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RESPONSE OF RHESUS MONKEYS TO PROBABILISTIC SEQUENTIAL DEPENDEN--ETC(U)
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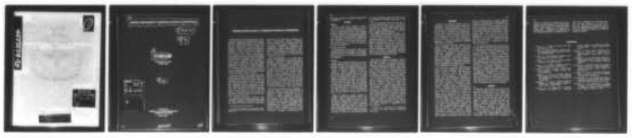

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RESPONSE OF RHESUS MONKEYS TO PROBABILISTIC SEQUENTIAL DEPENDENCIES,

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RESPONSE OF RHESUS MONKEYS TO PROBABILISTIC SEQUENTIAL DEPENDENCIES

Psychologists are becoming interested in the response of organisms to probabilistic stimulus situations. Tolman and Brunswik (13) recognized that the relationship between stimulus cues, behavior, and outcomes is seldom certain. The organism is forced to respond on the basis of hypotheses which depend upon probabilistic relationships between events. The advent of decision theory (1, 4, 14) has provided another great impetus to study of the role of probability in determination of behavior. The S is assumed to behave in a completely rational manner, to weigh various alternatives and, other things being equal, to choose the one with the greatest probability of resulting in a desired outcome. More recently, the stochastic models for learning (2, 3, 5, 6) have been developed to account for several of the major facts of probability learning in terms of stimulus-response concepts.

Although both theory and research have dealt largely with stimulus probabilities defined by the proportions of alternative events which are randomized within blocks of trials or over the entire stimulus sequence, it must be recognized that contingencies between consecutive events also determine stimulus probabilities on specific trials. Stimulus events may be distributed within a given sequence in such a way that half are E_1 and half are E_2, but this does not mean that E_1 will necessarily occur with a probability of .50 on each trial.

A *probability hyper-space* should be conceptualized in which stimulus proportions within the entire sequence, or population from which the sequence is drawn, determine a single dimension – that is, the "first-order" probability continuum. Relationships between consecutive events determine a second dimension which may be called "second-order" probabilities. Still "higher-order" probabilities, dependent upon contingencies between nonconsecutive events, form other dimensions of the *probability hyper-space*. Every probabilistic stimulus sequence can be defined in terms of its location in the *probability hyper-space*.

Many experiments (8, 9, 11, 12) have demonstrated that probabilities of response tend to approach "first-order" stimulus probabilities for both rats and human Ss. Hake and Hyman (10) and Goodnow and Pettigrew (7) confirmed the fact that this "probability matching" behavior in human Ss is not independent of "higher-order" stimulus probabilities. For example, stimulus sequences were constructed by the Markov process so that half of the events were E_1 and half were E_2; however, if E_1 occurred, the probability of E_1 occurring again on the next trial was .80, and if E_2 occurred, then E_2 was repeated with a probability of .80 on the next trial. The strategies employed were found to be sensitive to sequential dependencies in the stimulus chain.

The present experiment was undertaken to determine whether the probability learning of sophisticated rhesus monkeys depends on contingencies between consecutive events or whether it is solely a function of "first-order" probabilities. If the results of the present monkey experiment agree with findings for human Ss in indicating the importance of "higher-order" probabilities for response determination, then conceptualization of the probabilistic stimulus situation should encompass the entire *probability hyper-space*, rather than simply the single "first-order" continuum. A multivariate, not a

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univariate, approach to probability learning will be indicated.

METHOD

Subjects

Forty-nine male rhesus monkeys, about 4 years old, were Ss in this experiment. All monkeys had extensive laboratory experience on a variety of discrimination tasks in the apparatus employed. Thirty-one of the Ss had been exposed to low-level, chronic, mixed gamma-neutron radiation about three years earlier; the remaining 18 were nonirradiated. The Ss were housed in separate cages in air-conditioned living quarters and were fed about 4 p.m., after all testing for the day was completed.

Apparatus and stimuli

A modification of the Wisconsin General Test Apparatus (WGTA) was employed. A retractable, two-well tray with two identical, black stimulus blocks (4 by 4 by ½ in.) was used throughout the experiment.

Procedure

The Ss were randomly divided into two experimental groups of 24 and 25 animals. The proportions of normal and irradiated monkeys were matched as nearly as possible between groups.

Group I received a stimulus sequence involving a "positive contingency" between consecutive events. Reward was placed under the left and right stimulus objects on an equal number of trials each day; however, a positive sequential dependency resulted in consecutive events being more often alike than different. If reward were presented under the right-hand stimulus object on trial n, then the probability was .67 that the right-hand stimulus would again be rewarded on trial n + 1. If the left-hand stimulus were rewarded on trial n, the probability was .67 that it would be rewarded again on trial n + 1.

Group II received a stimulus sequence involving a "negative contingency" between consecutive events. Reward was placed at each alternative an equal number of times, as it was for group I; however, the negative sequential dependency resulted in consecutive events being more often unlike than alike. If reward were placed under the right-hand stimulus on trial n, then the probability of its being located there on trial n + 1 was .33. If the left-hand alternative were rewarded on trial n, then there was a 33 probability of repeating that event on trial n + 1.

Each S was presented with 41 trials a day for only two consecutive days. Thus, if differences in response to the two stimulus sequences are observed, the readiness with which "higher-order" stimulus probabilities are discriminated by the monkeys should be apparent.

