Journal of Experimental Psychology
1973, Vol. 100, No. 2, 416–418

PROBABILITY, COMPATIBILITY, SPEED, AND ACCURACY [1]

O. JOSEPH HARM [2] AND JOSEPH S. LAPPIN

Vanderbilt University

This study varied 2 levels of stimulus probability (50–50 and 70–30) and 2 levels of stimulus–response (S–R) compatibility in a 2-choice visual RT task. The latency operating characteristic (LOC) was used in the data analysis. In contrast to previous evidence, the present experiment indicated that stimulus probability has no effect on the speed of perceptual processing in either a compatible or an incompatible task; S–R compatibility affected the slope of the LOC but not the intercept.

Reaction time (RT) methods have become increasingly popular in the analysis of human information processing since their early application by Donders in 1868. Most theories of information processing assume a series of stages or subprocesses that intervene between the stimulus and the overt response. This approach has sparked a good deal of interest in the effects of many variables upon RT and the loci of these effects in the information-processing sequence. Stimulus probability and stimulus–response (S–R) compatibility are 2 variables recently studied in this vein.

Since Hyman (1953), researchers utilizing mean RT distributions have found that RT is inversely related to stimulus probability. These studies generally suggest that stimulus probability affects RT at a stage of the information-processing sequence primarily concerned with stimulus identification rather than response selection.

Lappin and Disch (1972) have recently reported that stimulus probability has no effects upon the speed of perceptual processing when the latency operating characteristic (LOC) is used as the dependent measure in a highly compatible choice-RT task. The LOC is a function relating RT to an accuracy measure such as d' (signal detection), H_t (information theory), or η (choice theory). Yellott (1971) also reported that stimulus probability had no significant effects when measured with his LOC analysis for the fast-guess model. In contrast, those studies reporting stimulus probability effects usually attempt to maintain low (less than 5%) error rates. However, as Lappin and Disch point out, methods employing low error rates and mean RT fail to separate the speed of perceptual processing from decision strategies or response bias. Often, the error rates in such studies are excluded from the data as being low enough to be nonsignificant. But as Pachella (1972) has demonstrated, even small error differences that may appear meaningless can contaminate RT values if these errors happen to occur in a region of RT where a speed–accuracy trade-off is being obtained. To ignore these errors may thus prove misleading; stimulus probability might affect response biases rather than the speed of perceptual processing. Bartz (1971) has found that probability effects may be observed on the first trial due to a set formed by *S* during the reading of instructions.

It is possible, though, that studies employing the LOC have minimized the effects of stimulus probability by using a highly compatible task. Fitts (1964) suggested that stimulus probability has little effect under a condition of high compatibility. As *S*s go from a task that is low in compatibility to one that is of relatively high compatibility, they are making more and more use of well-established habits that would seem to be less affected by stimulus probability.

The present study will examine stimulus probability under 2 levels of compatibility. While S–R compatibility has received considerable attention in the literature concerned with RT measures of performance, it has not been investigated with a speed–accuracy trade-off measure such as the LOC.

Method. The stimuli, apparatus, and general procedure of this experiment have been described elsewhere (Lappin & Disch, 1972). Two probability conditions were run in each session: 50–50 and 70–30.

In the 70–30 condition, the stimulus appeared on one side of the fixation point 70% of the time and on the other side 30% of the time. Stimulus position was randomized over blocks of 100 trials. The order of the probability conditions and whether the right or left stimulus was the more probable were counterbalanced across *S*s and sessions. Six sessions of 440 trials (200 trials per probability condition plus 40 practice trials) were run under each level of compatibility. In addition, several practice sessions were run at the beginning of the experiment and when *S*s switched to a different compatibility condition. Compatibility levels were also counterbalanced across *S*s. High compatibility was defined as a right-stimulus – right-key and a left-stimulus–left-key S–R mapping. Low compatibility was a reversal of this mapping.

The *S*s were 4 males, well practiced and familiar with the choice-RT task. The first author served as one *S*; the 3 other *S*s were paid student volunteers at Vanderbilt University.

Results. The LOC functions were fitted to the data by the least squares method in the manner described by Lappin and Disch (1972). Two line segments, $-\ln\eta = 0$ and $-\ln\eta = m(\mathrm{RT} - k)$, where

[1] This research was supported by U. S. Public Health Service Grant MH-21105 to the second author.

