# SOME ASPECTS OF HUMAN CURIOSITY

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# DIGEST

The dissertation consists of a theoretical section, an experimental section and an appendix.

In the theoretical section, entitled 'A behavior-theory analysis of human curiosity', a distinction is made between 'perceptual curiosity', which leads to exploratory activity and has been studied in the rat, and human 'epistemic curiosity', which is defined as a drive reduced by knowledge-rehearsal. 'Knowledge' is analyzed as consisting of habits mediating believed designative symbols, which often form long chains ('trains of thought'). A theory of epistemic curiosity is proposed, the principal elements being (1) an account of questions as 'thematic probes', which evoke drive-producing meaning-responses, and (2) the attribution to conflict of the curiosity aroused by strange, surprising or puzzling situations or questions.

The experimental section, 'An experimental study of human curiosity' and the appendix report two experiments, which were carried out in order to test some of the predictions from the theory. The predictions concerned the effects of pre-questioning on the learning of material supplying answers to the questions. In both experiments, an experimental group received (1) a fore-questionnaire of factual questions about invertebrate animals, (2) a communication containing the answers, and (3) an after-questionnaire, repeating the questions of the fore-questionnaire. A control group differed only in having no fore-questionnaire. The recalling of the answers to the after-questionnaire and subjects' reports of desire to know the answers were used as measures of curiosity. The principal conclusions that received support are (1) that pre-questioning increases curiosity, (2) that the two measures of curiosity are correlated, (3) that statements recognized as answers to previous questions are more likely to be recalled, (4) that the following classes of questions arouse more curiosity than others: questions conflicting with past experience, questions concerning more familiar concepts (animals), questions with 4 rather than 2 alternative answers.

# A BEHAVIOR-THEORY ANALYSIS OF HUMAN CURIOSITY

Few topics have excited as much discussion as human knowledge. Philosophers have long pondered over the various ways of acquiring knowledge, the exact nature of the entities we know and our precise relation to these entities (31). But this discussion has usually included very little about the motivation underlying the quest for knowledge, and the deficiency is a serious one, as it prevents us from answering two important questions. The first question is, why do human beings spend so much time and effort on obtaining knowledge? Sometimes, there is some obvious drive to whose satisfaction it can contribute, but, strangely enough, many of the queries that inspire the most persistent searches for an answer and the greatest distress when the answer is not available are of no manifest practical value or urgency. One has only to consider the ontological inquiries of metaphysicians or the frenzy of crossword enthusiasts to be convinced of this. The second question, which is the main concern of this article, is, why, out of the infinite range of knowable items in the universe, are certain pieces of information sought and learned more readily than others?

Modern learning theory leads us to look for motivational variables to answer these questions, and a drive which is reduced by the reception and subsequent rehearsal of knowledge is what is usually called 'curiosity'. However, we must draw a distinction between this curiosity and the curiosity-drive that has been studied in lower animals (4). In the case of the rat, for example, there appears to be a drive which is aroused by novel stimuli and reduced by continued exposure to these stimuli. Its reduction reinforces exploratory activity, i.e., activity such as approaching and examining the stimulus-objects, which increase stimulation of the animal's receptors by them. Now, similar exploration is undoubtedly elicited by strange objects in adult and especially infant human beings. But in an animal as well endowed for learning and remembering as the human adult, exploration is bound to leave a stock of permanent traces in the form of symbolic representations ('pure-stimulus acts' or 'cue-producing responses'), which are manifestations of what we call 'knowledge'.

The curiosity which leads to increased perception of stimuli and the curiosity whose main fruits are knowledge may well turn out to be closely related. But, as we are using different defining operations for them, we shall have provisionally to use two different terms for them. We shall therefore call the first '<u>perceptual curiosity</u>' and the second, which is our concern in this article, '<u>epistemic curiosity</u>'.

## KNOWLEDGE AND TRAINS OF THOUGHT

Epistemic curiosity is an intervening variable and must therefore be described in terms of its relations to antecedent and consequent variables. Since it is moreover a drive, this means specifying the conditions of its arousal and the conditions of its reduction (28, p. 467). The conditions of its arousal form the problem of this article, but we can state from the outset that what reduces it is knowledge-rehearsal. Our first task is thus to describe knowledge, the end-product of curiosity, and then we can consider the motivation behind its acquisition.

An account in behavior-theory terms of the nature of knowledge and of the stages by which it is likely to have developed out of simpler response-capacities will be given in a forthcoming publication. But we can here summarize by noting that knowledge consists of '<u>habits mediating believed designative symbols</u>'. These terms can be explained briefly:

(1) We base our definition of a '<u>symbol</u>' on Osgood's definition of a 'sign'. He states (37) that 'a pattern of stimulation which is not the object is a sign of the object if it evokes in organism a mediating reaction, this (a) being some fractional part of the total behavior elicited by the object and (b) producing distinctive self-stimulation which would not occur without the previous association of non-object and object patterns of stimulation.' The response-component ($r_m$) evoked by the sign is identified by Osgood with 'meaning'. We shall refer to its elements as 'concepts', and when they are evoked by a stimulus not emanating from the signified object or from an external sign ('signal', 32) (e.g., when they arise in the course of a thought-process through association with a previous $r_m$) we shall call them 'symbols' or 'symbolic responses'.

(2) The term '<u>designative</u>' is derived from Morris' classification (32) of symbols according to the distinguishing characteristics of the objects or events they signify. We translate this classification into Osgood's scheme by applying the term 'designative' to those symbols which refer to stimulus-properties of objects. They will include perceptual responses (5) and verbal responses of the kind Skinner calls 'tacts' (43).

(3) A symbol is <u>believed</u>, if overt instrumental behavior conditioned to the significatum is elicited by the symbol.

Symbols generally occur in long sequences, which are in everyday language known as 'trains of thought', and these sequences form some of the principal fruits of knowledge as well as some of the most important means of attaining new knowledge. But a given situation may well initiate several alternative trains of thought at different times. We are thus obliged to inquire after the factors that determine the actual course a particular train of thought will follow. Hull's account of behavior chains (18, p. 312) suggests that we shall find them to be the following determinants acting jointly: (1) <u>cue-stimuli</u>, which include external stimuli (S) and the self-stimulation resulting from previous items in the chains (s), and (2) <u>motivational stimuli</u>, which include drive-stimuli ($S_D$) and the goal-stimuli ($s_G$) produced by fractional anticipatory goal-responses ($r_G$). Each cue-stimulus serves to elicit the next item in the sequence by association. The motivational stimuli persist throughout the sequence, and thus they can perform the functions of keeping the train of thought directed towards drive-reduction and impelling it to continue until this drive-reduction has been effected.

We can now speculate on the first of the two questions we raised concerning the motivation behind knowledge: why do these trains of thought occur at all? Although the 'disinterested pursuit of Truth' is supposed to be highly valued in our culture, and we are given to reminisce in nostalgic 'sessions of sweet, silent thought', we can be sure that these were not the activities that gave the power to know its survival-value. It is rather that 'remembrance of things past' makes possible anticipation of things future, so that 'knowledge is power'. The learning that produces knowledge is clearly biologically helpful because (1) it enables goal-directed behavior to be more efficient through being better prepared for what is impending, and (2) it enables warning signals to be recognized, so that danger can be avoided (33). But these effects are usually delayed, so that their advantages do not explain what reinforces the learning in question. For long-term consequences to influence behavior, it is necessary for symbols to be used in such a way that the reinforcements of fear-reduction and secondary rewards can be brought to bear (35). The drives that are reduced by knowledge are thus largely the 'coexistent emotional components', which, as Ullman argues (44), we must assume to be present in all primary drives and to be capable of functioning anticipatorily. These components are what are called 'fears' - Ullman speaks of 'shock-fear' and 'hunger-fear', for example - and knowledge can lead to fear-reduction in various ways: (1) by depicting the future situation as a desirable one (reassurance), (2) by reducing 'fear of fear' or 'fear from a sense of helplessness' (36) (preparation), or even when the outlook is hopeless, (3) by reducing the increment of drive (conflict) due to uncertainty (the comfort of 'knowing the worst') or (4) extinction of fear by repeated exposure to frightening stimuli (getting used to unpleasant prospects).

