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ORDINAL POSITION EFFECTS ON SPEED-ACCURACY TRADE-OFF IN ABSOLUTE JUDGMENT

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The speed-accuracy trade-off function was determined for an absolute judgment task with ten equally likely stimuli. The mean trade-off shape was found to be similar to previously reported date. However, when the trade-off was computed separately for each stimulus, ten distinct curves were obtained which were shown to be not randomly distributed around the mean curve, this indicating a particular processing of some stimuli. These ordinal position effects on the parameters of the functions are interpreted as providing evidence that some cognitive strategy is involved in identification performance. It is finally suggested that a detailed analysis such as that reported might allow a sharper testing of some decision models.

Since Hick's statement (1952) of a linear relation between the average uncertainty of a set of stimuli and the average amount of time needed to respond to a stimulus from that set, this result, generally referred to as "Hick's law", has been frequently replicated and extended by many other subsequent studies (e.g., Hyman, 1953; Brainard, Irby, Fitts & Alluisi, 1962; Lamb & Kaufman, 1965). In situations where stimulus uncertainty and the amount of transmitted information, H_t, were unconfounded, further experiments (e.g., Pachella, Fisher & Karsh, 1968) have also shown that the linear relation was still obtained between H_t and RT.

On the other hand, several papers (Pachella, Fisher & Karsh, 1968; Pachella & Fisher, 1969; Lyons & Briggs, 1971; Pachella & Fisher, 1972) devoted more attention to the RT itself, manipulating it as an independant variable. The technique used in these experiments consists of forcing Subjects to work at different rates of speed in conditions with constant stimulus uncertainty, i.e. of urging Subjects to answer faster than they normally would. By varying the stress on speed, it is possible to characterize the relationship between the speed and the accuracy of the performance. This relationship, often referred to as "the speed-accuracy trade-off", has been found linear and interpreted as an enlargement of Hick's law.

However, as Pachella and Fisher (1972) clearly pointed out, a molar formulation such as Hick's law does not constitute an explanation, but represents itself a fact to be explained. Furthermore, it must be noted that previous studies consider only the trade-off between speed and accuracy as a function of the number of stimulus alternatives;

in other words, for each stimulus uncertainty condition, the speed-accuracy trade-off is given only for the different stimuli as a group. This, of course, excludes any information arising from a possible differential processing of the different stimuli within a particular number of alternatives. However, the importance of the ordinal position of a stimulus specially in relation to the role of anchoring effects and of cognitive encoding strategies in absolute judgment, has been well established (John, 1972; Siegel & Siegel, 1972; Hupet & Citta, 1973). The mere existence of anchoring effects might reflect the use of a strategy learned, adapted, sensitive to subjective as well as objective cues. Thus, in order to improve our understanding of the functioning of decision processes in RT tasks, a separate analysis of the RT per stimulus seems to be necessary.

The following experiment investigated the speed-accuracy trade-off at the single stimulus level in a constant stimulus uncertainty condition. The purpose of the experiment was threefold. First, it was hoped that the data would further confirm and extend our knowledge about the form of the relation between the speed and the accuracy of the performance. Second, analysis of responses was planned so as to check the validity of the speed-accuracy trade-off at the single stimulus level. Third, it was hoped that such a detailed analysis of performance would extend our understanding of Subjects' strategies in decision making, and provide additional cues for the hypothesized processes.

METHOD

Subjects. Four students, two males (s1 and s2) and two females (s3 and s4) aged 20 to 22 years, participated as volunteers in the experiment. All had uncorrected normal vision.

Procedure. The Subject and the apparatus were in a half-darkened room. Through an horizontal bar of grey translucid paper, each of 10 equally spaced lamps gave an easily detectable dot. The center-to-center distance between lamps was 20mm, and the diameter of a dot was 2mm. The Subject was seated 3 m in front of the bar, without any constraint on his body position, except that he had to keep his mouth near a dynamic microphone. A tape reader simultaneously lighted one of the lamps for 1 sec and started an electronic timer. On every trial, the Subject was required to make an absolute judgment about the position of the light, according a one-to-one stimulus-response mapping. The Subject's oral response (the number name of the stimulus, from 1 to 10) triggered the counter which provided a direct readout of the time from stimulus presentation to Subject's response. No feedback was given concerning response accuracy, but when RT was longer than requested, the instruction "faster" was given by the Experimentator.

Speed requirements. Three conditions were tested. In the first condition, C1, the Subject was instructed to take as much time as needed in order to make as few errors as possible. In the other two speed emphasis conditions, C2 and C3, the Subject was required to respond faster than a determined criterion time. The Subject was told that within this constraint he had to respond as accurately as he could, but that it was of primary importance to beat the criterion time. In condition C2, he was asked to respond faster than 800 msec; in C3, faster than 600 msec.

