Nonstationary probability processes, event runs, and the development of patterned response habits[1]

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A nonstationary probability process, which included variable runs of homogeneous events, was employed to examine patterning behavior in the uncertain-outcome/binary-decision task. The results showed that specific types of response patterns occurred which appeared to support an assumption that choice behavior was directed by discrete trial reinforcement effects. Further analyses demonstrated that the results were most accurately described by the formation of concepts leading to specific types of response patterning effects.

Anderson (1964) has emphasized the importance of the sequential structure of event outcomes in uncertain outcome prediction tasks. Research concerned with this event structure shows that specific types of response strategies, which are manifested in stable response patterns, often develop as a function of the reinforcement structure (e.g., Derks, 1963; Restle, 1966). Halpern, Lantz, & Schwartz (1969) have shown that event outcomes serve as discriminative cues and that they appear to be as robust as more traditional discriminative stimuli (e.g., auditory cues). It appears likely that a wide range of "patterned" responding can be obtained if the appropriate event structure is employed. Further, random sequences will likely contain such discriminative substructures (run cues) which will influence choice behavior.

The present experiment represents a further attempt to define the role of the reinforcing event in choice behavior. A binary-choice decision task with nonstationary probability processes was employed. Such nonstationary processes involve situations where relative event frequencies change over trials. Similar procedures have been employed to evaluate theoretical models of choice behavior (Friedman, Burke, Cole, Keller, Millward, & Estes, 1964). Anderson (1964) has suggested that nonstationary processes will result in marked discriminative contingencies across events. Further, if long runs of homogeneous events were involved, these would tend to induce response perseveration.

A procedure similar to that employed by Halpern et al (1969) was used in order to assess the strength and degree of patterning behavior induced by nonstationary probability processes that included short and long runs of homogeneous events. Further, clear discriminative cues in the form of auditory stimuli were present so as to assess the relative power of the run cue.

SUBJECTS

The Ss were 90 University of Denver undergraduate volunteers, randomly assigned to three groups of 30.

APPARATUS

Up to four Ss were run at a time. The apparatus was similar to that used by Halpern et al (1969). Each S was seated before a board consisting of a white warning light, two red event lights, and two spring-loaded switches. Audio stimuli were generated by an audio oscillator and modulated by two attenuators. Tones were presented over calibrated headphones. Experimental events were recorded on a strip chart digital recorder. Event and tone sequences were controlled by a micrologic module and a continuous white noise of 60 dB SPL was fed through the headphones.

PROCEDURE

Previous research (Halpern et al, 1969) established that tones of 65 and 61 dB SPL, when evaluated with respect to a comparison stimulus of 70 dB SPL, would result in proportions of responses of "different" equal to .71 and .99, respectively. Therefore, comparison stimuli of 70, 65, and 61 dB SPL defined situations of high, medium, and low stimulus similarity, respectively. All tones were presented at 800 Hz.

Each trial was initiated by one of two tones. The tones and the events were correlated. Thus, the occurrence of either tone would signal, with a greater-than-chance probability, the occurrence of one of the two events. The probability of an E_1 given either tone (T_i), $P(E_1 \mid T_i)$, varied randomly over a continuous interval from .60 to .80 in blocks of 30 trials. Thus, each S experienced 13 blocks of trials where $P(E_1 \mid T_1)$ and $P(E_1 \mid T_2)$ would be different within a block and each would vary independently across blocks. The overall $P(E_1)$ on any given block of trials was varied randomly and the maximum difference between $P(E_1 \mid T_1)$ and $P(E_1 \mid T_2)$ was .20 so that the former could equal .60 and the latter equal .80, and vice versa. The minimum difference between the two was .05. Since each S received a total of 390 trials, there were 195 trials with each tone. The relatively large N in each group served to insure a representative sample of the range of $P(E_1 \mid T_i)$, and the sequence of tones and events was different for each experimental session. The sequences were structured so that the shortest runs of homogeneous events tended to occur with the lowest $P(E_1 \mid T_i)$ and the longest runs with the highest probabilities. The size of the run could vary from four to nine with the probability of a run of four or more homogeneous events equal to .09 during a .60-trial block and to .69 on trial blocks where $P(E_1 \mid T_i) = .80$.

Each trial consisted of the presentation of one of two tones for .5 sec, a warning signal light occurring 1.7 sec after the onset of the tone, and a reinforcing light occurring 1.7 sec after the onset of the warning signal, its duration being 1.6 sec. Total time per trial was a constant 5 sec with a constant 3-sec intertrial interval. The Ss were instructed to respond after the onset of the warning signal and to make as many correct responses as possible. Reference to the discriminative aspects of the task were avoided. The position of the more frequently reinforced response alternatives was varied randomly across all Ss, and the more frequent event was always designated as A_1.