But our main concern is with the second question, viz., the question of the factors underlying the selectivity of epistemic curiosity. Why does an individual seek or learn one piece of knowledge rather than another? Representatives of various schools of psychology have provided hints but scarcely more:

(1) Psychoanalysis. The writings of Freud (e.g. 13) and his followers, especially Abraham (1), make it clear that a psychoanalytic theory of curiosity would attribute the desire to know to any one of several 'component instincts' of the libido, the direction it pursues being influenced accordingly. If the search for knowledge is regarded, consciously or unconsciously, as a process of laying bare hidden truths, the underlying drive is scoptophilia; if it is a matter of absorbing facts from the outside world and making them enhance one's own powers, it is the oral-incorporative drive; if it is seen as a struggle to wrest secrets from Nature or as a challenge to produce and create something, it is anal-aggressiveness; if it takes the form of an urge to label and classify or to arrange facts in an orderly system, it is the anal-retentive need to have everything under control or else safely screened by unemotional symbols. But this leaves many questions unanswered. How are we to predict when one of these 'component instincts' will find an outlet in curiosity, and how intensely? And which particular items of knowledge will be sought?

(2) Gestalt psychology. Although the Gestalt psychologists have not produced a systematic account of curiosity, it is not difficult to guess how such an account would go. They explain much of behavior by the 'principle of closure', the tendency to act in such a way as to close a 'gap', whether in a perceived figure or in some other aspect of the 'behavioral world' (19, 45). It is evident that curiosity is precisely a drive to fill in such gaps in the subject's experienced representations. But again, we have no definition precise enough to tell us infallibly what will constitute a 'gap', nor which gaps will have precedence over others.

(3) Reinforcement theory. The tendency to acquire the verbal or other responses which constitute knowledge is a product of learning, culturally conditioned, according to such reinforcement-theorists as have considered the problem. Dollard and Miller (10, pp. 119-20) mention learned drives to 'make a correct report of the environment' and to 'have an explanation' and the punishment that social training, as well as the demands of reality, imposes on those who fail to do so. Skinner similarly (43) describes how a child learns to emit 'tacts' (i.e., verbal responses controlled by properties of objects or situations) under the influence of 'generalized reinforcers', particularly approval. Mowrer (34) appears to identify the acquisition of 'beliefs' (p. 5) and 'knowing that' (p. 268) with the conditioning of emotional responses, but this does not acknowledge the role of symbolic responses in distinguishing pieces of knowledge with similar affective value but different content.

We shall take these treatments as a starting-point, although it is clear that they leave some essential questions unsettled. There is, for one thing, the paradoxical fact that curiosity seems to be evoked most uniformly by situations that are new and strange. This is what we have elsewhere discussed as the 'problem of novelty' (4, p. 71). Some stimulus-complexes seem to have their effect precisely by virtue of their differences from anything in the subject's previous experience. They would be the last we should expect to have any influence at all, if it was a matter of generalization from prior training. The frequently proffered suggestion that a child may be trained to respond to 'new' and 'strange' stimuli in a certain way and may transfer this response to other 'new' and 'strange' stimuli leaves unanswered the thorny problem of what novelty as such consists of and exactly what all novel stimuli have in common. It is evident that they have something in common, since certain responses, e.g., the verbal response 'new', can be evoked by them all, but we have still to identify the property responsible. It will be our contention that conflict supplies the clue.

## THE SEQUENCE OF EVENTS

Stimuli which are used to elicit verbal behavior, unless they resemble the behavior they call forth or have unique responses, are what Skinner calls '<u>thematic probes</u>' (42, 43). They can take the form of verbal or non-verbal stimuli, and they can be administered to oneself ('self-probes'), as a reaction to a perceived situation, or come from outside in the form of writing, speech or non-linguistic cues. We can extend Skinner's concept a little, but not, it is hoped, inexcusably, by including under it all stimuli which elicit trains of thought, whether verbal in content or not.

Skinner gives as illustrative cases of thematic probes the stimulus-words of association experiments and the material used in projection tests. But it has been known since the work of the Würzburg school (2) and of Lewin (20, 21) that it is not possible to predict what association, if any, will be given to a stimulus without taking into account the 'set', 'determining tendency', 'tension-system', etc., induced by other stimuli, usually instructions. In other words, we must have not only cue-stimuli to act as a starting-point, but also motivational stimuli to limit the responses to the general category required by the task on hand and to supply the motive force for the process. The thematic probe must thus have two parts or aspects, with these distinct functions, and the clearest example, as well as probably the commonest in practice, is the question. The question of the type called by linguists the 'specific interrogation' (as distinct from the 'yes-or-no question') (7, p. 52) has the two parts easily distinguishable. As an example, we may take the question, "how does the starfish eat?" We assume that the question, in common with all synonymous questions, evokes mediating 'concepts' or 'meaning-responses' ($r_m$). The meanings corresponding to 'starfish eat' act as the cue-stimuli with a patterning effect peculiar to that stimulus-complex; in some cases, such as when the question is put by an authoritative person, they may be tantamount to an assertion that the starfish eats, while in other circumstances the question may be taken to mean 'how, if at all, does the starfish eat?' The group of concepts that act as cue-stimuli we may, following Morris' terminology, call the 'designator'. On the other hand, the interrogative adverb 'how' produces a meaning which acts as a motivational stimulus. It limits the train of thought to 'how-concepts' and evokes a learned drive-state which motivates the reaction.

When a question is put, whether by the subject himself or by somebody else, and the answer is already known, the appropriate response is made as a reaction conditioned by previous learning to the stimulus-pattern, and this relieves the drive immediately, so that the subject can proceed to some other activity. However, when the answer is not known, the drive will persist, and some sort of trial-and-error process can be expected to follow as with any other drive-state. Of course, the trial-and-error will not be completely random, as it is not even for the rat in the Skinner box:

it will take the form of behavior resembling what has succeeded in similar situations. The most likely behavior-sequences to occur are (a) thinking - implicit trial-and-error, insightful restructuring (18, ch. 10), stimulus generalization (as in 'deduction' (34, ch. 11)), 'intuition' (40) and 'magical thinking' (11, p. 47)), (b) observation - approach, receptor-adjustment, manipulation of environment, so as to perceive relevant stimuli, culminating in the controlled experimental and other techniques of science, (c) recourse to authority - asking experts, consulting books or oracles. (Cf. intuitionism, rationalism, empiricism, and authoritarianism (31)).

If these processes lead to a pattern of responses that the subject's prior learning enables him to accept as an adequate answer, then the drive will be reduced. Since drive-reduction follows the rehearsal of the correct answer, the principle of reinforcement (18, postulate IV) implies that the latter will become strengthened as a response to the question. Furthermore, by the reinforcement-gradient principle, it will be learned more strongly than the responses that led up to it, so that in future the question will be followed immediately by it, and intermediate steps will be omitted. The nature of the learning which enables the subject to accept an answer as adequate needs, of course, much more elucidation. But the problem is in essence the same as with learned fear. Miller (27) and Mowrer (34) stress that in their rat experiments two distinct habits must be acquired: the animal learns to respond to the signal with fear and to respond to fear with some activity that brings about fear-reduction. But there is often a third piece of learning also, namely the learning that causes the rat to relax his fear when he is safe. This relaxation is evidently determined jointly by the fear-stimulus and other stimuli present, since what leads to safety in one dangerous situation may not do so in another. In the case of the answer being found to a question, the process is strictly analogous: the drive-reduction depends on the other stimuli present, since what will answer one question will not do for another.

