WADD TECHNICAL REPORT 60-673

JUDGMENTS OF THE RELATIVE FREQUENCY OF TWO RANDOM SEQUENTIAL EVENTS: EFFECTS OF DURATION OF OBSERVATION

Dwight E. Erlick

SEPTEMBER 1960

WRIGHT AIR DEVELOPMENT DIVISION

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

☆

Qualified requesters may obtain copies of this report from the Armed Services Technical Information Agency, (ASTIA), Arlington Hall Station, Arlington 12, Virginia.

☆

This report has been released to the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., for sale to the general public.

☆

Copies of WADD Technical Reports and Technical Notes should not be returned to the Wright Air Development Division unless return is required by security considerations, contractual obligations, or notice on a specific document.

WADD TECHNICAL REPORT 60-673

JUDGMENTS OF THE RELATIVE FREQUENCY OF TWO RANDOM SEQUENTIAL EVENTS: EFFECTS OF DURATION OF OBSERVATION

Dwight E. Erlick

SEPTEMBER 1960

Project 6190
Task 71556

BEHAVIORAL SCIENCES LABORATORY
AEROSPACE MEDICAL DIVISION
WRIGHT AIR DEVELOPMENT DIVISION
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

1,000 – November 1960 – 10-463

FOREWORD

This report was initiated by the Engineering Psychology Branch, Behavioral Sciences Laboratory, Aerospace Medical Division under Project 6190, Task 71556 entitled "Design Requirements for Decision-Making Displays," with Dr. Dwight E. Erlick acting as Task Scientist.

Acknowledgment is made of the overall very able assistance given by Jay Palmore. Most of the work on this investigation was carried out at the Engineering Psychology Research Project of Antioch College under Contract AF 33(616)-6095.

ABSTRACT

The purpose of this investigation was to determine the effect that duration of observation has on one's ability to tell which of two random sequential events has occurred more frequently. Using a rate of four events per second and observation durations ranging from 1.75 to 80 seconds, two specific conditions were studied: (1) the effect of having a constant observation period repeated so that Ss could anticipate the duration of each observation, and (2) the effect of having a highly variable observation time such that the observer could not accurately anticipate when the time sample would end. Using 75 per cent correct identification of the more frequent event as a threshold measure, the results indicate, for both presentation conditions, that a smaller increment in frequency of one of the events over the other was needed as the observation duration increased. An asymptote was reached as the ratio between the more frequent and the less frequent event approached 1.20. With a constant observation time, the asymptote is reached between 10 and 20 seconds duration, while with a variable observation time, it is reached between 40 and 80 seconds.

PUBLICATION REVIEW

Walter F. Grether

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

INTRODUCTION

If elements of situations that are highly unstructured or difficult to codify must be tallied simultaneously, the task usually falls to man. If the number of different 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 with pencil and paper. However, if the rate of occurrence of the different events is too fast to be tallied manually after each occurrence, then one might have to rely on man's ability to keep a running tally "in his head", so to speak. This type of task is quite essential in establishing priorities based on frequency of occurrence.

The use of automated equipment to perform tasks of this nature depends largely on the subtlety required to differentiate the unique characteristics of the categories being tallied. 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, it is expected that man will have tasks of this nature for some time to come.

The purpose of this experimental program is to determine how man's capability to perform this task of simultaneously tallying random sequential events is affected by various parameters of the task. Erlick (ref. 1) demonstrated that man's ability to perceive the more frequent of two random sequential events increases as a function of the per cent difference between the frequency of the events. Using a presentation rate of five events per second and a total observation time of 20 seconds, it was found that 75 per cent correct identification of the more frequent event was achieved when there was approximately an 8 per cent difference between the frequency of the events. It was also found that the absolute frequency of occurrence of the events tended to be overestimated.

The present investigation was designed to determine the effect that the length of the observation period has on one's ability to tell which of two random sequential events has occurred more frequently. Two specific parameters were of interest: 1) the effect of having a constant observation time repeated, so that Ss could anticipate the duration of each observation, and 2) the effect of having a highly variable observation time, such that one could not accurately anticipate when the time sample would end.

