Patterns of event runs in probability learning¹

MARI R. JONES and JAMES R. ERICKSON, *The Ohio State University, Columbus, Ohio 43210*

Forty-eight Ss were assigned to a 2 by 2 factorial design with two levels of risk (1¢ and .1¢) and two levels of sequence (patterned-run distribution and random-run distribution) in a two-choice probability learning task. All Ss received 300 trials. Conditional predictions were not affected by differences in risk. A significant effect of the sequence variable was found in responding conditional on runs of the less frequent event, but not in responding conditional on runs of the more frequent event. It was concluded that Ss respond to certain higher order regularities in the event-run structures.

Recent studies in probability-learning have suggested that in two-choice tasks, Ss respond primarily to runs of the reinforcing events (Gambino & Myers, 1967; Restle, 1966). Gambino and Myers have hypothesized that in situations characterized by an absence of single alternation patterns, the probability of repetition responding after runs of different lengths may be described by a linear conditioning model that assumes responses learned to run cues generalize along the run length continuum. One implication of the model that has received some support is that repetition responding is a function primarily of the distributional properties of run lengths in a particular sequence (Gambino & Myers, 1966).

One purpose of the present research was to further test the hypothesis that event runs constitute the primary discriminative cues in sequential tasks. According to this assumption, higher order contingencies such as run patterns should contribute little additional information that an S may use in prediction. In the present study two groups of Ss were presented with sequences having identical run length distributions but differing with respect to the particular arrangement of the event runs. Specifically both sequences contained runs of Lengths 1 through 4, the runs being randomly arranged for one group of Ss (R) and systematically patterned for the second group (P).

A second purpose of this research was to gather more information about the ways Ss respond to runs of events when the two reinforcing events have unequal frequencies of occurrence. A majority of current research has limited itself to situations in which the events occur equally often and have identical run structures. The unequal run structure situation has

the advantage of offering a test of the contention that failures of the conditioning model (Gambino & Myers, 1967) to handle sequences having runs of Length 1 is the result of patterns of single alternations. In the present study, only the less frequent (E_2) event occurred in runs of one and two, and since these were separated by either three or four E_1 s no single alternation patterns occurred.

A final question was asked: Would monetary gain and loss contingent on correct and incorrect predictions, respectively, affect conditional responding? Previous studies (Lipkin, Schnorr, Suydam, & Myers, 1965; Schnorr, Lipkin, & Myers, 1966) have shown that differences in non-zero amounts of risk are negligible when risk is varied as a between-S variable. However, these studies used completely random event sequences. It is possible that between Ss incentive differences are demonstrable only in tasks with relatively clearly defined or learnable strategies. For this reason, two levels of non-zero monetary risk were examined.

METHOD

Subjects

The Ss were 48 undergraduate females fulfilling a requirement in Introductory Psychology at The Ohio State University.

Design

Two levels of each of the two independent variables, sequence and risk, were combined factorially in a 2 by 2 design. Twelve Ss were randomly assigned to each of the four conditions.

High-risk groups received 1¢ for correct predictions and lost 1¢ for incorrect predictions. Similarly, low-risk groups won or lost .1¢.

The two sequence conditions were identical in all respects save higher order run contingencies. Sequences in both the P and R conditions contained E_1 runs of Lengths 3 and 4, and E_2 runs of Lengths 1 and 2. The two conditions differed in that event runs for the P condition occurred in a predetermined order for every 20 trials, while the order of event runs in the R condition was randomly determined within each 20-trial block. The order of runs for the P condition was as follows: $4E_1$ s, $2E_2$ s, $3E_1$ s, $1E_2$, $3E_1$ s, $2E_2$ s, $4E_1$ s, and $1E_2$. In this sequence the probability of an E_1 after either $1E_2$ or $3E_1$ s (critical points) was .50 but its occurrence was completely determined by the preceding pattern of event runs.

Procedure

Ss were run individually in a soundproof booth equipped with a standard probability learning panel containing two red reinforcement lights and two response keys. In addition, risk level lights and nixi counters were mounted at either side of the panel.

The sequences of reinforcing lights were preprogrammed on paper tape; responses and event outcomes were automatically recorded on paper tape. Programming and recording equipment were located outside the experimental booth.