If the answer is not arrived at readily by any of the procedures mentioned, then the process may be brought to an end in other ways. Some distraction may occur, i.e., an incompatible response-tendency with a higher reaction-potential may arise, or extinction may supervene. There will be both extinction of each line of inquiry as it turns out unsuccessful and gives way to another, exactly as in trial-and-error learning (16), and ultimately, the drive-producing responses may be extinguished, so that the subject gives up altogether. It is unlikely that extinction will affect the intervening link, that between the words and the drive, since the motivating power of interrogative adverbs is frequently and partially reinforced in everyday life.

Let us now suppose that the subject fails to hit upon the correct answer in the course of striving for it. And let us suppose that on some future occasion he is told or shown the answer, i.e., exposed to some stimulus-complex which evokes the response he was seeking. We can expect this answer to evoke, by ordinary redintegrative remembering, an internal rehearsal of the question, so that it is <u>recognized</u> as the answer he was looking for on the earlier occasion. The stimuli produced by the response of rehearsing the question will thus occur about the same time as the rehearsal of the answer and the stimuli produced by rehearsal of the answer will be followed closely by reduction of the drive that the question has re-aroused. Thus we can see the answer being learned by reinforcement as a response to the question, so that a new piece of knowledge is acquired.

It will by now be evident that the drive aroused by questions and other thematic probes is, by our definition, a form of epistemic curiosity. And an important consequence follows from the principles of behavior theory, if our account so far is valid, which gives us a way of measuring this curiosity through its effects on remembering. Both introspective and behavioral evidence reveal that when the correct answer to a question has been encountered and rehearsed curiosity is reduced to a subthreshold value. But the higher the drive before such reduction, the greater the amount of reinforcement or quantity of drive-reduction (K). But, according to Hull's postulates (17, 18), the probability of a response occurring on future occasions increases with reaction-potential ($_SE_R$), which in its turn increases with K. It follows that those questions which evoke more curiosity are more likely to be answered correctly after the answer has been presented to the subject, and we can use the probability of recall as a measure of curiosity. An additional measure depends on the fact that subjects are likely to have learned to respond with tacts to their own internal stimuli (42, 43), although less accurately than to external stimuli. They can accordingly be instructed to indicate which questions arouse the greatest desire to know the answer.

We have therefore arrived at the hypothesis that curiosity is aroused in a subject when a question is put to him, whether by himself or by an external agent. Some component ($s_{mD}$) of the response-produced stimulation resulting from the meaning of the question ($r_m$) is assumed to act as a drive-stimulus. And we can see that the intensity of this drive-stimulus, which will in its turn depend on the amplitude of the response ($r_{mD}$) that produces it, will be one of the most important variables affecting the drive-strength of the curiosity.

There is some experimental evidence (6) for the curiosity-inducing role of questions, but it is also borne out by everyday experience. Many celebrated thinkers have been stimulated to a lifetime's meditation simply because they thought of questions about matters that ordinary men have taken for granted. Similarly the skillful lecturer excites curiosity in his audience by putting questions to them, perhaps about familiar phenomena, which it has never occurred to them to ask themselves.

However, the factors mentioned so far do not adequately explain the most striking cases of curiosity-arousal, those concerning the strange, the unusual, the puzzling. Phenomena which excite a 'disinterested' or 'intellectual' curiosity, simply because they do not make sense on first acquaintance or do not fit in with what one has learned to expect or are difficult to understand, are responsible for much of the history of human ingenuity from primitive myth to modern philosophy and science. But they have not always inspired a delving into profundities, nor have they confined their spell to a few individuals of an unusually contemplative and impractical turn of mind. Literature intended to capture the popular imagination has long relied on tidbits of grotesquerie and bizarrerie with minimal utilitarian value; there were fanciful travellers' tales in classical and medieval times, and today we have the quiz and 'believe-it-or-not' feature occupying a prominent place in mass communication media. To attempt an explanation of this side of human nature, we shall have recourse to another variable, conflict.

THE ROLE OF CONFLICT

After the necessary preliminary phase of considering oversimplified situations, in which either only one response-tendency or motive is active or else one response-tendency or motive is so much stronger than others as to be virtually alone in its influence, psychological theory had to turn to more realistic situations where there are factors in competition. Even an elementary treatment of trial-and-error learning (16) forces us to consider the process whereby one response overcomes alternative ways of reacting, but special phenomena result when competing tendencies are fairly evenly matched in strength. The study of such phenomena was begun by Lewin (22) and then carried further on both theoretical and experimental planes by Miller and his associates (25, 29). Dollard and Miller have shown (10) how the behavior-theory of conflict can be extended to embrace the main effects ascribed to conflict by Freud, while Hull has endeavored to reveal its roots in the basic principles of learning (18, chap. 8). A theory of emotion, based on the assumption that conflict (F) is in itself drive-producing, is an important recent development for which Brown and Farber are responsible (8), and there are various observations from experiments with rats that tend to confirm this assumption (12, 23, 30).

A rather different recent emphasis on conflict has come from Hebb (14, 15). This is particularly deserving of mention here, because it involves the central processes intervening between stimulus and response, and that is precisely where we must seek the kernel of curiosity. Behavior, in Hebb's view, depends on the intricate and nicely timed cooperation between 'cell-assemblies' in the cerebral cortex. If the timing goes awry, or if the processes ('phase-sequences') in the cortex otherwise interfere with one another, disruption will be the result. Some phase-sequences require the support of externally initiated sensory processes, and if these are not forthcoming, as when something familiar with an unexpected feature is perceived, disruption is once again a likely outcome. This disruption, which leads to a diffuse and disorganized release of energy, is what, according to Hebb, lies behind emotion. His principal illustration is his description of the fear induced in chimpanzees by surprising sights, but it is easy to see that these sights might instead have aroused curiosity in slightly different conditions. In his treatment of perceptual learning, Hebb describes how repeated exposure to a complex of stimuli builds up integrated and organized patterns of activity in the cortex, and thus conflict is eliminated as the unfamiliar becomes familiar. If we admit the possibility that the curiosity aroused by unusual perceptions has something to do with conflict, then the elimination of this conflict by exploration and the consequent drive-reduction might well play a part in perceptual curiosity. If we then extend these ideas to the autonomous processes which are the result of prior learning but can later run off in the absence of the corresponding environmental events, we can readily imagine how strange and puzzling thoughts or concepts may likewise involve conflict, and the acquisition of knowledge may mean the formation of new structures which obviate this interference. If conflict is a drive, the reduction of conflict will be reinforcing, and it will provide the explanation for the reward-value of investigating things that are puzzling and the learning of knowledge resulting from this investigation. Epistemic curiosity also will thus be attributable in many cases to a similar mechanism.

Hebb's concepts are physiological and refer to neural processes. But since these processes are at present not observable and serve merely as devices for explaining what can be observed, they are best regarded as intervening variables. It should not be difficult therefore to translate them into behavioral terms. The preference for purely behavioral terms may be justified as more than a matter of verbal taste by their being the key to relationships between the sort of conflict under discussion and other areas in behavior theory, including other forms of conflict.

We can begin our inquiry into the conflicts affecting trains of thought by recalling Miller's (25) list of ways in which responses may be incompatible and therefore conflict. Sometimes the incompatibility is physical and innate, like that between approaching and avoiding the same object. But at other times, the conflict is learned. The responses are not inherently antagonistic, but learning has made the organism unlikely to perform both simultaneously or in close succession. This means that the response-produced stimulus ($s_1$) resulting from the first response ($R_1$) has become conditioned to a response ($R_{-2}$) which is physically incompatible with the second ($R_2$). If $R_{-2}$ is stronger than $R_2$, the latter will thus be inhibited. When we extend these notions to symbolic responses, it is clear that physical incompatibility will not be of major importance.