RESULTS AND DISCUSSION

Preliminary analyses showed that choice behavior, after approximately the first 100 trials, was virtually identical for all conditions of tonal cue similarity. The tones, then, were largely ignored after some initial experience. This was likely due to the constantly shifting reinforcement contingencies associated with the tones. Consequently, Table 1 gives the response probabilities conditional only on the

Table 1
First Order Conditional Probabilities for All Ss for the Last 210 Trials*

	Probability	
$P(A_{1,n} \mid A_{1,n-1}E_{1,n-1})$	.95	(11,546)
$P(A_{1,n} \mid A_{2,n-1}E_{1,n-1})$	.93	(1,162)
$P(A_{1,n} \mid A_{1,n-1}E_{2,n-1})$	.09	(1,243)
$P(A_{1,n} \mid A_{2,n-1}E_{2,n-1})$	.05	(4,859)

* *Values in parentheses are frequencies summed across A_1 and A_2 responses.*

Table 2
$P(A_{1,n})$ as a Function of the Events on Trials n−1 and n−2

	Probability	
$P(A_{1,n}E_{1,n-1}E_{1,n-2})$	.98	(10,324)
$P(A_{1,n}E_{1,n-1}E_{2,n-2})$	.97	(2,194)
$P(A_{1,n}E_{2,n-1}E_{1,n-2})$	.07	(1.926)
$P(A_{1,n}E_{2,n-1}E_{2,n-2})$	.01	(4,276)

Table 3
Response Perseveration and Alternation as a Function of the Preceding Run of Homogeneous Events

	m=2	3	4	5	6	7	8	9
$P(A_{i,n} \mid A_{j,n-1}E_{i,n-1}E_{j,n \to m})$*	.94	.92	.96	.97	.94	.93	.94	.96
$P(A_{i,n} \mid A_{j,n-1}E_{j,n-1}E_{j,n \to m})$	.04	.03	.01	.03	.05	.04	.07	.03

* *The notation "$n \to m$" refers to $n-2$ for $m = 2$, $n-2$, and $n-3$, for $m = 3$, etc.*

response and event of the preceding trial. These first-order conditional response probabilities are based on data generated by all 90 Ss for the last 210 trials. The data showed that whatever learning occurred did so relatively rapidly, and that choice behavior was clearly stable over the final 210 trials.

The first order conditional response probabilities in Table 1 provide some support for a stimulus sampling theory. The theory predicts $P(A_{1,n} \mid A_{1,n-1}E_{1,n-1})$ to be greater than either $P(A_{1,n} \mid A_{2,n-1}E_{1,n-1})$ or $P(A_{1,n} \mid A_{1,n-1}E_{2,n-1})$ and that the latter conditionals be greater than $P(A_{1,n} \mid A_{2,n-1}E_{2,n-1})$. Further, the reinforcement effect appears rather marked in that $P(A_{1,n})$ was a good deal larger subsequent to $E_{1,n-1}$ than after $E_{2,n-1}$.

Table 2 gives the $P(A_{1,n})$ conditional only on the events of the two preceding trials. Again, response probability is seen to be heavily influenced by the event but the influence appears to be limited only to the preceding trial. The table exhibits an almost classic form of a one-trial dependent positive recency effect. Tables 1 and 2 demonstrate the virtual absence of any negative recency. Interpretation of these data is difficult because of the problem in separating negative recency from response alternation, and positive recency from response perseveration. The recency phenomena refer to response tendencies under the apparent control of discrete events, while alternation and perseveration are presumably reflections of response patterns induced by the event structure. One method of determining whether the present data are best characterized in terms of recency phenomenon or the result of some patterned response process, is to categorize response probabilities as a function of runs of homogeneous events. Such a categorization is provided in Table 3. The first expression in the table gives the probability of a response shift (response alternation) subsequent to an event shift as a function of the run of preceding homogeneous events. The entries show large and consistent response shifts with event shifts on the preceding trial. The behavior appears to be largely independent of the size of the run. If events were operating in some discrete manner as "reinforcements," then one would expect some consistent increase in $P(A_{i,n})$ with increased run length. The second expression in Table 3 shows the probabilities of response shifts, in the absence of preceding event shifts, to be uniformly low.

Table 3, then, shows certain regularities in response patterns which provide support for an assumption that choice behavior was most heavily influenced by the sequential structure of the event outcome. That is, Ss followed runs, and this run-following resulted in a specific type of response pattern that included response perseveration along with a one-trial event dependence. It would be misleading to conclude that the event outcome served as a reinforcer. A more accurate description might involve some concept-formation notion. The specific concept would include the assumption of an expectancy of a run, and the occurrence of the run would result in reinforcement of the expectancy. In this case, the specific concept could be described in terms of response perseveration and a one-trial event dependence.

If one conceives of the typical probability learning situation as an ambiguous task where Ss are actively engaged in a search for discriminative cues, then the situation is made even more ambiguous by nonstationary probabilities. The resultant nonindependent event contingencies inherent in any departure from the random 50:50 schedule provide the S with an apparent discriminative cue. The rapidity with which the tonal cue was disregarded here is an indicant of the inherent attractiveness of the run cue. Similar auditory stimuli have been shown to be most effective discriminative cues in probability learning tasks that have used stationary processes (e.g., Halpern & Moore, 1967).

The results demonstrate the potent effects of the event structure as opposed to the singular effects of the events. A clear suggestion is that events do not function as reinforcers in the traditional sense but rather that they aid in the development of a concept or expectancy which can result in very specific response patterns. Further, theoretical models of choice behavior such as those proposed by Restle (1966) and Gambino & Myers (1967), that emphasize the importance of the run structure, would appear to show more potential than the more traditional models which emphasize the reinforcing properties of discrete events.

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NOTE

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