Ss were instructed to predict which of two lights would come on during each of 300 self-paced trials. After each prediction S received feedback by the onset of the appropriate event light and the automatic tabulation of a corresponding gain or loss.

RESULTS

Both the probability of an A_1 response after kE_i events and the accuracy of responding at critical points in the sequences were used as measures of conditional responding. Table 1 presents A_1 conditional and marginal probability scores for the four conditions. Analyses of variance on run statistics showed that neither risk nor sequence variables affected predictions conditional on runs of the more frequent event. However, after E_2 runs of Lengths 1 and 2, A_1 responses were significantly higher asymptotically for Ss in the P conditions ($F = 7.66$, $df = 1/44$, $p < .01$). These data are presented in Fig. 1 where the statistic, $P(A_1/0E_1)$, is pooled over risk levels to indicate conditional responding after E_2 runs for the sequence conditions. The increased frequency of A_1 predictions in the P conditions could reasonably be attributed to greater accuracy of Ss in this condition since the probability of a correct response

Table 1
Marginal and Conditional A_1 Probabilities for the Four Sequence-Risk Conditions in the Last 100 Trials

Asymptotic Value	P Conditions		R Conditions	
	1c	.1c	1c	.1c
$P(A_1)$	.71	.70	.66	.70
$P(A_{1,n}/0E_1)$	.75	.77	.63	.60
$P(A_{1,n}/1E_1)$	.95	.95	.93	.97
$P(A_{1,n}/2E_1)$	.96	.93	.89	.94
$P(A_{1,n}/3E_1)$	.64	.61	.62	.74
$P(A_{1,n}/4E_1)$	.38	.31	.27	.29
$P(A_{1,n}/0E_2)$	.48	.41	.46	.50
$P(A_{1,n}/1E_2)$	.39	.36	.32	.29
$P(A_{1,n}/2E_2)$	.90	.91	.60	.85
$P(A_{1,n}/A_{1,n-1}E_{1,n-1})$	.78	.77	.78	.81
$P(A_{1,n}/A_{2,n-1}E_{1,n-1})$	.69	.68	.61	.74
$P(A_{1,n}/A_{1,n-1}E_{2,n-1})$	.54	.56	.64	.52
$P(A_{1,n}/A_{2,n-1}E_{2,n-1})$	.61	.59	.43	.48

Fig. 1. The probability of an A_1 response given E_2 runs of Lengths 1 and 2 as a function of sequence over blocks of 50 trials.

after runs of one and two E_2 s was significantly higher asymptotically ($p = .77$) for these Ss ($F = 7.66$, $df = 1/44$, $p < .01$) than for Ss predicting random run structures ($p = .62$).

The fact that A_1 responding after three E_1 events or one E_2 event [i.e., $P(A_1/3E_1)$ and $P(A_1/1E_2)$], showed no significant effects of sequence is not surprising since an A_1 response was correct half of the time at these critical points in both sequence conditions. A statistic more sensitive to possible effects of preceding run cues is the conditional accuracy of a response at each of the two critical points. Ss in the P conditions were found to be significantly more accurate after a single E_2 event ($F = 6.04$, $df = 1/44$, $p < .025$), but not after three successive E_1 s.

The probabilities of an A_1 response after E_2 events, $P(A_1/E_2)$, and after E_1 events, $P(A_1/E_1)$, were consistent with the above findings. A significant sequence effect characterized $P(A_1/E_2)$ asymptotically ($F = 4.34$, $df = 1/44$, $p < .05$), while $P(A_1/E_1)$ was not similarly affected.

First order conditional response probabilities, $P(A_1/A_1E_j)$, are also presented in Table 1. The rank order of these statistics in the R groups conformed to predictions of traditional probability theory (e.g., Atkinson & Estes, 1963) with $P(A_1/A_1E_1)$ being the highest score and $P(A_1/A_2E_2)$ being the lowest. Similar rank ordering was not found for statistics in the P conditions where $P(A_1/A_2E_2)$ exceeded $P(A_1/A_1E_2)$. The $P(A_1/A_2E_2)$ was the only first order conditional statistic to be significantly affected by the sequence variable ($F = 4.99$, $df = 1/44$, $p < .05$). A significant Risk by Sequence interaction was found in the $P(A_1/A_2E_1)$ statistic ($F = 4.87$, $df = 1/44$, $p < .05$) with Ss in the .1¢ R conditions exceeding Ss in the .1¢ R conditions in A_1 predictions.

