

**JUDGMENTS OF THE RELATIVE FREQUENCY  
OF TWO RANDOM SEQUENTIAL EVENTS:  
EFFECTS OF RATE OF PRESENTATION**

*Dwight E. Erlick*

*Behavioral Sciences Laboratory  
Aerospace Medical Laboratory*

*James Palmore, Jr.  
Antioch College*

*MARCH 1961*

Project 6190  
Task 71556

WRIGHT AIR DEVELOPMENT DIVISION  
AIR RESEARCH AND DEVELOPMENT COMMAND  
UNITED STATES AIR FORCE  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

1,100 - May 1961 - 27-1,002

# *Contrails*

## FOREWORD

This study was initiated by the Engineering Psychology Branch, Behavioral Sciences Laboratory, Aerospace Medical Laboratory of the Wright Air Development Division, under Project 7183, "Psychological Research on Human Performance," Task 71617, "Fundamental Parameters in Perception." This investigation was carried out at the Engineering Psychology Research Project of Antioch College, Yellow Springs, Ohio, under Contract AF33(616)-6095.

The effect of presentation rate on a man's ability to determine which of two mutually exclusive random sequential events has occurred more frequently was investigated using rates of one, two, four and eight events per second. Two specific studies were carried out using the same relative differential frequencies between the events but varying the absolute number of events in the total series. The results indicate that the accuracy of perceiving the more frequent event decreases as the presentation rate of the events increases. The effect of rate also acted differently for a short and long series of events; as presentation rate increased, a short series of events showed a significantly steeper decline in accuracy than a long series of events.

PUBLICATION REVIEW

*Walter F. Grether*

WALTER F. GRETHER  
Technical Director  
Behavioral Sciences Laboratory  
Aerospace Medical Laboratory

# *Contrails*

Two earlier studies (ref. 1, 2) showed that the ability to perceive which of two mutually exclusive random sequential events has occurred more frequently is influenced by the difference between the relative frequencies of the events, the actual duration of observation of the sequential series, as well as the subjects' knowledge of duration of the observation time.

The present investigation was designed to determine man's ability to perceive which of two mutually exclusive random sequential events has occurred more frequently as a function of the rate at which the events are presented.

If a mechanical or electronic sensor could be made which would differentiate events reliably, the simultaneous counting and tallying of them would be fairly low order functions for automation. However, since many elements of situations are highly unstructured or difficult to codify, they will have to be tallied by man for sometime to come. When the number of unique events is small - say two or three - and the rate at which they occur is quite slow - of the order of one occurrence every few seconds - a man might do a fairly accurate tallying job. However, if the rate of occurrence of the different events is too fast to be tallied after each occurrence, then one would have to rely on man's perceptual judgment as to which event had occurred more frequently. This type of perceptual task is quite essential in establishing priority based on frequency of occurrence, and is analogous to that required from the observer in a reconnaissance mission seeking to determine the relative occurrence of two distinct types of targets that have been observed in a random fashion. It would have greatest similarity to situations in which the rate of occurrence of the events was too fast to be individually tallied by the observer. Another analogous situation would be one in which the relative frequency of occurrence of two events is shifted from time to time with the observer trying to detect this shift as soon as possible. Changing schedules of partial reinforcement might be one example, or attempting to perceive the "payoff" odds in a risk situation in which the odds continually change might be another example.

It was hypothesized that as presentation rate increased there would be a general decrease in accuracy of perceiving which one of the events occurred more frequently because of the decrease in reliability produced by the shorter time sample. It was also hypothesized that rate would interact with the length of the series observed, i. e. , a short series of events as compared to a long series would show a steeper decline in accuracy as presentation rate increased. The rationale for the latter hypothesis was that at very slow rates, where one can count each event and maintain an actual tally of events, the shorter the series the more accurately one could retain the tally. However, as the presentation rate increased and one resorted to other

techniques for determining the more frequent event, such as obtaining an "overall impression" based on bursts of events or running sequences, the longer the series the better the opportunity one would have to sample the series of events (ref. 2).

## METHOD

### Apparatus

A punched paper tape reader was used to present a preprogrammed series of two mutually exclusive events on a single plane, in-line display unit. This unit utilized lenses etched with the symbols to be used, in this experiment, the letters A and B. Lights behind each of the lenses projected the symbols, one at a time, on to approximately the same location on a 3 by 4 inch frosted plastic surface. The symbols, which were 3 3/4 inches high, were seen as an outline of light against a dark background. A motor-driven cam supplied a pulse to the tape reader at one of four different rates. The symbols were presented one at a time and were on for approximately half of each cycle, producing an equal on-off ratio. This ratio was sufficient so that a distinct off-time could be noticed when the same symbol was repeated in sequence. All of the programming equipment was housed in a separate room to reduce noise.

