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negative motivations have more tendency to organize conditioned reflex learning processes and automatic behavior.

Finally, it is held that negative motivation has found a better reception in experimental psychology because it has been tied to a continuous physical variable, electric shock; and because it is easier to conceive a theory of avoidance mechanisms than pursuit ones.

The constructive part of the paper, then, is to remedy these two deficiencies, first by establishing a simple theory of cognitive-approach behavior, and second by establishing an experimental psychology of positive motivation on the basis of the same continuous physical variable, electric shock, as has been previously used only in studies of negative motivation.

In these experiments, where electric shocks delivered to certain parts of the brain produce extremely intense positive motivational effects, it will be shown that about five times as much of the central nervous system in the rat is devoted to positive motivational processes as to negative ones. Further, these experiments begin to demonstrate specifically a series of categorical differences between positive motivational mechanisms and negative ones.

ON THE NEUROLOGY OF VALUES

BY

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Psychological processes seem to be especially responsive to environmental events of two sorts: 1) those that momentarily excite receptors, and 2) those that are the outcomes or consequences of the use made by the organism of its effectors. The discussion of discriminative behavior from which the visual field is inferred could serve as an example of the type of relationship initiated by the first; a neurobehavioral analysis of preferential behavior provides some empirical relations that help to understand the type of relationship that stems from the second.

A MULTIPLE OBJECT EXPERIMENT

A modified Wisconsin General Testing Apparatus is used to test twelve rhesus monkeys in the solution of a complex problem. The monkeys are divided into three groups, two operated and one control, each containing four animals. The animals in one operated group had received bilateral cortical resections in the posterior intrinsic cortex and those in the other operated group, bilateral cortical resections in the frontal intrinsic cortex some two and a half years prior to the onset of the experiment; those in the control group are unoperated. In the testing situation these animals are initially confronted with two junk objects placed over two holes (on a board containing twelve holes in all), with a peanut under one of the objects. An opaque screen is lowered between the monkey and the objects as soon as the monkey has displaced one of the objects from its hole (a trial). When the screen is lowered, separating the monkey from the twelve hole board, the objects are moved (according to a random numbers table) to two different holes on the board. The screen is then raised and the animal again confronted with the problem. The peanut remains under the same object until the animal finds the peanut five consecutive times (criterion). After a monkey reaches criterion performance, the peanut is shifted to the second object and testing continues (discrimination reversal). After an animal again reaches criterion performance a third object is added. Each of the three objects in turn becomes the positive cue; testing proceeds as before—the screen separates the animal from the twelve hole board, the objects are placed randomly over three out of the twelve holes (with a peanut concealed under one of the objects), the screen is raised, the animal allowed to pick an object (one response per trial), the screen is lowered and the objects moved to different holes. The testing continues in this fashion until the animal reaches criterion performance with each of the objects positive, in turn. Then a fourth object is added and the entire procedure repeated. As the animal progresses, the number of objects is increased serially through a total of twelve. The testing procedure is the same for all animals throughout the experiment; however, the order of the introduction of objects is balanced—the order being the same for only one monkey in each group.

RESULTS

Analysis of the problem posed by this experiment indicates that solution is facilitated when a monkey attains two strategies: 1) during search—moving on successive trials, each of the objects until the peanut is found; 2) after search—selecting, on successive trials, the object under which the peanut had been found on the preceding trial.

The difficulties in performance encountered by the frontally operated group follow completion of search, *i.e.*, after the first response on which the peanut is found. The lag shown by the frontally operated group in reducing the number of trials taken to reach criterion (or the number of repetitive errors made) occurs after the peanut has been found. This group of monkeys experiences difficulty in attaining the strategy of returning on successive trials to the object under which they have, on the previous trial, found the peanut. Whatever may be the explanation of this difficulty, a precise description can be given: for the frontally operated group, the outcome of the action "finding the peanut" has less "utility" in determining subsequent behavior than this outcome has for the controls (or for the posteriorly operated group). In the more popular argot of experimental behaviorism the effectiveness of the reinforcement is diminished for the frontal group.

Interestingly, before the frontally operated group begins to attain the necessary strategy, performance of this group reflects the number of alternatives in the situation. This finding suggests a parallel with analyses of the determinants of the preference developed in the theory of games and economic behavior. Preference is determined by two classes of variables: "demand" (desirability, need) and "expectation" (availability, needs of other interactants in the system). The finding that performance of the frontally operated group is related to the number of alternatives in the situation suggests that this group is deficient in evaluating the "expectation" variables --but this is only suggested by these results. Support for the hypothesis that frontal lesions do *not* affect the "demand" variables that determine preference comes from the results of another experiment.

