Stimulus-response compatibility and the rate of gain of information¹

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Abstract

Fifty-four Ss responded vocally at three levels of stimulus uncertainty to visually presented Arabic numerals. Responses were paired with stimuli in three ways to create ensembles that demonstrated high, intermediate, and low S-R compatibility effects. RT was found to be an increasing linear function of the amount of information transmitted (Ht); the degree to which RT is influenced by Ht was found to be an inverse function of the degree of S-R compatibility.

Introduction

Since Hick (1952) initially pointed out that the rate of gain of information is a constant, several researchers have found that disjunctive reaction time (RT) is an increasing linear function of the amount of information transmitted (Ht) per S-R event (e. g., Crossman, 1953; Gregg, 1954). Others, however, have found conditions under which RT has failed to increase with either Ht or stimulus uncertainty (Leonard, 1959; Mowbray & Rhoades, 1959; Mowbray, 1960), or under which various factors apparently influence the degree of increase (Brainard et al., 1962; Fitts & Switzer, 1962). The present experiment was intended as a general test of the notion that the rate of gain of information varies as a function of S-R compatibility.

Method

Fifty-four undergraduates at Emory University served as volunteer Ss. Each S responded vocally at one of three levels of stimulus uncertainty (Hs) to visually presented Arabic numerals with one of three S-R ensembles (representing high, intermediate, and low degrees of S-R compatibility). The three levels of Hs were combined factorially with the three degrees of S-R compatibility, and six Ss were assigned at random to each of the nine conditions with the sole restriction that the male-to-female ratio in each group was 4/2.

The stimuli for the Hs levels of 1, 2, and 3 bits/stimulus were the Arabic numerals 1 and 2, 1 through 4, and 1 through 8, respectively. The numerals were projections of photographic reproductions of the AND-10400 numerals. They appeared as dark figures on an illuminated field at the center of a 3-in-diameter circular display area about 28 in from S. As projected, each stimulus figure was 1.5 in high; brightness contrast was high and the figures were quite legible.

The display screen was mounted near the center of a display surface (about 1 yd sq), and both were tilted 30 deg from vertical so that S's line of sight was normal to the screen. A green warning light, 3.5 in below the center of the screen, was lit during the 2-sec. period

immediately preceding the onset of any stimulus. The display board and the interior of the 5 x 7-ft experimental booth were painted a flat gun-metal gray.

In the high-compatibility condition, S responded with typical number-naming: "one" to the numeral 1, "two" to the numeral 2, etc. Essentially the same number names were used in the low-compatibility condition ("nine" and "ten" were also used), but the names were paired with the Arabic numerals at random and differently for each S. In one case, for example, S was instructed to respond to the numeral 1 with the vocalization "five," and to the numeral 2 with "eight." The intermediate condition of S-R compatibility was created by defining the correct vocal response as the number name of the numeral displayed plus two; here S correctly responded "three" to the numeral 1, "four" to the numeral 2, etc. All Ss assigned to the low-compatibility ensembles at the two higher Hs levels were permitted to use a written decoding aid and all did so; no other S used such an aid.

During the 1-hr. experimental session, S wore a headset consisting of two earphones and a boom microphone. Approximately 65 db (SPL) of broadband noise were presented through the earphones to mask extraneous sounds. The microphone was connected through an electronic voice key to a timer and to the shutter that controlled the display; the shutter was opened (the stimulus displayed), the timer was started, and the microphone was activated 2 sec. after the onset of the warning signal. When S made his vocal response, the shutter was closed, the timer was stopped, and E recorded S's RT to the nearest 0.01 sec.

The order of the 80 stimulus presentations that constituted each session was random and different for each S with the sole restriction that each assigned stimulus appeared equally often during each set of 80 presentations. No S served under more than one level of Hs and one level of S-R compatibility, and Ss were tested in random order.

Results and Discussion

The median RT was computed from each S's 80 responses. The median was used as the measure of choice because of the bias in means typically obtained with RT data. The within-cells variances were homogeneous ($F = 0.935$, $df = 8/9$, $P > .10$); the results of an analysis of variance of the data are reported in subsequent paragraphs.

The first question to be answered is whether the three S-R ensembles did create three different levels of S-R compatibility. Although they had been constructed

to involve different levels of intervening information transformations, the elemental condition thought to be primary in determining S-R compatibility (cf. Deininger & Fitts, 1955), final demonstration of the compatibility effects rests with the data.

In the present case, the mean RTs obtained with the high, intermediate, and low degrees of S-R compatibility are 477.7, 649.8, and 743.1 msec., respectively. The differences among these means are statistically significant ($F = 54.40$, $df = 2/45$, $P < .001$). It can be concluded that the three conditions were different; i.e., that there were three degrees of S-R compatibility, high, intermediate, and low.

The next question to be answered is whether differences in average RTs occur across the different levels of stimulus uncertainty, and, more specifically, whether these differences vary as a function of compatibility. This is a two-part question. The first part relates to the generality of Hick's (1952) observation that the rate of gain of information is a constant (or that RT is a linear increasing function of Ht), and the second relates to the specific interaction of S-R compatibility with Ht.

The mean RTs obtained with the Hs values of 1, 2, and 3 bits/stimulus are 521.1, 657.3, and 692.2 msec., respectively. The differences among these means are statistically significant ($F = 26.78$, $df = 2/45$, $P < .001$); average RT increased as Hs was increased. Furthermore, the interaction of compatibilities with uncertainties was statistically significant ($F = 4.91$, $df = 4/45$, $P < .005$); this is a necessary, but not a sufficient, condition for concluding that the rate of gain of information is a function of S-R compatibility.

Two things are necessary before this conclusion can be reached. First, it is necessary to relate Hs and Ht, because Hick's (1952) observation that the rate of gain of information is a constant (and its interpretation, that $RT = a + b Ht$) relates RT with Ht, the transmitted information, and not with Hs, the stimulus uncertainty. Secondly, it is necessary to show not merely that an interaction exists, but also that it is an interaction in which the slope constant changes systematically with the three levels of S-R compatibility.

The differences between Ht and Hs can be considered inconsequential in the present study because performance was essentially errorless (mean errors of about 0.8%); this satisfies the first requirement. Clarification with regard to the second was obtained through use of an alternative partitioning of the between-cells variance. The results indicated that there are no significant differences among the RTs obtained at the different levels of Hs in the high-compatibility group ($F < 1.00$, $df = 2/45$, $P > .10$), but that there are significant differences in the intermediate-compatibility ($F = 7.93$, $df = 2/45$, $P < .005$) and the low-compatibility groups ($F = 27.88$, $df = 2/45$, $P < .001$). Furthermore, in both of these latter cases there are significant linear regressions ($F = 15.15$ and 48.04 , respectively, $df = 1/45$, $P < .001$ in each case). The means and the linear regression

Fig. 1. Reaction time as a function of stimulus uncertainty at three levels of S-R compatibility. Performance was essentially errorless so that Hs is here equivalent to Ht, the amount of information transmitted per S-R event.

lines are shown in Fig. 1. Each of the three slope constants is significantly different from each of the other two ($P < .001$ in each case).

From these data it can be concluded that RT is an increasing linear function of Ht, except in the case of highly compatible S-R ensembles. Furthermore, the degree to which RT will be influenced by Ht is an inverse function of the degree of S-R compatibility. That is to say, the rate of gain of information is an inverse function of S-R compatibility, and it may even be used as a measure of S-R compatibility effects in much the same way that "resistance to extinction" is used as a measure of learning.

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Note

1. Supported in part by Emory University Research Committee Grant-in-aid No. 8376-29, "Investigations of Information Processing in Man."