### Procedure

Sixty-eight college students were paid to serve as subjects and were run in groups of seven to nine. Each subject was seated in an individual booth facing the display so as to view the symbols binocularly from a distance of from six to nine feet.

Four rates of presentation were used: one, two, four, and eight events per second. The four relative frequencies between the more frequent event ( $E_M$ ) to the less frequent event ( $E_L$ ) are defined by the increment ( $\Delta F$ ) of  $E_M$  over  $E_L$  as indicated by the formula:

$$\Delta F = \frac{E_M - E_L}{E_L} \times 100 = 0, 11.1, 25.0, \text{ and } 42.9 \text{ per cent.}$$

$E_M$  and  $E_L$  were counterbalanced for the letters A and B for all  $\Delta F$ s. A trial required one judgment and consisted of observing a random series of the two events with one  $\Delta F$ . At the end of each trial the subject was instructed to write on his answer sheet the symbol that appeared more frequently and then to cover his answer with a piece of cardboard with which he was provided. Subjects were told to guess if they were not sure of the answer. A session consisted of 16 trials - all at the same rate - counterbalanced so that each of the four  $\Delta F$ s preceded and followed

every other  $\Delta F$ , including itself, once. An experimental period consisted of four sessions, each with one of the four different rates of presentation. The sequence of rates per session was determined by a latin square design. An experimental period took approximately one hour, subjects being given a five minute rest period between each of the sessions. Subjects made four judgments for each  $\Delta F$  at each of the rates. Sessions were punched on one continuous tape with an automatic stop programmed between successive trials. The experimenter, who sat in the room with the subjects, called out the number of each trial before it was presented and started the trial by pressing a button. Subjects were given three practice trials before each session. An attempt was made to motivate the subjects by giving a monetary bonus based on the number of correct answers.

Two series of experiments were carried out:

I. Short Series: The actual frequencies of  $E_M:E_L$  were 10:10, 10:9, 10:8, and 10:7. Four groups, consisting of one group of seven and three groups of nine subjects each, were run in a latin square design with the sessions counterbalanced with regard to the four rates of presentation. All subjects took all four rate conditions, each subject making 4 observations at each of the 16 different experimental conditions, i. e. , 4  $\Delta F$ s by 4 rates.

II. Long Series: The actual frequencies of  $E_M:E_L$  were 40:40, 40:36, 40:32, and 40:28. Four groups, consisting of two groups of eight and two groups of nine subjects each, were run in a latin square design with the sessions counterbalanced with regard to the four rates of presentations. As in the short series all subjects made 4 observations at each of the 16 different experimental conditions.

## RESULTS

The equation  $\frac{E_M - E_L}{E_L} \times 100 = \Delta F$  gives a measure of the percent increment that  $E_M$  exceeds  $E_L$ ; thus 11.1 percent indicates that the frequency of  $E_M$  is 11.1 percent more than  $E_L$ . The percent correct responses were obtained by averaging responses over subjects. The same  $\Delta F$ s were used for all rates. Because of the very high percent of correct responses for the large  $\Delta F$ s at all the rates, a typical phi-gamma type function was not obtained. In other words, the  $\Delta F$ s of 25.0 and 42.9 percent did not discriminate the effects of rate because of the fact that an asymptote in percent correct responses was reached at a  $\Delta F$  somewhat below 25 percent (table 1). Therefore, in analyzing the relative effects of different rates of presentation, the percent of correct identifications of  $E_M$  at the smallest  $\Delta F$  (11.1 percent) was used as the performance measure.

$\Delta F = 0$  gives a measure of symbol bias. Inspection of this bias showed no systematic interaction with the rate of presentation or the series length. Therefore, the  $\Delta F$ s which were counterbalanced with regard to the two symbols were combined in the following analysis.

Percent Correct Judgments as a Function of the Number  
of Events Observed and the Rate of Presentation

Rate/Sec.	Series	$\Delta F = \frac{E_M - E_L}{E_L} \times 100$			
		0*	11.1	25.0	42.9
1	Short	47.9	87.9	89.3	94.3
	Long	54.0	81.1	93.9	91.9
2	Short	43.6	77.9	83.6	95.0
	Long	56.1	77.0	86.5	87.8
4	Short	49.3	70.0	82.9	90.7
	Long	46.0	73.0	87.2	88.5
8	Short	56.4	52.4	88.6	92.1
	Long	71.6	70.3	85.8	87.8

\* Percent letter A responses

Table 2

Analysis of Variance of Correct Responses  
( $E_M > E_L$ ) at  $\Delta F = 11.1$  Percent

Source	df	MS	F
Between Subjects	71		
Length (L)	1	1.68	1.51
RO	3	.41	.37
ROL	3	7.38	6.65*
error (b)	64**	1.11	
Within Subjects	216		
Rate (R)	3	9.67	15.35*
Order (O)	3	.03	.05
RO	6	.60	.95
RL	3	3.61	5.73*
OL	3	.80	1.27
ROL	6	1.14	1.81
error (w)	192**	.63	

\*  $P = < .001$

\*\* 60 and 180 were used in computing P values since the equivalent of 4 subjects for all 4 conditions were missing and missing cells were filled in by averaging.