METHOD

Apparatus. A five-hole punched-paper tape reader was used to present a pre-programmed series of events on a one plane in-line display unit. This unit utilized lenses etched with the symbols to be used, in this case the numbers 1 and 2. Lights behind each of the lenses projected the symbols, one at a time, onto approximately the same location of a 3-inch 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. They were presented randomly one at a time at the rate of four symbols per second, each symbol being on for approximately .125 seconds producing an equal on-off ratio. This was sufficient so that a distinct off-time could be noticed when the same symbol repeated itself in sequence. A relay circuit was included that allowed for programming the starting and stopping of the tape transport. All of the programming equipment was housed in a separate room to reduce noise.

Subjects. College students were paid to serve as Ss. Ss were run in groups of from six to twelve. Each S 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.

Procedure. The observation times, which ranged from 1.75 to 80 seconds, and the actual frequencies of the more frequent event (E_M) and the less frequent event (E_L) are shown in Table 1. The per cent frequency increments are defined by the equation:

$$\Delta F = \frac{E_M - E_L}{E_L} \times 100$$

the actual values of ΔF were 0, 11.1, 25.0 and 42.9 per cent, except for the shortest observation times where the smallest ΔF possible was 25 per cent. E_M and E_L were counterbalanced for the numbers 1 and 2 for all ΔF's. It will be noticed that the observation time varies with the ΔF within each time period. This was necessary in order to obtain small per cent increments in frequency.

A trial consisted of one random series of events with one observation time and elicited one judgment. At the end of each trial the S was instructed to write on his answer sheet the symbol that appeared more frequently, then to cover his answer with the cardboard with which he was provided. Ss were told to guess if they were not sure of the answer. Trials were grouped into sessions, counterbalanced so that each ΔF preceded and followed every other ΔF, including itself, once. Ss were presented several sessions in one experimental period with rest periods between each session. A series of trials were punched on one continuous tape with a programmed stop between each trial. The experimenter who sat in the room with the Ss called out the number of each trial before it was presented and started the trial by pressing a button. Ss were given three practice trials before each session. An attempt was made to motivate the Ss by giving a bonus in money as a function of the number of correct answers.

Experimental Design. Two series of experiments were carried out:

Series I: Random Presentation of Observation Times: Fifty-three Ss were run on the six different observation times. The order in which the observation times were presented from trial to trial was completely random, i.e., Ss might be presented with observation times in a sequence like 2, 80, 10 and 40 seconds etc., not knowing when each observation period would stop. Each S made four judgments of each of the experimental conditions.

Series II: Non-Random Presentation of Observation Times: In this series, separate groups of Ss were run at each of five different observation times, i.e., 2.5, 5, 10, 20 and 40 seconds. Each group received only one of the five different observation times. The size of the groups varied from 10 to 31 and the number of observations by each S varied from 16 to 44. The total number of observations for each of the observation times varied from 160 to 656 (table 2).

Table I

OBSERVATION TIMES, FREQUENCIES OF EVENTS, AND PER CENT INCREMENTS OF MORE FREQUENT EVENT

Observation Time (Sec.)	Number of Events E_M	E_L	$\Delta F = \frac{E_M - E_L}{E_L} \times 100$
2.50	5	5	0
2.25	5	4	25.0
2.00	5	3	66.7
1.75	5	2	150.0
5.00	10	10	0
4.75	10	9	11.1
4.50	10	8	25.0
4.25	10	7	42.9
10.00	20	20	0
9.50	20	18	11.1
9.00	20	16	25.0
8.50	20	14	42.9
20.00	40	40	0
19.00	40	36	11.1
18.00	40	32	25.0
17.00	40	28	42.9
40.00	80	80	0
38.00	80	72	11.1
36.00	80	64	25.0
34.00	80	56	42.9
80.00	160	160	0
76.00	160	144	11.1
72.00	160	128	25.0
68.00	160	112	42.9

RESULTS

The ratio of $\frac{E_M - E_L}{E_L} = \Delta F$ gives a measure of the per cent increment that E_M exceeded E_L, thus a ΔF of 25 per cent indicates that the frequency of E_M is 25 per cent more than E_L. The per cent correct responses for each series was obtained by averaging the responses of all Ss for each of the observation times. The ΔF required for 75 per cent correct identification of E_M furnishes a measure of the relative effect of the different lengths of observation. This measure was obtained by linear interpolation. The per cent $\Delta F = 0$ was obtained by randomly calling one of the two symbols used correct for half the trials and the other symbol correct for the other half.