[2] Requests for reprints should be sent to O. Joseph Harm, Department of Psychology, Vanderbilt University, Nashville, Tennessee 37240.

m and k represent the slope and intercept, were fitted to the set of points where perfect discrimination was not obtained. The equation for the calculation of $-\ln\eta$ is:

$$-\ln\eta = \frac{1}{2}\log_e\left[\frac{p(r1|s1)}{p(r2|s1)}\cdot\frac{p(r2|s2)}{p(r1|s2)}\right].$$

The measure is highly similar to d' and is used here mainly for its ease of calculation relative to d'.

Separate regression lines were fitted to the 50–50 and the 70–30 data points under each compatibility condition for each *S*. These linear fits accounted for over 92% of the variance in all cases. In order to test for a difference between the 2 probability conditions, a single regression line was fitted to the combined 50–50 and 70–30 data points. The numbers of points for each probability condition above and below the second regression line (where the speed–accuracy trade-off is obtained) were then tabulated in a 2 × 2 contingency table. Fisher's exact method for analyzing fourfold contingency tables was then applied to test for significant differences between the probability conditions. None of the differences between the 2 probability conditions

TABLE 1

NUMBERS OF POINTS ABOVE AND BELOW COMMON REGRESSION LINES ACROSS PROBABILITY LEVELS

Probability level	Compatible condition		Incompatible condition	
	No. above	No. below	No. above	No. below
50–50	10	10	11	11
70–30	11	9	10	11

Note. Computed on pooled reaction times for all *Ss*.

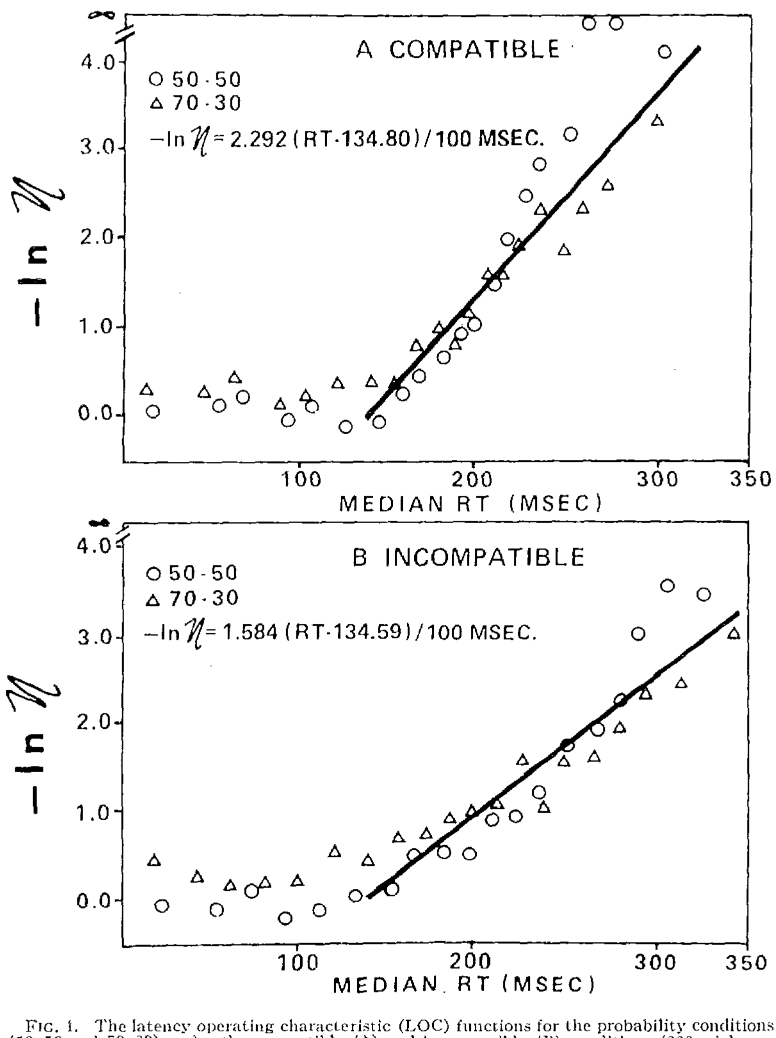

FIG. 1. The latency operating characteristic (LOC) functions for the probability conditions (50–50 and 70–30) under the compatible (A) and incompatible (B) conditions (220 trials per data point).

in either the high or low compatibility conditions for any of the individual *S*s approached significance. Significant compatibility effects ($p < .05$) were found for all *S*s and were characterized by a flattening of the slope of the LOC in the low compatibility condition relative to the high compatibility condition.