Table 2 presents an analysis of variance of the number of correct responses ( $E_M > E_L$ ) at  $\Delta F = 11.1$  percent. Each of the four counterbalanced groups within each series length were equated to equal nine subjects, by the method of averaging for empty cells. Table 2 shows that the effect of rate of presentation is significant ( $p < .001$ ); the interaction between rates and length of presentations is significant ( $p < .001$ ); and the between and within interactions for subgroups (order of rate of presentation) and length of series is significant ( $p < .001$ ). Analysis of figure 1 shows that the two original hypotheses were substantiated. Overall accuracy of perceiving the more frequent event decreased as rate of presentation increased. Also, the effects of rate acted differently for the short and long series of events: as presentation rate increased the short series showed a significantly steeper decline in accuracy than the long series.

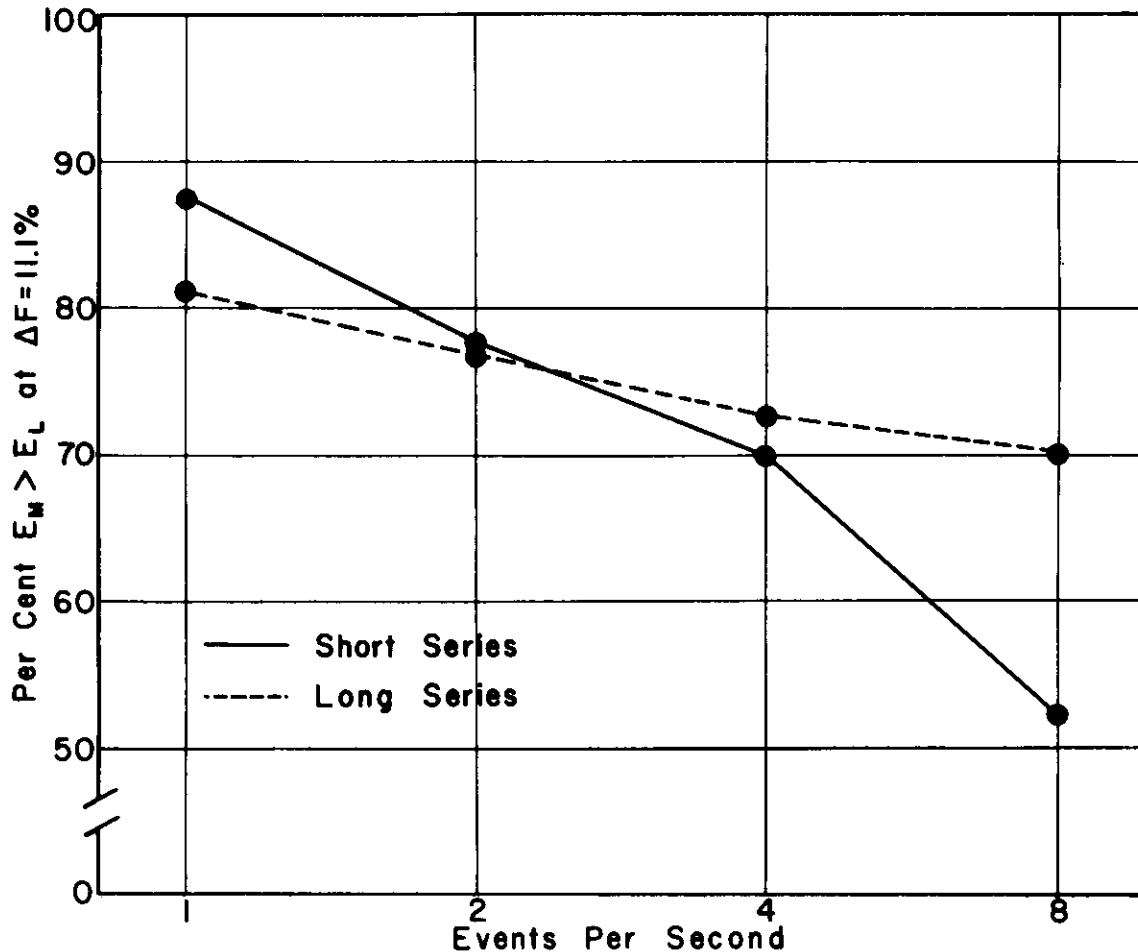


Figure 1. Percent Correct Identification of "More Frequent" Event ( $E_M$ ) at  $\Delta F = 11.1$  Percent as a Function of the Rate of Presentation of the Events. The Abscissa is Scaled Logarithmically.

