Choice reaction and unequal stimulus frequencies in an absolute judgment situation¹

HERBERT KAUFMAN, UNIVERSITY OF CONNECTICUT
JERRY LAMB, GENERAL DYNAMICS, ELECTRIC BOAT DIVISION

Previous investigators have reported discrepant results for Ss in a choice reaction time (CRT) situation when stimuli are not equi-probable. Sixty Ss participated in an absolute judgment CRT task under three conditions of equi-probable stimuli and three of unequally probable stimuli. The results indicate that previous findings may be determined by a threshold dependent upon the effect of unequal stimulus frequencies and the utilities of different response strategies.

Previous investigators (Hick, 1952; Hyman, 1953; Crossman, 1956; Doherty, 1965) have found a linear relationship between choice reaction time (RT) and stimulus information when all stimulus alternatives are equally likely. However, when stimuli are not equally likely, the results are less clear-cut. Hyman (1953) and Stone and Calloway (1964) found that for low information stimuli (those with a high probability of occurrence) RT was greater than would be predicted using the regression line for equally likely alternatives, and conversely for high information (low probability) stimuli. Lamb and Kaufman (1965) and Kaufman and Levy (1966) both found results contradictory to the Hyman results; RT for low information stimuli was markedly less and RT for high information stimuli was greater than would be predicted from the regression line for equally likely alternatives, giving a generally quadratic function. Although a variety of different procedures were used in the above studies, only Doherty for equally likely alternatives and none for the unequally likely case have used the method of absolute judgments with unfamiliar stimuli. The present experiment was designed to determine the shape of the function relating RT to stimulus and transmitted information for unequally likely stimuli in an absolute judgment situation and to explain previous discrepancies.

METHOD

Subjects

The Ss were 60 male and female undergraduate students from introductory psychology courses at the University of Connecticut. The 60 Ss were assigned randomly to six groups of 10 each.

Apparatus

The apparatus consisted of a Gerbrands tachistoscope, a voice key and a Hunter millisecond timer. A button held by S initiated the trials and actuated the timer; S's response activated the voice key, turning off the stimulus and stopping the timer.

The stimuli were eight lines (Black on White) 1/8 in. wide and varying in length from 1 in. to 3.72 in. by successive ratios of 1.22 to 1. These stimuli have been previously shown (Doherty, 1965) to be relatively easy to discriminate. The responses used were *bun, boo, bee, bore, bive, bix, bev, bate* for stimuli 1 to 8.

Experimental conditions and procedure

There were six experimental conditions, three with equally likely alternatives (ELA) and three with unequally likely alternatives (ULA). The ELA conditions had 2, 4, and 8 alternatives; for 2 alternatives, stimuli 1 and 2 were used; for 4 alternatives, stimuli 1 to 4; and for 8 alternatives the entire set was used. In the ULA conditions, two stimuli were always used, the pairs being drawn randomly from the entire set with the restriction that they be consecutive members of the set, in order to keep discriminability approximately constant. The relative frequency of the members of each pair was varied, the values being 90/10, 75/25, and 60/40.

Each group of 10 Ss was assigned to an experimental condition and served in one experimental session lasting approximately 1 hr. The E informed the Ss of the relative frequency of occurrence of the stimuli for all conditions. Pretraining consisted of 15 trials for familiarization with the apparatus, presentation in both ascending and descending order of the stimuli to be used in the particular condition, and 40 to 60 practice trials. After pretraining, 100 test trials were administered; S initiated each trial with the hand held button and was informed of both his response time and the correct stimulus after each trial.

RESULTS AND DISCUSSION

Medians of blocks of 10 trials were calculated and the mean of the medians for each S was used in subsequent analyses to minimize the effects of skewness in the RT scores. Two analyses were done of the ELA data, one for stimulus information and one for transmitted information. The stimulus information data for the three groups with ELA stimuli were analyzed by means of a double classification analysis of variance. The linear trend of RT against stimulus information was highly significant ($df=1/18$, $F=30.5$, $p<.01$). Neither the residual (quadratic) component nor difference among Ss were significant. The relationship between RT and transmitted information was analyzed by means of a partial correlation technique and again the linear trend was significant ($df=1/26$, $F=48.9$, $p<.01$). Thus,

Fig. 1. CRT as a function of stimulus information for equally probable and unequally probable conditions.

Doherty's (1965) finding of a linear relationship between RT and ELA stimuli for absolutely judged stimuli was verified.

The plot of mean RT for the surprisal values (the amount of information in the individual stimuli) of the ULA conditions is shown in Fig. 1. The most striking result is that the slope of the ULA function (.02 sec./bit) is much less than that of the ELA function (.23 sec./bit) over the same range of stimulus information. The RT curve for ULA stimuli relative to the ELA function is of the same general form as those of the Hyman (1953) and Stone and Callaway (1964) experiments. Hyman did not report the values of the obtained slope for the surprisal values; estimation from two individual stimulus points given in his article indicate that one S had a ULA slope of .05 sec./bit and an ELA slope of .15 sec./bit.