The number of alternations in response (left to right and right to left) were counted for each S, as were the total number of choices of the right-hand alternative by each S. The number of choices of the position reinforced on the immediately preceding trial was also recorded for each S. Even if "higher-order" probabilities affect the behavior of rhesus monkeys, a minimum of experience with the stimulus sequence should be necessary; consequently, data from only the second day of training were considered in the statistical treatment of results.

RESULTS

The stimulus sequence involving a positive contingency contained 13 alternations between right and left, while the negative-contingency sequence contained 27 alternations. The number of response alternations differed significantly at the .025 level for Ss of the two groups. Subjects of group I (positive contingency) made an average of 20.8 alternations and those of group II (negative contingency) made an average of 25 alternations during the second day of training.

In the positive-contingency sequence, consecutive events were more likely to be similar than to be different; while in the negative-contingency sequence, consecutive events were more likely to be different than similar. This "second-order" probability influenced the behavior of the Ss. Subjects of group I (positive contingency) responded to the position rewarded most recently and avoided the position nonreinforced most recently on an average of 71 percent of the trials. Subjects of group II (negative contingency) responded to the most recently rewarded position on an average of 63.4 percent of the trials. This difference in response to the two Markov sequences is significant beyond the .025 level.

Comparison of irradiated and nonirradiated Ss within each group yielded no significant differences.

DISCUSSION

Theorists on probability learning and decision-making have directed their attention to "first-order" stimulus probabilities. The sole specification of the probabilistic stimulus situation has almost invariably been the proportions of each kind of event randomized within blocks of trials. Thus, Jarvik (12) employed three stimulus probabilities which were identified as 50-50, 67-33, and 75-25, indicating the relative proportions of stimulus alternatives randomized within blocks of 10 trials.

The two stimulus sequences employed in the present experiment were alike in that each contained a 50-50 proportioning of alternative stimulus events. With attention restricted to "first-order" probabilities, it should be predicted that "probability of response will approach the probability of stimulus events as a limit." Moreover, the results of the experiment, although not definitive with respect to asymptotic level, indicate no significant differences between probabilities of response and the "first-order" probabilities of stimulus events.

Use of the term "first-order" probability may appear somewhat inappropriate since a Markov sequence fails to maintain independence between consecutive events. The probability learning theorist would, no doubt, prefer to restrict his investigations to situations involving "first-order" probabilities with complete independence between events. Several objections may be leveled at this attitude, however. To restrict attention to "first-order" probabilities, assuming complete randomization of events, is to restrict the field of investigation in a very artificial manner. It has been suggested that *every* probabilistic stimulus sequence can be characterized as located in a multidimensional hyper-space. The "first-order" continuum (100-0, 75-25, 67-33, 50-50, 33-67, 25-75, and 0-100) with complete randomization as far as "higher-order" components are concerned represents a single vector in this conceptual space. Nonexperimental situations, to which the psychologist should ultimately generalize his findings, seldom involve complete independence between successive events; hence, they are seldom located on the idealized single vector in *probability hyper-space.* Even more important at the present time, the probabilistic stimulus sequences actually employed in almost all learning and decision-making experiments cannot properly be conceived to fall on the "first-order" vector determined by complete independence between successive events. If events are randomized within blocks of trials, "second-order" and still "higher-order" probabilities which *differ* from the "first-order" probabilities are necessarily built into the sequence. Even if events are randomized within the entire experiment, or indeed within any *finite* number of trials, "higher-order" probabilities are affected.

It has been demonstrated by other investigators (7, 10) that the responses of human Ss in a probabilistic stimulus situation are affected by "higher-order" stimulus probabilities. The present experiment extended this finding to sophisticated rhesus monkeys. Even albino rats have been found to learn alternation patterns ("second-order" contingencies) in stimulus sequences (15). In light of these findings, it becomes imperative for the probability learning theorist to do one of two things: either restrict his inquiry to situations involving *complete* absence of "higher-order" probabilities which differ from the stated "first-order" probabilities, or enlarge his conceptualization of the probability-stimulus to behavior to encompass the several dimensions of *probability hyper-space* which have been found to affect response selection. Since the former is very difficult to accomplish and places a severe restriction upon the area of investigation, the latter is suggested.

SUMMARY

Forty-nine rhesus monkeys were divided into two treatment groups of 24 and 25 animals. Two identical stimulus objects were presented at each trial in a Wisconsin General Test Apparatus with reward presented for an equal number of trials on the left and right sides. For one group, the sequence of reward placements contained a positive contingency; for the other group, it contained a negative contingency. The distribution of responses for sophisticated rhesus monkeys was found to depend on the statistical structure of the stimulus sequence.

It is recognized that *all* sequences of stimulus events may be characterized in terms of "first-order" and "higher-order" probabilities.

Because the behavior of monkeys in this experiment, like that of human Ss in other investigations, has been found to be readily affected by rather slight differences in "higher-order" probabilities, an adequate conceptualization of the probability-stimulus for learning must include these components. A *probability hyperspace* in which "first-order," "second-order," and other "higher-order" probabilities can be located on independent dimensions is suggested for a more adequate description of the effective probability-stimulus.

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