It may be that certain perceptual responses are innately incompatible, so that the conflict between an expectancy and a perception, for example, may not be learned, but not enough is known about perceptual responses at the present time for us to decide. Most of the antagonisms of symbols are almost certainly the results of learning, which trains us not to apply two particular words to the same object or combine two particular concepts ($r_m$) in the same complex. Thus a thought or a perception may conflict with past experience by incorporating two elements previously learned as incompatible. There are two special cases of learned incompatibility that are likely to affect trains of thought. One is the learned incompatibility between contradictory beliefs, which enables us to recognize and avoid fallacious symbol-sequences. The other is the conflict between the learned fear of irrelevance and the tendency to perform an irrelevant verbal response. As we have already noted, the Würzburg school were impressed with the way in which the determining tendency kept thought in the right direction by excluding irrelevant associations. Modern learning theory (e.g. 10) leads us to the conclusion that this happens because the emergence of an irrelevant thought evokes a learned drive and its inhibition reduces the drive and is consequently reinforced. The existence of a strong 'drive to be relevant', at least in our culture, can be demonstrated in almost any session of psychotherapy with a neurotic. Long before his free association has led him to touch on anything delicate, he shows resistance due to his previous training to speak relevantly and coherently. It takes several sessions before he can flit inconsequentially from one topic to another or expatiate on matters that seem unconnected with his symptoms, as he must if he is to obey the 'basic rule'.

In order to show how conflict can affect curiosity, it is helpful once again to take a concrete example of a question, "what crops do some ants cultivate in underground 'farms'?" We have already introduced the assumptions that a question arouses concepts ($r_m$), including some which are drive-producing. But in addition, we can indicate, with the aid of our illustrative question, four stages, at any or all of which conflict may occur to bring about an increment of curiosity-drive:

(1) The question itself may evoke concepts which past experience and instruction may have made incompatible for the subject. In the case of our example, learned conflict may well exist in a zoologically naive person between all concepts relating to farming and all relating to subhuman animals. This is what happens when the designator of the question is said to be 'surprising' or 'unexpected' or 'strange' or 'puzzling'. Instead of such a question being put to the subject by an outside source, he might have come across a stimulus-situation arousing perceptual responses which he has been trained to regard as incompatible. This might lead him to take a closer look (perceptual curiosity) or to formulate such a question himself.

(2) Even if the question itself did not imply any surprising fact (e.g., "how does the starfish eat?") conflict may well arise immediately after its formulation, if the answer is unknown. If the answer is known, then there will be a response already learned to the stimulus-pattern produced by the question, and this response will probably occur without delay. But if the answer is unknown, then we must turn to behavior theory for some hints as to what might ensue. If the organism is confronted with

a combination of stimuli to which it has learned no response, we shall not expect it to do just nothing, unless it is a very primitive or young organism indeed. As Hebb has aptly reminded us (15), even the most novel situation for an adult rat or human being is built up of elements which resemble some things he has met many times before. Therefore, if a new question is the stimulus-situation, the responses that we can expect to occur are those which are aroused by stimulus generalization from similar patterns or elements. The strongest will be those conditioned to patterns consisting of some identical and some slightly different elements, as compared with the present pattern, or else those conditioned to single elements. For example, if no responses have been learned to a combination of 'ants' and 'farming', we can expect responses to occur which are associated with 'ants' plus some other activity, or 'farming' plus some other animal, or with 'ants' or 'farming' alone. This follows from Hull's treatment of stimulus generalization and of patterning (17, chaps. XII, XIX). However, the trains of thought leading out from 'ants' and from 'farming' etc., are likely to be of comparable strength and incompatible. So, here again, conflict may add to the drive-strength.

(3) As these associative processes continue, they are likely to lead, in the absence of other trains of thought, to some which are irrelevant to the motivation to answer the question. This will produce the type of learned conflict to which we have already drawn attention.

(4) Finally, in all probability, concept-patterns will be arrived at, which are recognised as possible answers. If one is strong and the others are not, then that one will be accepted and learned, and there

the process will end. But it may very well be that the subject is faced, either through his own cogitations or through the intervention of some external agency (as in 'multiple-choice questions'), with a number of possible answers which seem about equally plausible. In that case, conflict between them is to be anticipated. Moreover, if any answer is of such a strength that tendencies to accept or reject it are more or less equal, we shall have another source of conflict, reminiscent of the approach-avoidance conflict. The conflict characteristic of this fourth stage is, of course, particularly prominent in the 'yes-or-no question' (or the 'which ... question'). The drive to have the answer will be strongest, according to our expectations, if the tendencies to say 'yes' and 'no' are about equal.

Now, the drive produced in these various ways by conflict can only rightly be called 'curiosity' or a 'drive to know' if it is reduced by the process of knowledge-rehearsal. We must then see how exposure to concepts which are acceptable as the correct answer might lead to conflict-reduction. There are in fact three ways in which this might happen, corresponding to our four cases of conflict as follows:

(1) The answer, by implying that two concepts formerly regarded as incompatible need not be so, may inhibit learned conflict. This would mean that the S-R bond between $s_1$ and $R_{-2}$, to use Miller's notation (25), would be extinguished by the action of verbal stimuli (10). To revert to our example, the subject would cease to find the idea that ants engage in a kind of farming surprising.

(2) and (3) The answer may reduce the conflict derived from irrelevant, generalised trains of thought by evoking a new response-sequence which is strong enough to crowd them out and prevent them from arising.

Thus, our subject, having been told something of the activities of harvesting ants, will in future, when confronted with a pattern of concepts combining 'ants' with 'farming', be led off along trains of thought peculiar to harvesting ants and capable of overcoming irrelevant digressions.

(4) The answer may reduce conflict by strengthening one competing response and weakening others, thus reducing the equality between them. This happens when we are made to believe that one of our suspected answers is right and the other is wrong. There is henceforth, therefore, no competition between them.

Since conflict (F) is an intervening variable, we must ask what variables affect its magnitude. Brown and Farber (8) postulate F increases with (1) the absolute strength of the competing tendencies and (2) the equality between them. There is some experimental evidence for the first of these hypotheses. Sears and Hovland (41) found that avoidance-avoidance conflicts provoke more blocking when the competing responses are stronger. The assumption that the symptoms of conflict only occur when the conflicting tendencies are about equal is confirmed time and time again in Miller's experiments (29). Nevertheless, we are obliged to hypothesize that the intensity of the conflict-drive depends also on two more variables, which have been little studied, but which are of prime importance for conflict between thought-processes. These are (3) the number of conflicting response-tendencies and (4) the degree of incompatibility between them. A few remarks on each of these are in order.

Firstly, Miller's treatment of conflict has been confined to cases where only two tendencies are in competition. For that matter, Lewin's, Freud's and Hebb's theories do not consider fully the possibility of there being more than two. Pioneering studies have of necessity to begin with the simplest cases, and there may be special reasons why dual rather than higher-order conflicts are the most frequent. When the theory of higher-order conflicts comes to be attacked it is likely to be found that usually two or more tendencies among those competing will have more in common than others, so that they form an alliance, and the situation resolves itself into virtually a dual conflict. It is interesting to note how this happens in Freudian theory. There are three elements in the personality - id, ego, superego - but neurotic conflicts take the form ego + superego vs. id or ego vs. id + superego (11, p. 132). However, in the higher mental processes, higher-order conflicts may be common. Several trains of thought may be leading symbol-sequences in many incompatible directions at once, just as, in Hull's treatment of learning (e.g., 16), one stimulus may arouse three or more reaction-potentials at once. It seems reasonable to assume that if the number of conflicting tendencies is increased, all things being equal, the severity of the conflict will increase.

Secondly, both Hull (18, corollary xiv) and Miller (25) speak of cases where the incompatibility between response-tendencies is absolute. But, as we have elsewhere mentioned (5, p. 144), even with innate reflexes intermediate degrees of incompatibility and partial interference are known. Learned conflict is likely to make even more indispensable the concept of degree of incompatibility, since the $s_1 \rightarrow R_2$ bond may have various strengths. Subjects may, for instance, be surprised to different extents to hear of ants farming.