Since the Hyman (1953) study found a ULA slope less than the ELA slope while the Lamb and Kaufman (1965) study found a ULA slope greater than the ELA slope, the question arises as to the kind of behavior that could explain the small slope obtained in the present study and also the discrepant results found by the various experimenters. Other experimenters (Mowbray, 1960; Mowbray & Rhoades, 1959; Leonard, 1959; Seibal, 1959) have found that under conditions of high stimulus-response compatibility or extensive practice the slope of the function for ELA stimuli may approach zero. Neither of these conditions applied in the present study, as indicated by the large slope of the ELA function.

Hick's Law that the rate of information gain is a constant implies that there is a trade-off between speed and accuracy, i.e., S can respond more quickly only

at the cost of more mistakes and thus less transmitted information. In the present experiment, S could lower his RT by being prepared on a given trial to make a particular response. If the response S is prepared to make is not correct, however, transmitted information is lowered. If S wishes to lower his RT without reducing transmitted information significantly, S must adopt a rule for choosing the "prepared" response. In the ELA conditions, there is no reason for S to expect any one stimulus more than another; hence RT is strictly a function of the number of stimuli. In the ULA conditions, S knows which stimulus is more likely to appear but the difference in relative frequencies must be great enough to justify the risk of making a mistake if the predicted stimulus does not occur. Hick hypothesized that "...the effective probabilities are very little affected by increasing inequality in the stimulus frequencies until something like a threshold is reached" (p. 25).

The present data support the hypothesis of a threshold for disparate stimulus frequencies to elicit differential behavior. Fig. 1 shows that Ss' responses to the two stimuli in the 60/40 and 75/25 conditions were essentially the same; the difference in RT between the two responses in each condition is less than .06 sec. For the 90/10 condition, the difference is .19 sec. indicating that Ss responded differently to the two stimuli in this condition. Further evidence is provided by the differences between the RT when a particular stimulus is presented regardless of the response made and the RT when the response corresponding to that stimulus was made regardless of the stimulus presented. This dif-

ference should be large only when S's threshold was exceeded and then only for the less frequent stimulus. This is because the first case would include many very short RTs when S was prepared for the more frequent stimulus and was incorrect; the second case would include only the longer but correct RTs. For all stimuli except the .10 stimulus the difference is less than .01 sec., while for the .10 stimulus the difference is .15 sec.

If the threshold hypothesis is correct, then Ss should behave to two ULA stimuli as they would to two ELA stimuli until the threshold is exceeded. The mean RT to all stimuli except for the 90/10 condition differed from the RT to the two equi-probable stimuli by less than .06 sec., while the .90 stimulus differed by .17 sec. All the above evidence indicates that Ss were generally unwilling to "bet" on the occurrence of a particular stimulus and the consequent chance of making a mistake until the relative stimulus frequencies were very disparate (90/10), and until that threshold was reached behaved essentially as they would be two equally likely stimuli.

This type of behavior may also explain the results of Kaufman and Levy (1966) and Lamb and Kaufman (1965). In their experiments, S's task was to move his finger from a starting position to a response button. Under these conditions, it is possible for S to begin to make one response (the "prepared" one) and if that stimulus does not occur, to change his response and make the correct one, leading to very short RTs for the more frequent stimulus and relatively long RTs with very few errors for the other stimulus. Thus, S may "bet" on the occurrence of a particular stimulus and rarely be penalized by a mistake, and the threshold for discrimination of unequal stimulus frequencies could be lowered with little or no loss in transmitted information.

Hyman also reported that mean RT for a ULA condition is linearly related to the average stimulus information (the sum of the surprisal values times the probability of occurrence of each value) for that condition. This result is also compatible with the threshold type of behavior exhibited by Ss in the present experiment. The linear correlation between RT and average stimulus information for the present study was .53 ($df = 29$, $p < .01$). This is surprisingly large, since the data are grouped for 30 Ss instead of for individual Ss as in the Hyman study; the curves for the ULA data are flatter than Hyman's, and most importantly,

only two alternatives were used with a correspondingly small range of average stimulus information (.15 to 1 bit) where Hyman used up to eight alternatives with a range of .15 to 2.75 bits.

Thus, it appears that the discrepant results reported by various investigators may be the result of different experimental procedures which produce different thresholds at which unequal stimulus frequencies elicit differential behavior. It also appears that the information content of ULA stimuli has little effect and RT for ULA stimuli is a function of the utilities for different response strategies.

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Note

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