The RTs were pooled across all *S*s for graphical conciseness. Separate regression lines were plotted for the 50–50 compatible points, the 70–30 compatible points, the 50–50 incompatible points, and the 70–30 incompatible points; the linear regression lines accounted for 97%, 93%, 96%, and 92% of the variance, respectively. The procedure used for individual *S*s was then applied to the pooled data. Table 1 consists of the numbers of points above and below the common regression lines (common for the 50–50 and 70–30 probability conditions) computed on pooled RTs across *S*s for each compatibility condition. As can be seen from Table 1, the numbers of points above and below the regression lines were not significantly different in either the 50–50 or 70–30 probability condition under either compatibility condition. That is, a common LOC could be fitted to both probability conditions for both compatibility levels. These common regression lines accounted for 87% and 89% of the variance in the compatible and incompatible conditions, respectively.

The LOCs for the compatible and incompatible conditions are plotted in Figure 1. As can be seen from the graphs, the probability conditions are very close together, while the slopes of the compatibility conditions differ. The probability conditions tend to diverge slightly in both compatibility conditions at relatively long RT and high accuracy levels. While this divergence is not statistically significant, it is of minor interest. Since the 50–50 condition is a bit better than the 70–30 condition in each compatibility condition (contrary to what is normally found), it seems possible that response competition occurred in the 70–30 condition.

Discussion. The present study has replicated Lappin and Disch's (1972) findings for a highly compatible task and has extended these findings for an incompatible case. Stimulus probability appears to have no significant effects upon the speed of perceptual processing, at least in the simple 2-choice task employed here. Also, Fitts' (1964) suggestion that probability effects are dependent upon S–R compatibility is not borne out.

Stimulus–response compatibility acts upon the slope of the LOC but not the intercept. The compatibility effect varies 0–100 msec., depending on whether the accuracy level is at chance or at a high level. Perfect discrimination was not obtained in the incompatible condition as it was in the compatible condition. The effects of S–R compatibility appear to act upon a translation stage of information processing where perception is translated into action (after Welford, 1971). Compatibility seems to determine the level of "noise" that hinders the translation of perception into action after the selection of the response has occurred and before the actual execution of the response. The correct response may be properly selected but incorrectly executed. A high noise level due to an incompatible S–R mapping would also lead to longer RTs for both correct and incorrect responses. The slope of the LOC was thus flattened, but the intercept remained approximately unchanged. Hence, the mean and variance were greater in the incompatible condition than in the compatible condition—as would be expected from a higher noise level.

Should all effects of stimulus probability be dismissed as artifacts which occur due to shifts in response criteria rather than to effects on the speed of perceptual information processing? Without doubt, variation in response criteria has influenced the RTs in large numbers of studies on stimulus probability and may be sufficient to account for many reported results. In the present experiment there were always only 2 alternative stimuli, differing in their spatial position. In many other experiments, however, the stimuli have been more complex, providing information by more abstract properties. Some experiments have manipulated probability by varying the number of alternative stimuli assigned to the same response, in contrast to the manipulation of relative frequency of the 2 alternatives in the present experiment. Stimulus probability has been found to affect the LOC (Pachella, 1972; and unreported studies in our laboratory) when varying numbers of alphanumeric stimuli are assigned to the same response. Whether these effects are specifically dependent upon manipulating the size of the set of alternatives or upon the complexity of the stimuli is as yet uncertain.

REFERENCES

Bartz, A. A. Reaction time as a function of stimulus uncertainty on a single trial. *Perception & Psychophysics*, 1971, **9**, 95–96.

Fitts, P. M. Perceptual-motor skill learning. In A. W. Melton (Ed.), *Categories of human learning.* New York: Academic Press, 1964.

Hyman, R. Stimulus information as a determinant of reaction time. *Journal of Experimental Psychology*, 1953, **45**, 188–196.

Lappin, J. S., & Disch, K. The latency operating characteristic: I. Effects of stimulus probability on choice reaction time. *Journal of Experimental Psychology*, 1972, **92**, 419–427.

Pachella, R. G. Memory scanning under speed stress. Paper presented at the meeting of the Midwestern Psychological Association, Cleveland, May 1972.

Welford, A. T. *Fundamentals of skill.* London: Methuen, 1971.

Yellott, J. I. Correction for fast guessing and the speed–accuracy tradeoff in choice reaction time. *Journal of Mathematical Psychology*, 1971, **8**, 159–199.

(Received September 9, 1972)