A further analysis of the interaction between rate of presentation and length of series, using Tukey's test for multiple comparisons (ref. 3), showed that the difference in accuracy between the short and long series at the fastest rate of eight per second was significantly greater ( $p < .01$ ) than the differences at the slower rates of one, two, and four events per second. There were no other significant differences among these means. It is apparent from figure 1 that the difference between the short and long series changes in a systematic manner as a function of rate of presentation; the short series shows a higher degree of accuracy at the slowest rate of one per second; both the short and long series indicate about the same accuracy at the rate of two events per second; at four events per second the longer series shows a slightly higher degree of accuracy; this difference of higher accuracy for the long series is quite marked at the fastest rate of eight events per second.

## DISCUSSION

The overall decline in accuracy of perceiving the relative frequency of two events as their presentation rate increases might be expected in terms of the reliability of serial decision making. Erlick (ref. 2), using a constant rate of four events per second, found that accuracy of perceiving the more frequent event decreased as observation time decreased. This was explained in terms of the subject making a series of decisions throughout the observation period as to which event was more frequent; the longer the observation period the larger the number of decisions that could be made with a consequent better reliability of the sample. Increasing the rate of presentation may be somewhat the same as decreasing the observation time. It might be hypothesized that it takes a minimum time to make a decision of the nature required in this investigation. Thus, given a specified number of events to observe, the faster they are presented the fewer the number of decisions possible in the shorter time interval, with a consequent decline in reliability. This would tend to explain the general decline in accuracy with increased rate for both the short and long series of events. Rate might be expected to have a greater influence on the short series, since the absolute observation times were somewhat shorter and thus probably more sensitive to change; the duration of the short series ranged from 2.1 to 20 seconds, as opposed to the long series which ranged from 8.5 to 80 seconds.

The general tendency for the shorter series to give more accurate results than the longer series at the slowest rate might be explained in terms of the task being performed somewhat differently at the slower rates. When the random series of events is presented very slowly, one can count the items individually; and the smaller the number to keep track of, the better the accuracy one might expect. However, at fast rates of presentation, one probably obtains an overall impression possibly based on bursts of events or running sequences of events; therefore, the longer the series of events, the better the opportunity the subject is afforded to sample the general burst sequences.

It is difficult to postulate a rationale for the significant between subjects triple interaction found for rate, order of rate presentation, and series length.

The general problem of perceiving the more frequent or modal event in a random series of events has been shown to be a function of the total number of events observed, the rate at which the events are presented and the interaction between the length of observation and the rate of presentation. Further variables that might be of value to investigate are: (1) the number of different classes of events presented, (2) the degree of ordering required of the events, i. e. , whether only the most frequent events must be noted or whether all events must be rank ordered, (3) the number of separate distributions being simultaneously analyzed, i. e. , whether a rank ordering of events is required of two or more separate classes of events, (4) the sequential patterning of the events, (5) the strength of cues used to differentiate the different events, and (6) characteristics of the individual such as motivation.

#### SUMMARY AND CONCLUSIONS

Two symbols (the letters A and B) representing two distinct events with different frequencies of occurrence were presented in a random sequence at one of four different rates; one, two, four and eight events per second. Four different increments of frequency ( $\Delta F$ ) between the more frequent event ( $E_M$ ) and the less frequent event ( $E_L$ ) were used:

$$\Delta F = \frac{E_M - E_L}{E_L} \times 100 = 0, 11.1, 25.0 \text{ and } 42.9.$$

Subjects were required to judge which event occurred more frequently. Two studies were carried out using the same relative frequency relationships between the events but varying the absolute number of events in the total series.

The percent correct identification of  $E_M$  at  $\Delta F = 11.1$  percent was used as the performance measure.

The results indicate that the accuracy of perceiving the more frequent event of two mutually exclusive random sequential events decreases as the presentation rate of the events increases. The effects of rate also act differently for a short and long series of events; as presentation rate increases a short series shows a significantly steeper decline in accuracy than a long series.

*Records*  
REFERENCES

1. Erlick, D. E. , Judgments of the Relative Frequencies of Sequential Binary Events: Effects of Frequency Differences. WADC Technical Report 59-580, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, October 1959.
2. Erlick, D. E. , Judgments of the Relative Frequency of Two Random Sequential Events: Effects of Duration of Observation. WADD Technical Report 60-673, Wright Air Development Division, Wright-Patterson Air Force Base, Ohio, September 1960.
3. Ryan, T. A. , Multiple Comparisons in Psychological Research. Psychol. Bull., 1959, 56, 26-47.