Tables 1 and 2).

A number of experiments (*18, 45*) have indicated that conditions conducive to abnormally high levels of arousal (for example, hunger, pain, fear, noise, exposure to an incomprehensible tape-recorded message) make rats and human beings less eager than usual to seek out novel or complex stimulation. The findings just cited seem relevant to this phenomenon, among others.

Under the impact of experimental findings on exploratory behavior and cognate phenomena, motivation theory is undergoing some extensive remodeling. These findings have opened our eyes to the pervasive psychological importance of collative variables and arousal. We find ourselves forced to recognize that the disturbances that motivate behavior can come not only from external irritants, visceral upheavals, and deprivation of vital substances, but also from clashes between processes going on in the central nervous system. Related to these additional sources of motivation, there must be a wide range of hitherto overlooked reinforcing conditions that can promote learning of new behavior patterns. In opening up these new prospects, the study of curiosity, exploration, and epistemic behavior merges with developments in several other areas of psychological research (*1, 27, 32*), including personality theory, ethology, child development, education, attitude change, social interaction, esthetics, and humor.

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