It may now be possible to understand a little better the relations between human curiosity, directed towards puzzling novelties, and the curiosity that has been the subject of experimentation with rats (4). In the discussion arising out of the latter, it was pointed out that two sorts of stimulus might be the adequate stimulus for curiosity: a novel variation in something familiar (suggested by McDougall (24)) or something completely new. The concept of complete novelty is unsatisfactory, because it is hard to specify exactly how unlike things experienced before a situation must be to be regarded as new. But the introduction of conflict enables us to see the question in a new light, which makes the two proposed types of curiosity-arouser not so different as might at first appear. In the case of a familiar stimulus-complex with an unexpected modification, the role of conflict is obvious, since this is precisely the case that Hebb speaks of at length. But Hebb reminds us that nothing is so new to a sophisticated animal that it does not contain elements similar in some respects to what he has met with before. If a 'completely novel' pattern, then, is one which by stimulus generalization evokes a number of disparate reactions of about equal strength, we shall have once again a conflict-situation. This will provide us with a more useful analysis of novelty, and at the same time show us that a novel stimulus-object for a rat may be equivalent in its effects to an unanswered question for a human being.

Our theory may also link up with certain threads in contemporary social and developmental psychology. Many writers have been showing (6, 9, etc.) that one of the most distressing plights for human beings is not to know or to understand a state of affairs, particularly if it is important for their security or contrary to their expectations. One of society's most vital functions is to provide norms and frames of reference for the evaluation of new contingencies. If these are lacking or inapplicable to an unprecedented crisis-situation, people will be prone to accept and spread rumors, or to succumb to suggestion. Many of the rumors and fanciful stories accepted by them in this gullible mood are the very reverse of reassuring. Indeed, they often show a tendency to believe in the most alarming prospects they can imagine, so that this desire to have an explanation available does not seem to be reinforced by fear-reduction. But the principal drive behind it may well be the conflict-drive, produced by uncertainty, which, as many wartime phenomena showed, is often more agonizing than realistic anticipation of unpleasantness. When there is a perplexing situation, raising an unanswered question, we predicted from the principles of behavior theory that responses due to generalization from similar stimuli would occur. This casts light on the inveterate proclivity, so often observed in children and in primitive peoples, to interpret in terms of familiar phenomena those things that are of moment to them but they have little objective information about, which gives their speculations an 'artificialistic' and 'animistic' stamp (38). Similarly, when irregular figures are exposed in a tachistoscope, Bartlett (3) reports that subjects evince an 'effort after meaning', which leads them, as their immediate reaction, to relate the figures to something familiar.

Our theory of curiosity implies that patterns will be most curiosity-arousing at an intermediate stage of familiarity. If they are too unlike anything with which the subject is acquainted, the symbolic response-tendencies aroused will be too few and too feeble to provide much conflict, while too much familiarity will have removed conflict by making the particular combination an expected one. Once again, we have a prediction that accords with the observations of psychologists working in several fields. McDougall's contention that something with an intermediate degree of familiarity is the adequate stimulus for curiosity has already been touched on. Hebb (15) expresses the belief that the mental processes corresponding to cortical processes ('phase-sequences') will be most rewarding, and therefore most likely to occupy the subject, when the phase-sequences are in the course of being built up. The cell-assemblies and phase-cycles will then be in existence, but they will not yet have been molded into a firm unity. Freudians (11, p. 45) attribute many of the play-activities of children to the discovery that they are now able 'to overcome without fear a situation that formerly would have overwhelmed (them) with anxiety'. But this 'functional pleasure' will only be attached to a given activity during the comparatively short interval between coming to fear it and triumphing over the fear. Piaget (38, 39) writes of the apparently useless actions that infants are prone to indulge in repeatedly (primary, secondary and tertiary circular reactions); but each of these actions dominates the child's activity for a brief period while he has discovered the ability to produce the effects in question but has not yet assimilated them to the point where they cease to be interesting.

## RELATIONS OF CURIOSITY TO OBSERVABLE VARIABLES

Our discussion has so far been concerned with postulated unobservable central processes. It is now necessary to relate our intervening variables to observable variables in order to reveal the empirical content of the theory.

On the consequent side, we have already related the strength of the curiosity-drive to two variables which enable us to measure it. The drive-strength will be positively correlated with (1) the probability of recalling, on a future occasion the answer to the question arousing the curiosity, and (2) the probability of reporting a wish to know the answer to the question.

On the antecedent side we stated that curiosity is aroused by a question or other thematic probe. A question evokes meaning-responses ($r_m$) which produce both cue-stimuli and motivational stimuli. The curiosity-drive-strength will increase with (1) the intensity of the drive-stimulus ($s_{mD}$) produced by the meaning of the question ($r_m$), and (2) the degree of conflict (F) between symbolic responses.

The intensity of the $s_{mD}$ will depend on the prolongation (extinction-resistance or n) and the strength (amplitude or A) of the drive-producing response. These quantities, according to Hull (17, 18) depend on reaction-potential ($_SE_R$), which itself is largely a function of habit-strength ($_SH_R$), inhibitory aggregate ($\dot{I}_R$) and drive (D). To take these in turn, $_SH_R$ will be a function of number of reinforcements (N) which will, in this case, mean the number of times that arousal of curiosity by similar questions has led to a successful quest for the answer, with consequent reward, social or material. Then $\dot{I}_R$ will depend on the difficulty of finding the answer to similar questions in the past (amount of effort, W) and the number of times the quest has led to failure (n) (18, corollaries x and xi). As for D, Hull states that any drives present at the time will help to swell this variable, but in our case it is likely that irrelevant drives like hunger or thirst will evoke their own distracting responses more strongly than they will increase curiosity. But drives whose relief has in the past been furthered by finding the answer to similar questions may well add their quota. They may include practical purposes for which the knowledge sought would be useful, social motives, such as drives for prestige and approval, and possibly such drives as the Freudians mention, acting by displacement (29). The other variables on which $_SE_R$ is stated to depend are likely to play a minor role in curiosity, but they may possibly have some influence. They are J, or the speed with which reward has followed a successful search for an answer in the past - this is probably of minor importance, because secondary rewards or 'confirmatory reactions' are likely to be immediate - and V (stimulus-intensity dynamism), which may represent the effect of the loudness, if spoken, or size or brightness, if written, of the question.

The degree of conflict (F)is assumed to increase with the equality of the conflicting reaction-potentials ($_SE_R$), the absolute strengths of the $_SE_R$'s, the number of competing response-tendencies, and the degree of incompatibility between them. The following variables, all amenable to experimental study, may be cited as playing a part in determining these quantities:

(1) The more <u>familiar</u> the concepts figuring in the question, the

more numerous and the stronger are likely to be the competing trains of thought emanating from them. This means that two of the variables affecting F will be increased.

(2) The incompatibility of the concepts in the question for the subject, as judged for example by the amount of surprise he reports, will determine the initial conflict evoked by the question and also the degree of incompatibility and mutual irrelevance between the symbol-sequences that follow.

(3) If multiple-choice questions are given, the number of conflicting response-tendencies will be a function of the number of answers provided. In open-ended questions, the number of possible answers entertained by the subject before he decides between them will exert a similar influence.

(4) The relative plausibility of the alternative answers, whether provided by the experimenter or by the subject's own thought-processes, will affect the equality of the conflicting tendencies.

Experimental data, reported elsewhere (6), have supplied some confirmation for several of the predictions from our theory. The difficulties of using the techniques of behavior-theory for complex forms of human motivation are undeniable. Several alternative theories may, because of the necessary indirectness of the evidence, yield similar predictions. In a well-trodden field like animal psychology, an experimenter feels obliged to review the various theories that have been proposed and to design his experiment so as to adjudicate between them. But he can never exclude the possibility that some future date may see a new theory, differing from any he can at the moment imagine, which explains his own and other data better than any of its predecessors. In a relatively unbroached area like human curiosity, these alternative theories must be much more numerous, they all belong to the future and they must be even more clearly impossible to anticipate in the early stages of research. We can therefore only follow out the implications of one theory and hope that its inadequacies will hasten the appearance of the more satisfactory alternatives that will undoubtedly succeed it.