DISCUSSION

The fact that Ss in the P conditions did not significantly differ from Ss predicting randomly ordered runs in their A_1 predictions after E_1 runs

lends some support to the Gambino-Myers contention that Ss rely primarily on run cues. The data are not unequivocal in their support, however. The superiority of the P groups after E_2 events suggests that the inadequacy of the conditioning model with sequences containing runs of Length 1 may not be merely the result of patterns of single alternations.

In general, the results indicate that the conditioning model must be revised to include the effects of certain higher-order contingencies on prediction behavior. Ss seem to be sensitive to particular higher-order regularities in the run structures of the separate events. The E_2 run distribution in the P groups was characterized by single alternation of run lengths (i.e., $2E_2$ s, $1E_2$, $2E_2$ s, $1E_2$, etc.) regardless of the length of the intervening E_1 run. The E_1 run structure was a double alternation in run lengths (i.e., $3E_1$ s, $3E_1$ s, $4E_1$ s, $4E_1$ s, etc.). The responsiveness of Ss in P conditions to the E_2 and not the E_1 regularities may be the result of Ss' increased attentiveness immediately following the cessation of a long repetition of E_1 events. Thus Ss would be less susceptible to errors such as miscounts at these points and so better equipped to detect the regularities in the E_2 sequence. Some support for the latter hypothesis derives from the finding of Rose & Vitz (1966) that Ss are more accurate following long runs of an event. This interpretation, while incompatible with a simple conditioning approach, does permit limited predictions of the relative difficulty of different run distributions.

In many respects, responding to sequences with unequal event run structures did not differ greatly from behavior reported with equal-event structures (Gambino & Myers, 1966; Restle, 1966). Both sequence conditions produced marginal matching of the E_1 event frequency, as might be expected. In the R groups, conditional responding to event runs decreased in accuracy at points of certainty as a given run progressed (see Table 1). There is some evidence of a similar trend in the P groups' data. Neither group attained perfect accuracy at these points. At the critical points, Ss in both conditions tended to predict more E_1 runs of Length 4 and more E_2 runs of 2 than actually occurred; repetition responding was roughly equivalent in frequency at the two critical points in both sequence conditions.

Risk primarily served to inflate the probability of predicting an E_1 after the loss of .1¢ on an incorrect A_2 prediction. Accuracy conditionals did not indicate that the Sequence by Risk interaction in this case was the result of increased accuracy on the part of Ss in the .1¢ R condition. The facilitation of a lose-shift strategy by low incentive has not been reported in studies in which the two events were completely randomized (Schnorr, Lipkin, & Myers, 1966), and is difficult to explain in the present context.

REFERENCES

- ATKINSON, R. C., & ESTES, W. K. Stimulus sampling theory. In R. D. Luce, R. R. Bush, & E. Galanter (Eds.), *Handbook of mathematical psychology*. Vol. 2. New York: Wiley, 1963. Pp. 121-268.
- GAMBINO, B., & MYERS, J. L. The effect of mean and variability of event run length on two-choice learning. *Journal of Experimental Psychology*, 1966, 72, 904-908.
- GAMBINO, B., & MYERS, J. L. The role of event runs in probability learning. *Psychological Review*, 1967, 74, 410-419.
- LIPKIN, S. G., SCHNORR, J. A., SUYDAM, M., & MYERS, J. L. Effects of risk as a within-subject variable in probability learning. *Psychonomic Science*, 1965, 2, 145-146.
- RESTLE, F. Run structure and probability learning: Disproof of Restle's model. *Journal of Experimental Psychology*, 1966, 72, 383-389.
- ROSE, R. M., & VITZ, P. C. The role of runs in probability learning. *Journal of Experimental Psychology*, 1966, 72, 751-760.
- SCHNORR, J. A., LIPKIN, S. G., & MYERS, J. L. Level of risk in probability learning: Within- and between-subjects designs. *Journal of Experimental Psychology*, 1966, 72, 497-500.

NOTE

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