Analysis of the data showed there was no interaction between symbol preference and the different ΔF's. Therefore, the correct responses for the corresponding ΔF's that were counterbalanced with regard to the symbols were averaged.

I. Random Order of Observation Times: Analysis of the effects of observation time when the observation times were presented in a random order to the observer shows that the per cent ΔF required for 75 per cent correct identification of E_M decreases as observation time increases (fig. 1, table 2).

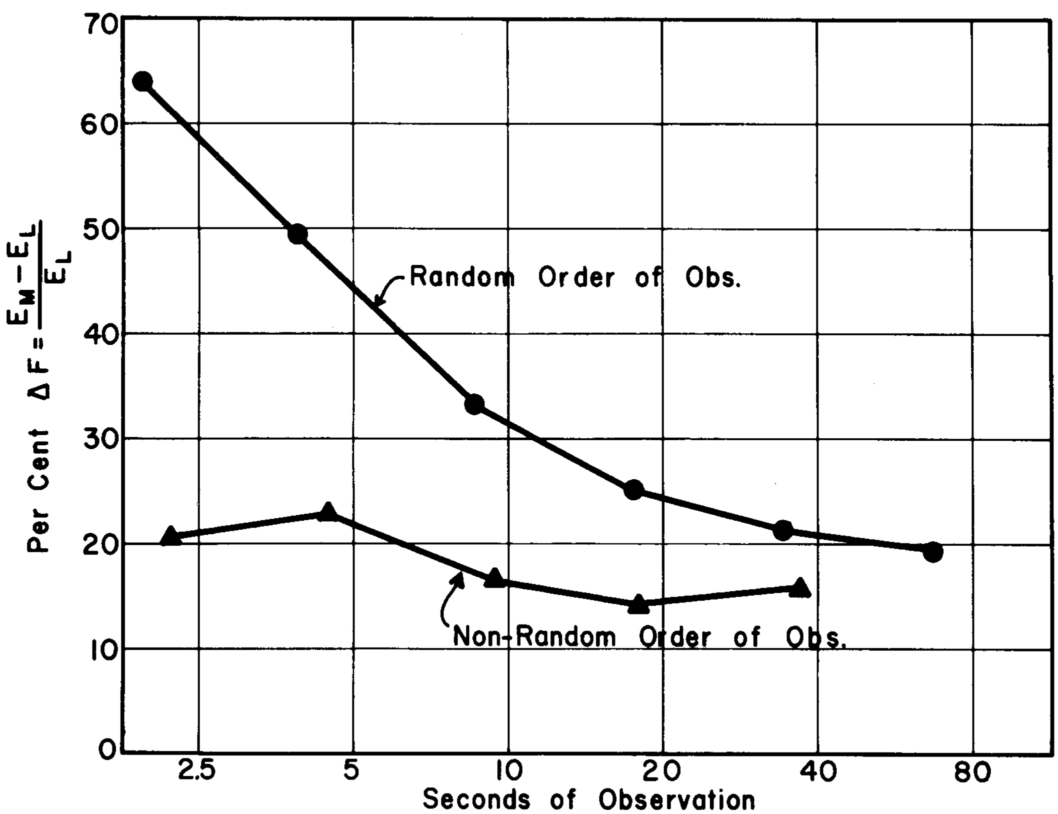

Figure 1. Seventy-five per cent correct identification of "more frequent" event (E_M) as a function of observation time for random and non-random order of presenting observation times. The abscissa is scaled logarithmically.