## SUMMARY

Human 'epistemic curiosity', to be distinguished from the 'perceptual curiosity' that is found in lower mammals as well as in human beings, is defined as a drive reducible by knowledge-rehearsal. Knowledge is analyzed as consisting of habits mediating believed, designative symbols, which often form 'trains of thought'. A theory of epistemic curiosity is presented, its principal elements being (1) an account of questions as 'thematic probes' which evoke drive-producing meaning-responses, and (2) the attribution to conflict of the curiosity aroused by strange, surprising or puzzling situations or questions.

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# AN EXPERIMENTAL STUDY OF HUMAN CURIOSITY

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The experiment to be reported below was designed to investigate some of the principal predictions from a theory of human curiosity, which has been outlined elsewhere (3,4). The type of curiosity with which it deals is 'epistemic curiosity', defined as a drive reduced by knowledge-rehearsal. It is distinguished from 'perceptual curiosity', which leads to exploration and exists in lower animals.

When we set out to inquire into such a complex form of human motivation, we find ourselves faced with a bewildering array of variables that may possibly be influential. The difficulty of knowing where to begin is, no doubt, one reason why little work in this area has been done.

An indispensable aid is to have a theory to suggest relationships that are likely to repay study (6,8). But even when the variables that are worth investigating have been identified, the task may still seem baffling. Something like human curiosity must depend on a vast network of factors, each of which may make a comparatively slight contribution, and individual differences must be enormous. Large groups of Ss and quantities of experimental material may thus be required to establish that a single variable has a significant effect.

An intermediate stage appears necessary if the project is to become practicable, namely the exploratory experiment. This would use small numbers of subjects and sample the effects of several variables at once. Such an experiment may well prove too insensitive to permit definitive conclusions about some of the relationships it studies. But it could save us from many a costly blind alley by indicating which variables appear to be important and worth pursuing. The experiment discussed in this article was intended to perform this exploratory function.

PREDICTIONS

According to the theory, epistemic curiosity is aroused by stimulus-patterns of the sort Skinner calls 'thematic probes' (11). The clearest examples are questions, which are assumed to evoke, among others, drive-producing responses. The curiosity drive-strength is stated to increase with the amplitude of these drive-producing responses ($r_{mD}$) and also with the degree of conflict ($F$) between symbolic responses.

In the experiment, an experimental group received (1) a fore-questionnaire about invertebrate animals, (2) a communication giving answers to the questions, and (3) an after-questionnaire which repeated the questions. A control group underwent the same procedure except for omission of the fore-questionnaire. In this situation, several phenomena could be predicted from the theory:-

A. Effects of pre-questioning 1) It would be expected that the experimental group, at the time of reading the answers to the questions, would, more often than not, recall the questions and thus have their curiosity re-aroused. No such process could occur with the control group. The reduction of the curiosity to a subliminal value by the rehearsal of the answers would thus increase the amount of reinforcement (K) or drive-reduction, and this would make the experimental group learn the answers more effectively than the control group. The experimental group would thus recall more answers when the after-questionnaire is presented.

2) The arousal and subsequent reduction of curiosity is stated to increase the amplitude of curiosity-producing responses ($r_{mD}$) to similar questions on future occasions. When Ss are required to indicate which of the animals figuring in the experiment they would like to know more about, we can consequently expect the experimental group to check off more animals than the control group.

B. Recognition of answers When one of the answers in the communication is received, curiosity aroused by the recall of the question will be reduced. If a question is recalled, its answer will presumably be recognized as such. It follows that the learning of statements recogni.ed as answers to questions from the fore-questionnaire will have the reinforcement of this curiosity-reduction, and so they will be more probably recalled than others during the after-questionnaire.

C. Effectiveness of different classes of questions We have two ways of comparing the effectiveness in arousing curiosity of two different classes of questions. Ss were instructed to mark with 'K' 12 questions out of the 48 in the fore-questionnaire whose answers they most wanted to know, and so we can note the number of questions in each class that were marked 'K'. Secondly, we can note the number of questions in each class that were answered correctly during the after-questionnaire.

The conflict-variable (F), which the theory cites as a determinant of strength of curiosity, is stated to depend on the equality, the absolute strength, the number and the degree of incompatibility of the competing response-tendencies. This allows us to identify certain classes of questions which can be expected to arouse more curiosity than others, as shown by both measures:-

1) Familiarity. It is hypothesized that the more familiar the principal concepts in the questions, the more numerous and the stronger the competing symbolic response-sequences to which they give rise. Noble (9,10) has demonstrated that there is a correlation between the familiarity of words and the number of associations they elicit. Ss were instrusted to rate the animals figuring in the questions for familiarity at the start of the experiment, and familiarity was also manipulated by providing introductory information about two of the animals. Questions about more familiar animals, familiarity beigg judged by either operation, should arouse more curiosity than others.

2) Incompatibility. Questions whose concepts seem incompatible to Ss will arouse more conflict than others and consequently more curiosity. Incompatibility was judged by having Ss mark those questions in the fore-questionnaire which surprised them, and also by using a group of judges, who indicated which

predicates seemed to them least applicable to the animals.

3) A preliminary experiment, reported elsewhere (3, appendix), supported the prediction that questions with four alternative answers arouse more curiosity than those with two alternative answers, as we should expect in view of the number-of-competing-tendencies variable .

D. Correlation between measures of curiosity. The questions which Ss marked with 'K', as arousing most curiosity in the fore-questionnaire, should be more likely than others to be answered correctly in the after-questionnaire. There are two mechanisms by which this could occur. Whether a question is marked 'K' depends on how much curiosity it arouses in the fore-questionnaire, and whether it is answered correctly in the after-questionnaire is assumed to depend on the strength of curiosity at the time of reading the answer in the communication. The theory implies that these two degrees of curiosity will be correlated. A supplementary or alternative mechanism might be a closer reading of questions selected for marking with 'K' and consequently a more probable recall of such questions in the communication. Either mechanism would cause our two measures to be correlated and would make both depend on the degree of curiosity aroused by the questions.

E. Surprisingness of answers. Ss were instructed to indicate which statements in the communication they found surprising. Such statements will have some apparent incompatibility between their concepts, and this will add to the curiosity aroused and then reduced. These statements should therefore be more effectively learned and more probably recalled in the after-questionnaire than others.

## PROCEDURE

Experimental Group (54 Ss). The following three phases were taken in immediate succession.

<u>Phase I</u>. <u>Section 1</u>. A list of twelve animals was presented, and Ss were instructed to rate each animal for familiarity on a 4-point scale, ranging from 'seen, read or heard a fair amount of' to 'never heard of'. The twelve animals consisted of eight that Ss were almost bound to have heard of and four 'exotic' animals that were unlikely to be known to them. Of the 'exotic' animals, two were real (the sea-mat and the sea-gooseberry) and two were fictitious (the 'sea-wasp' and the 'stringworm').

<u>Section 2</u>. Paragraphs of about 120 words each, giving a general description of two of the 'exotic' animals, one real and one fictitious, were read by Ss. For half the Ss (sub-group EA) the animals were the sea-gooseberry and the 'stringworm', while for the remainder (sub-group EB) they were the sea-mat and the 'sea-wasp'.

<u>Section 3</u>. A series of 48 questions, four on each animal, was presented, and S had (a) to check off the correct answers from two alternatives per question, (b) to mark with 'C' those answers of which he felt certain from previous knowledge, and (c) to mark with 'S' those questions which surprised him.

<u>Section 4</u>. S had to go back over the questions in Section 3 and mark with 'K' the three questions out of each consecutive group of twelve whose answers he would most like to know. Twelve questions out of 48 were thus to be so marked.