An operant conditioning experiment

Ten rhesus monkeys are tested in an "operant conditioning" situation which consists of an enclosure (discarded icebox) in which a lever is available to the monkey. Occasionally, immediately after a depression of the lever, a pellet of food also becomes available to the monkey. The experimenter schedules the occasions on which the action of pressing the lever has the outcome that a food pellet becomes available. In this experiment, these occasions recurred regularly at a constant (fixed) interval of two minutes. The conditioning procedure, as a rule, results in performance curves (scallops) which reflect, during the early portions of the interval, a slow rate of response, and during the latter portions an accelerating rate which reaches asymptote just prior to the end of the interval. All of the monkeys used in this experiment were trained every other day for two-hour sessions until their performance curves remained stable (as determined by superimposition of records and visual inspection) for at least ten consecutive hours.

Two experimental conditions were then imposed, one at a time. 1) Deprivation of food for 72 and 110 hours; 2) Resection of frontal and posterior intrinsic cortex. Food deprivation increases the total rate of response of all animals markedly but does not alter the proportion of responses made during portions of the interval. Resection of the frontal intrinsic sector does not change the total rate of response but does alter the distribution of responses through the interval—there is a marked decrease in the difference between the proportion of responses made during the various portions of the interval. Monkeys with lesions of the posterior intrinsic sectors and unoperated controls show no such changes.

The results of this experiment support the contention that the utility of an outcome of an action is influenced by variables which can be separately classified. Deprivation influences total rate of response; frontal lesion, the distribution of that rate. Deprivation variables are akin to those which have in the past been assigned to influence "desirability," "demand" or "need". The effect of the frontal lesion is more readily encompassed under the heading of those that influence "expectation." This finding is thus in accord with that obtained in the multiple object problem. Both experimental findings can be formally treated by the device of "mathematical expectation." The distribution of response probabilities in the constant interval experiment can be considered a function of the temporal "distance" from the outcome; distribution of response probabilities in the multiple object experiment is a function of the number of objects in the situation. Frontal intrinsic sector lesions interfere with those aspects of preference specified by mathematical expectation—evaluations of the utility of an outcome of an action in terms of a total set of possible outcomes.

The Mediobasal Forebrain and Desirability

From these data, some elements of the neural mechanism that underlies the effect of frontal intrinsic sector resections on preferential behavior can be suggested. A crucial factor in this mechanism is the neural relationship between the frontal intrinsic sector and the mediobasal structures of the forebrain, a factor which may be related to the observation that two classes of variables determine preference. A large body of data has been accumulated in the last twenty years as a result of studies which made use of surgical ablation and electrical stimulation that demonstrates the special relation of the mediobasal systems of the forebrain to the class of variables subsumed under the rubrics "demand," "need," "desirability."

Changes in the following types of behavior are reported: fighting (dominance, reaction to frustration); fleeing (escape and avoidance); feeding (appetitive, such as hoarding, and consummatory); and mating and maternal (nest building and care of the young). Stimulation or ablation which affects one of these behavior patterns is likely also to affect the other (though not necessarily to the same extent). On the other hand, the performance of discrimination tasks remains unaffected.

Typically the damage or stimulation of mediobasal sectors affects preferential behavior by disrupting the more or less orderly recurring sequences of actions which constitute feeding, fighting, fleeing, mating and maternal behavior. None of the elements of the sequence drop out; rather the duration of any one such element of action is altered. The outcome of an action appears, in these damaged animals, to be an ineffective terminant or maintenant of acts in the sequence. Specifically, animals with mediobasal forebrain resections continue feeding long after control subjects (with the same amount of deprivation and in the same situation) have stopped eating. The duration of avoidance behavior is shortened: *e.g.*, a monkey will repeatedly grasp a flaming match even though he is burned each time. A fighting reaction is not maintained. An animal with a mediobasal lesion may draw blood or have a finger bitten off and within a few seconds sit unconcernedly munching peanuts. This effect, as that on avoidance, is especially easy to discern in measures of extinction. Reactions to a "frustration situation" are also altered along this dimension: the intensity of an animal's reaction to frustration is unimpaired, but the duration of the reaction is shorter than that of a control subject. When closely examined, the effects of mediobasal forebrain ablations on hoarding, mating, and maternal behavior are on the duration of a particular element of the sequence, *e.g.*, food or an infant are dropped before the nest is reached, or occasionally, carried to the nest and then taken out again to be dropped elsewhere.

The neural mechanisms whereby the mediobasal affect the outcome determinants of bahavior are only beginning to be detailed. Essentially, the mediobasal forebrain structures are especially related afferently and efferently to medial mesencephalic and diencephalic structures in which are located the slowly adapting receptors surrounding the 3rd and 4th cerebral ventricles (such as the osmo- and temperature-sensitive elements) as well as to the non-specific diffuse systems. The latter are characterized by networks of short, fine-fiber neurones. In such networks synaptic, dendritic and electrotonic phenomena, especially sensitive to neurochemical influences are most likely of greater total significance than are rapidly propagated patterns of neural impulses. In fact, the connections between the mediobasal forebrain and medial mesencephalic and diencephalic structures are so arranged that even when propagated signals are transmitted, the effect on the target site is more often a change in local excitability than the firing of neurones.