Table 2

PER CENT CORRECT JUDGMENTS AS A FUNCTION OF OBSERVATION TIME

Series	Seconds of Observation at $\Delta F = 0$	Number of Ss	Total Number Observations	$\Delta F = \frac{E_M - E_L}{E_L} \times 100$					
				0	11.1	25.0	42.9	66.7	150.0
I	2.5	53	212	42.4		57.1		76.4	94.8
II		10	440	50.0		80.2		94.1	98.0
I	5	53	212	49.1	53.8	66.2	72.6		
II		31	656	52.3	61.4	77.5	87.6		
I	10	53	212	56.6	58.5	70.8	80.2		
II		26	416	47.2	67.8	85.1	90.1		
I	20	53	212	50.9	60.4	74.5	85.4		
II		10	420	55.4	70.0	83.5	90.2		
I	40	53	212	53.8	63.2	78.3	85.8		
II		10	160	50.0	70.0	85.0	87.5		
I	80	53	212	45.3	71.2	77.8	86.3		

The slope of the line relating correct judgments to observation time decreases as the observation time increases, approaching an asymptote between 40 and 80 seconds.

II. Non-Random Order of Observation Times: Analysis of the groups which had repeated measures at the same observation time showed no systematic effects of practice. A slight improvement in the ability to perceive E_M as a function of observation time was indicated (fig. 1 and table 2). The per cent ΔF required for 75 per cent correct identification of E_M appeared about the same between 2 to 5 seconds of observation, decreasing beyond 5 seconds and leveling off between 10 and 20 seconds of observation.

Analysis of the random and non-random observation time studies indicate lower thresholds for all conditions of the non-random series. The differences are most marked at the shorter observation times, where the random order thresholds are much higher. For both groups, the 75 per cent correct identification of the more frequent event appears to reach an asymptote with a frequency increment of between 15 and 20 per cent over the less frequent event. This asymptote is reached between 10 and 20 seconds of observation for the non-random condition, increasing to between 40 and 80 seconds when the observation times are presented randomly.

DISCUSSION

In terms of statistical sampling theory, a larger sample tends to increase reliability. In view of this, the decrease in threshold found with increased observation time might be expected, especially with the 40:1 ratio of 2 to 80 seconds of observation used in this investigation. It is expected that during the observation of the events, Ss make a series of decisions as to which event is ahead, i.e., which has occurred more frequently up to a given point. Longer observation periods would tend to give a more reliable sample of this running tally.

The overall deterioration in performance of perceiving the more frequent event when the observation times are randomly presented lends support to the thesis that expectation might play a role in the determination of thresholds. Thus, if Ss were to develop expectations for the mean observation time, about 20 seconds, they would be "caught short" or unprepared to make their decision at the shortest observation times. This might tend to increase their threshold. While for observation times that were beyond the anticipated mean, Ss would have arrived at their decisions and consequently would tend to reflect thresholds more equivalent to the non-randomly presented groups. The results tend to substantiate this. It would be interesting to investigate a broader sample of "randomly presented" observation times to further quantify the role of expectation.

SUMMARY AND CONCLUSIONS

Two distinct events (the numbers 1 and 2) with different frequencies of occurrence were presented in a random sequence at the rate of four events per second to groups of college students for varying lengths of time ranging from

1.75 to 80 seconds. Four different increments of frequency (ΔF) between the more frequent event (E_M) and the less frequent event (E_L) were used:

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

Ss were required to judge which event occurred more frequently. Two series of studies were carried out: (a) random order of observation times in which Ss received all the observation times in an unpredictable sequence during a session, and (b) non-random observation times in which Ss received the same observation time throughout a session.

The interpolated 75 per cent correct identification of E_M was used as a threshold measure. The results indicate that the threshold decreases as observation time increases for both studies, reaching an asymptote when E_M is between 15 and 20 per cent more frequent than E_L. This asymptote is reached between 10 and 20 seconds of observation for the non-random series, and increases to between 40 and 80 seconds when observation times are randomly presented. A comparison of the random and non-random studies shows the thresholds to be lower for the non-random conditions for all observation times, the difference being most marked at the shorter observation times. The results are discussed in terms of reliability of making serial decisions and the effects of expectation on thresholds.

REFERENCE

Erlick, D. E., Judgments of the Relative Frequency 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.