<u>Phase II</u>. S received sheets containing 72 statements, 6 about each of the 12 animals. These were in a random order, not corresponding to the random order of the questions in Phase I. S was (a) to mark with 'S' every statement that surprised him and (b) to check off every statement that he recognized as an answer to one of the questions in Phase I. An answer to each of the 48 questions, coinciding with one of the alternatives offered in Phase I, was included among the 72 statements. The tasks served the double purpose of providing E with information and inducing, as far as possible, a non-learning set.

Phase III. Section 1. The 48 critical questions were again presented, this time in an open-ended form and in yet a third random order. Ss had to fill in the answer given in Phase II, where remembered.

Section 2. The 12 animals were listed, and S had to check off those he would like to know more about. Finally, there were questions on the interestingness of the experiment and desire to know more about animals.

Control Group (34 Ss) The procedure was exactly the same as for the experimental group, except that Section 3 and Section 4 of Phase I (the fore-questionnaire) were omitted, and the recognition-test in Phase II did not apply. Phase I existed in two versions, as with the experimental group: 17 Ss (sub-group CA) received paragraphs about the sea-gooseberry and the 'stringworm', and the other 17 (sub-group CB) read about the sea-mat and the 'sea-wasp'.

Judges (30). The judges, taken from the same population as the Ss, received a list of the eight 'non-exotic' animals used in the experiment. Opposite the name of each animal were four phrases, representing the predicates implied by each of the four questions about that animal. The judges had to check off the two phrases that seemed to them least likely to apply to the animal concerned.

Of the 48 answers to questions from the fore-questionnaire that were presented in Phase II, 24 (2 per animal) were true and 24 (2 per animal) were false. This was to control for previous knowledge of the subject-matter and for the fact that the animals mentioned differed in familiarity. If all the answers provided had been true, more knowledgeable Ss would have had more coincidences between the answers checked in Phase I and those larned in Phase II, and the following possibilities might have invalidated the conclusions:-

(1) Any previous knowledge that inclined S to prefer a particular response in Phase I may have made the corresponding fact easier to learn in Phase II.

(2) The act of selecting an answer in Phase I may have provided reinforcement for the bond between question and answer to supplement the learning in Phase II.

The familiarity-variable necessitated precautions against two further possibilities:-

(1) The correct anwers to questions about familiar animals might have been encountered in the past. These answers might have been subliminal, so that they could not be recalled in Phase I, but they might nevertheless have provided a residue of habit-strength to make the re-learning of them in Phase II easier.

(2) It might have been possible to infer the correct answers from what was already known about the animals. (We guarded against this also by inclusion of fictitious animals, the answers being selected at random in their case).

The expedient of making half the answers false ensured that, no matter how much S's prior knowledge about the animals, this knowledge would facilitate and hinder the learning of equal numbers of answers. It caused the proportion of coincidences per S between answers checked in Phase I and answers learned in Phase II to approximate one half.

SUBJECTS

All 68 Ss and 30 judges were undergraduates taking a course in Normal Human Personality at Brooklyn College. They had all had a previous introductory course in General Psychology.

RESULTS AND DISCUSSION

The following rules were observed in computing results, except where stated otherwise.

(1) All questions marked 'C' in the fore-questionnaire (i.e. those whose answers Ss claimed to know with certainty) were omitted. This was because in such cases curiosity may not be aroused at all or may function in a special

way, and different Ss felt certain of different numbers of answers.

(2) In some cases, Ss appeared to have misunderstood or overlooked some of the tasks. Therefore, (a) if S had marked no question with 'S' (to indicate surprise) in Phase I, his data were omitted from all calculations involving that variable, (b) if S marked all statements in Phase II with either 'S' (indicating surprise) or with a check (indicating recognition of an answer), but not both, his data were disregarded where these variables were relevant, (c) if S marked more or less than 12 of the questions in Phase I with 'K' (indicating desire to know the answer) his data were included, but if he marked none at all they were disregarded where relevant.

For the comparisons between experimental and control groups, we use the t-test. But for other results, which involve comparisons between questions or answers, differing in number from S to S, that belonged to different categories, we use the $chi^2$-test for data pooled from all Ss, with Yates' correction. Some statisticians object to the use of the $chi^2$ for such data, one objection being that the test does not distinguish between effects which the group as a whole has produced and those due largely to a few exceptional individuals. We have consequently given, in columns headed 'Ss' in the tables, the numbers of Ss whose data show a deviation from expected proportions in the same direction as the contingency table for the whole group. For example, 26/29 indicates that 26 out of 29 Ss show such a deviation. In many cases it will be seen that the results would emerge as significant by the sign-test. But in general our only justification for using this method of analysis is the necessity for an exploratory and consequently relatively insensitive experiment, as explained above. The effects we are seeking are too slight and the data too few for such techniques as analysis of variance of proportions based on different numbers (5), and so we have to content ourselves at this stage of research with more tentative conclusions than they would sanction.

A. Effects of pre-questioning. Table I displays the comparisons between experimental and control group that show whether the pre-questioning, which only the experimental group underwent, increased curiosity. We compare the mean numbers of questions answered correctly in Phase III and also the mean numbers of animals checked in Section 2, Phase III. Both differences confirm the prediction significantly. All questions, including those marked 'C' are included. No significant differences were produced by any of the questions on interest, etc.

In view of the fact that the experimental group had two tasks to carry out in Phase II and the control group had only one, it might be thought that some difference in the thoroughness of reading the statements might have been responsible for the greater recall-scores of the experimental group. But a similar significant difference was found in the preliminary experiment (3, appendix), in which both groups alike had merely to read through the communication in Phase II.

B. Recognition of answers. The first row of Table II shows that statements recognized by the experimental group as answers to questions from Phase I were, as predicted, more likely than others to be recalled in the after-questionnaire. The second row of the table shows that questions Ss marked 'K' (i.e. those whose answers they most wished to know) in Phase I were more likely to have their answers recognized in Phase II. The latter relationship was not predicted by the theory. To explain it, we can only hazard the hypotheses that (1) questions evoking more curiosity may, like other drive-arousing stimuli, receive more attention (2 p.143) and thus be more easily remembered, (2) questions marked 'K' may receive more attention, or (3) the drive-producing responses, though subliminal, may persist in some form, so as to supplement the statements in Phase II as stimuli re-evoking the questions. Such subliminal drives, known as 'quasi-needs' or 'tensions', have been posited by Lewin and his followers (7)

## TABLE I

### EFFECTS OF PRE-QUESTIONING

(EXPERIMENTAL GROUP (34 Ss) VS. CONTROL GROUP (34 Ss))

| Mean correct answers in Phase III | | t | p | Mean animals checked in Phase III | | t | p |
|---|---|---|---|---|---|---|---|
| Exp. Gp. | Cont. Gp. | | | Exp. Gp. | Cont. Gp. | | |
| 32.41 | 27.15 | 3.29 | $< .01$ | 5.38 | 3.36 | 2.90 | $< .01$ |

TABLE II

RELATION BETWEEN RECOGNITION OF ANSWER AND MEASURES OF CURIOSITY
(EXPERIMENTAL GROUP)

| Questions | Answers recognized | Answers not recognized | $Chi^2$ | p | Ss |
|---|---|---|---|---|---|
| Answered correctly in Phase III | 732 | 72 | 31.38 | $< .0001$ | 26/29 |
| vs. | | | | | |
| Not answered correctly | 325 | 91 | | | |
| Marked K | 256 | 24 | 7.25 | $< .01$ | 21.5/27 |
| vs. | | | | | |
| Not marked K | 780 | 138 | | | |

as an explanation of the Zeigarnik effect. They are also reminiscent of Freud's 'unconscious wishes', which may likewise lie dormant until they determine a response jointly with incoming external stimuli.