VALUES

The empirical relations that determine the value of a piece of currency depend in part on the utility of that piece of currency for any individual. The currency used in the primate neurobehavioral experiments reported here is a food pellet or a peanut. Two interrelated classes of variables have been abstracted by economists to determine utility: expectation and demand; two similar classes (distributive and energic) can be delineated from the experiments reported here—each of the classes related to an independently defined neural mechanism. Another neural mechanism is known whereby values as well as other "environmental" situations can be *discriminated;* this mechanism differs in locus and mechanism from that which subserves "utility" as described here. How an organism's discriminations of values affect his "expectations" remains to be explored. But the day may not be too far off when we know as much about the organismic variables that critically determine behavior with regard to value systems as we now know about the variables that critically determine behavior with regard to the visual field.

ON VALUES IN CROSS-CULTURAL PERSPECTIVE

BY

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Linguists in their elegant analyses of one aspect of culture have found it extremely useful to set up a series of distinctive contrasts or oppositions, usually binary, which serve to identify each separate phoneme (sound class distinctive in that language). There are grounds, both empirical and theoretical, for supposing that a similar approach will yield good results with other aspects of culture, including cultural values. Human nature and the human situation are such that there are some fundamental questions of value upon which all cultures have felt compelled to take a position, explicit or implicit. As in the case of language, the foci or structure-points are largely volving seemingly unimpaired parts of the patient's body. The observations are strikingly parallel to those made on visual functions after lesions of the central visual pathways.

General Changes

In addition, there are general (nonlocalizable) deficits, revealed by a series of complex tactual tasks. These tasks were constructed to represent logical, if not perceptual, analogues of various visual complex tests (sorting tests and their variants). Impairment on these complex tasks was found for all groups of men with brain injury, irrespective of the particular location of their lesion.

Disturbances in somesthesis, just as those in vision, thus range from deficits that are most specific and circumscribed to those that are neither; which kind of symptom appears depends entirely on the tasks employed. Beyond this, the studies in vision and somesthesis have permitted us to explore the nature of altered performance. In most forms of aphasia, we found undoubted signs of nonverbal impairment (cf. the hidden-figure task). In some conditions which used to be labelled "agnosia," (e.g., astereognosis), we encountered a curious association of higher with primary sensory changes. Since classical definitions of agnosia require selective loss of higher (gnostic) functions, it might be better to analyze perceptual alterations without reliance on this or similar clinical terms. It is through such continued analyses of performance, in the presence of brain injury, that we hope to come closer to an understanding of the neural bases of perception.

THE NEUROLOGY OF PERCEPTION

BY

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Procedure

A complex discrimination problem is given to twelve rhesus monkeys for solution. These animals are divided into three groups of four subjects each. One group has been given a bilateral cortical resection in the posterior, another in the anterior intrinsic (association) cortex; the third serves as an unoperated control group. The problem consists of eleven situations: in each situation the monkeys must discriminate among a certain number of junk objects randomly placed over twelve holes in a board. The situations are arranged serially to contain from two to twelve cues. In each situation each of the objects is in turn placed over a peanut; one response is permitted per trial and when a monkey has obtained the peanut in five consecutive trials the peanut is shifted to one of the other cues. This procedure is repeated until each of the cues in the situation has in turn been the rewarded one.

RESULTS

Formal analysis of the results shows that solution of the problem is facilitated when the monkeys attain two strategies: 1) searching each of the objects presented and 2) returning to the rewarded object after finding the peanut (until the reward is shifted from that object). These strategies are shown to be dependent on 1) the capacity of the organism to sample widely—perceptual awareness and 2) the capacity of the organism to utilize the outcome of his actions—evaluation.

Monkeys with resections in the *posterior* intrinsic system (when compared with control and frontal operate groups) show a lag in extensive sampling of the objects. The resulting performance curve suggests that the role of the posterior intrinsic systems is to provide the animal with a mechanism for determining the informational content of an observed array.

Monkeys with resections of the *frontal* cortex (when compared with control and posteriorly operated groups) show a lag in utilizing the outcome of their actions. During the period of lag the utility of the outcome (as these terms are used in the theory of games and economic behavior) has a linear relation to the number of objects in the situation. This suggests that the role of the frontal cortex is to provide the animal with a mechanism for computing the relative expectations of desirability of the outcome of his actions.

CONCLUSIONS

These results indicate that lesions of the intrinsic (association) areas of the primate cerebral cortex impair the ability to attain strategies necessary to the solution of complex problems. Resections in the posterior intrinsic cortex interfere with perceptual awareness: i.e. such lesions limit the information which an observable array conveys to the animal. Lesions of the frontal cortex interfere with evaluation of the utility of the outcome of his actions: i.e. such lesions limit the expectations which the relative desirability of outcome to the animal.