C. Effectiveness of different classes of questions. The last four rows of Table III present comparisons between different classes of questions put to the experimental group according to our two ways of estimating the effectiveness with which they arouse curiosity. We examine the number of questions in each class answered correctly and the number answered incorrectly in Phase III, and similarly we compare the numbers marked 'K' (as among the 12 whose answers Ss most wished to know) and not marked 'K' in Phase I.

1) Familiarity. We compare questions about animals marked 'seen, read or heard a fair amount' or 'seen, read or heard a little' (hereafter referred to as the 'more familiar animals') with those marked 'heard of, but know nothing about' or 'never heard of' (hereafter referred to as the 'less familiar animals'). Table III shows that questions about more familiar animals evoked more curiosity by both tests. The two 'exotic' animals about which Ss received previous information were omitted from this comparison, as they received a special treatment. The other two were included, except where a fictitious animal received a rating other than 'never heard of'.

It might be suggested that the better recall-scores for qestions about more familiar animals were due to the fact that more of these questions were marked 'K', which may have caused them to be read more attentively in Phase I and perhaps remembered more easily in Phase II. However, in the preliminary experiment (3, appendix), onlyhalf the Ss in the experimental group had to carry out the task of marking questions with 'K', and no significant effects on recall-scores of the presence or absence of this operation were found.

The effects of questions about familiar animals must be distinguished from any tendency there might be to remember facts about familiar animals better. The data on the Control Group in Table IV reveal that there is such a tendency.

TABLE III

EFFECTIVENESS OF DIFFERENT CLASSES OF QUESTIONS. (EXPERIMENTAL GROUP)

NS = not significant

| Classes of questions | Correct in Phase III | Not correct in Phase III | Chi$^2$ | p | Ss | Marked K | Not marked K | Chi$^2$ | p | Ss |
|---|---|---|---|---|---|---|---|---|---|---|
| Marked K | 251 | 76 | 20.11 | .0001 | 28/31 | | | | | |
| vs. | | | | | | | | | | |
| Not marked K | 670 | 390 | | | | | | | | |
| More familiar | 659 | 239 | 44.50 | $<.0001$ | 29/34 | 259 | 535 | 36.70 | $<.0001$ | 26/32 |
| vs. | | | | | | | | | | |
| Less familiar animals | 187 | 163 | | | | 50 | 286 | | | |
| Previous-information | 149 | 111 | NS | | | 28 | 213 | NS | | |
| vs. | | | | | | | | | | |
| Non-previous-information 'exotic animals | 138 | 135 | | | | 23 | 225 | | | |
| Surprising | 135 | 88 | NS | | | 81 | 130 | 20.11 | $<.0001$ | 23/28 |
| vs. | | | | | | | | | | |
| Non-surprising | 751 | 411 | | | | 230 | 761 | | | |
| Incompatible | 362 | 159 | NS | | | 169 | 293 | 6.98 | $<.01$ | 24.5/31 |
| vs. | | | | | | | | | | |
| Non-incompatible concepts | 355 | 140 | | | | 131 | 329 | | | |

However, we can ascertain whether questions about more familiar animals have an effect over and above this by comparing for the two groups the proportions of questions answered correctly in Phase II that fell in the two categories. We already know that pre-questioning increases the probability of recalling facts. But we wish to know whether this increase is significantly greater for questions about more familiar animals, i.e., whether such questions arouse more curiosity. If they do not, we should expect the correctly answered questions to be distributed in equal proportions between more familiar and less familiar animals for both groups. Table V supports the prediction that more curiosity is aroused by questions relating to more familiar animals. In the case of the control group, the figures are adjusted, because those for the experimental group exclude questions marked 'C' (those whose answers Ss claimed to be certain of). It is assumed that the control group would have marked with 'C' the same proportions of questions in each category as the experimental group, and the totals are reduced by these proportions.

Each of the four 'exotic' animals received an introductory paragraph of information for half the Ss of each group, but not for the other half. We are thus enabled, confining our attention to the 'exotic' animals alone, to compare the effects of questions about previous-information and non-previous information animals respectively. Table III shows that there is no significant difference in curiosity by either test. But the data from the control group in Table IV (adjusted, as above) show that there is a tendency for facts about previous-information animals to be learned better. The failure of a significant difference to appear for the experimental group may well have been due to its being swamped by the pre-questioning variable, which may have produced a ceiling-effect.

2) Incompatibility. There are two indications available to us of which questions contradicted Ss' expectations. We have the marking of questions with

TABLE V

QUESTIONS ANSWERED CORRECTLY IN PHASE III
(EXPERIMENTAL GROUP)

| Group | More familiar animals | Less familiar animals | $Chi^2$ | p |
|---|---|---|---|---|
| Exp. | 659 | 187 | 3.46 | $<.05$ (1 tail) |
| Cont. | 498 | 178 | | |

'S' in Phase I, which reveals those Ss found surprising, and we have the judges' selection of the two questions out of the four on each animal that involved what appeared to them the least applicable predicates. The latter dichotomy between 'incompatible-concept' and 'non-incompatible-concept' questions has the advantage of being orthogonal to any comparisons between animals on the grounds of familiarity etc., as each animal had two questionsin each category. Table III shows that, according Ss' reports (marking 'K') of desire to know answers, surprising and incompatible-concept questions evoked more curiosity than the others. But no effect of these variables on recall was manifested. We can check on the agreement among the judges in their selection of incompatible concepts by counting the number of judges marking the two most and the number marking the two least frequently selected concepts for each animal, and performing a mean-difference test. The mean difference per animal is 14.52, $t = 4.09$ and $p$ is less than .01. The preliminary experiment (5, appendix) supplied some slight evidence in favor of a correlation between surprise and probability of recall, and so lack of sensitivity may have been responsible for the failure of this effect to reveal itself.

D. Correlation between measures of curiosity. The first row in Table III confirms that questions marked 'K' by the experimental group in Phase I, indicating desire to know the answers, were more likely to be answered correctly in Phase III, thus revealing the predicted correlation between our two measures of curiosity. Since we find that both the recognition and the subsequent recall of answers are more probable if the corresponding questions are marked 'K', the relation between the first two may be a reflection of these correlations instead of being due to the reasons we adduced. The present experiment alone does not allow us to decide between these alternative explanations.

E. Surprisingness of answers. It remains to investigate the comparative ease of learning statements marked 'S' (as surprising) in Phase II and statements not marked 'S'. The last two rows of Table IV show that the experimental group, as predicted, recalled a higher proportion of surprising statements in Phase III. But this prediction was not significantly borne out by the control group.

No legitimate conclusion can be drawn from this difference between the two groups, as the control group marked significantly more statements as surprising ($chi^2$ = 237.94, p is less than .0001). This was probably due to the fact that the control group had only one task to perform in Phase II, whereas the experimental group had two. As a result, the control group are likely to have had a lower threshold of surprisingness for a statement to be marked 'S', and so their data may have been less sharply discriminating.

The effect of the surprisingness of an answer could be explained away if this variable were associated with the familiarity of the animals. But $chi^2$ for both experimental and control groups is under 1.00, and so this can be ruled out.

SUMMARY

An exploratory experiment, designed to test some of the predictions from a theory of human epistemic curiosity, is reported. An experimental group received (1) a fore-questionnaire about invertebrate animals, (2) a series of statements including answers to the questions, and (3) an after-questionnaire, repeating the questions of the fore-questionnaire. A control group underwent the same procedure except for the fore-questionnaire. The recall of the answers in the after-questionnaire and Ss' reports were used as measures of curiosity. The results tend to confirm the following predictions: (1) that pre-questioning arouses curiosity, (2) that the two measures of curiosity are correlated, (3) that statements recognized as answers to questions from the fore-questionnaire are more likely than others to be recalled in the after-

questionnaire, (4) that questions about more familiar animals and questions whose concepts seem incompatible arouse more curiosity than others, (5) that surprising statements are more likely to be recalled in the after-questionnaire than others.

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