Experimental conditions. The condition C1 consisted of 4 sessions of 100 trials each; C2 et C3 were of 8 sessions of 100 trials each. After attending several training sessions during three days, each Subject experienced one session per experimental condition per day, the order being mixed for and between Subjects. Within a session, the Subject was given several warm-up trials, followed by two blocks of 50 trials separated by a few minutes rest. The time interval between trials was held constant at 4 sec. Within each block, each position was randomly presented an equal number of times, and within each session the conditional probability of a position given the preceding position was constant and equal to 0.1.

RESULTS AND DISCUSSION

Before computing the average information transmission for each speed-requirement condition, histograms of the observed RTs for each Subject and for each speed condition were drawn. The analysis of the distribution of RTs revealed that in both speeded conditions C2 and C3 a high proportion of RTs actually exceeded the time limits defining the experimental conditions. This is probably due to the difficulty experienced by Subjects in adjusting their response to the E-determined criterion time while avoiding responding, at least subjectively, in a random fashion. One way of analyzing the data might thus be to discard the too slow responses in each condition. However, it should be considered that such a discarding would be wasteful since, in this case, 20 to 40 percent of the responses, depending on the Subject, would be ignored. Even more so if one considers that, for a given Subject in a given task, the speed-accuracy trade-off may be independant of "external" speed instructions. Furthermore, the observed distributions of RTs overlap: indeed, some RTs obtained in speed condition C2, for example, are shorter than many RTs obtained in speed condition C3. Consequently, analysing the data per condition, as Pachella and Fisher (1972) did, would lead to an artificial distinction between two responses having the same RT, the first belonging to one condition, the second to another one. Therefore, taking the considerations into account, the analysis of data has been made as follows. For each Subject, all RTs from the three conditions were ranked and split into 4 classes: the new first class, NC1, consisting of the first 500 slowest RTs; NC2, consisting of the next 500 slowest RTs; NC3, the following 500 RTs, and NC4 the final 500 shortest ones. The choice of 4 classes was dictated by two opposite requirements: estimating as many points as possible of the speed-accuracy relationship and yet maintaining an adequate number of observations per estimated point. Because we planned to analyze the data both per condition and per stimulus, a reasonable compromise resulted in 500 observations per class. Again, however, the implicit assumption underlying this rationale is that the central mechanism under study does not vary with different "external" speed instructions.

In order to compare our data with those previously reported, the compound speed-accuracy trade-off has been calculated for the new classes; this is shown in Figure 1. Four points give only a rough

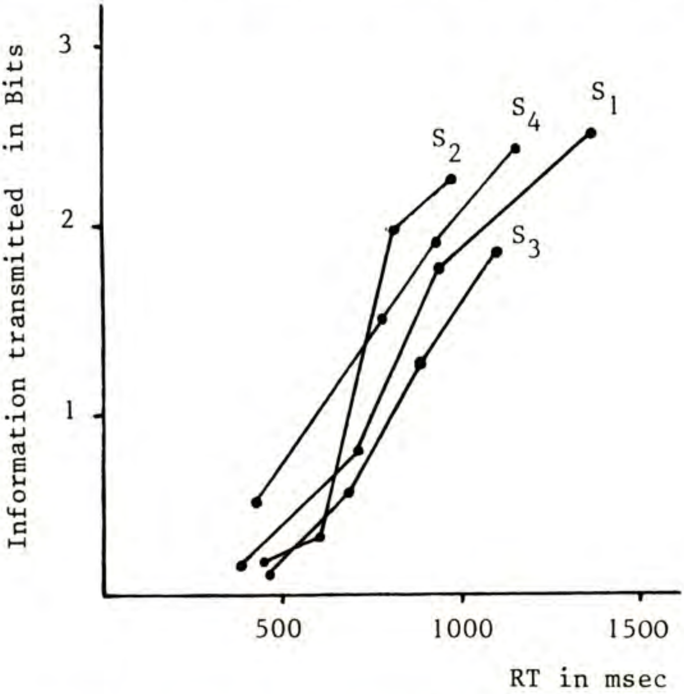

FIG. 1. SPEED-ACCURACY TRADE-OFF FUNCTIONS FOR EACH SUBJECT

shape of the real function, but some comments may still be made. First, some information, though less than half a bit, it transmitted even in very fast responses, NC4. This may be explained by a few correct responses above chance level, but hides the exact zero performance level. Second, maximal information transmission is never reached. Even if one considers only the responses obtained in the accuracy emphasis condition, C1, performance is not perfect: 3.03, 3.05, 2.61, and 3.04 bits depending on the Subject (instead of 3.32 bits).

Pachella and Fisher (1969), in a similar experimental design, reported the same findings. Perhaps, the Subjects have not had sufficient practice to reach perfect performance even when under no speed stress, but it could also be argued that they were subjectively always under stress. These two factors render it difficult to determine the slope of the trade-off function because of the S-shaped function observed. However, considering only the steepest part of the observed curves, the slopes are 5.9, 10.0, 4.5 and 4.0 bits/sec. These values are higher than those reported by Pachella and Fisher (1972), i.e. 3.02, 3.36 and 3.69 bits/sec. for 8, 4 and 2 alternative conditions. The experimental conditions, however, were not identical, and it seems established (Briggs & Shinar, 1972) that the noise level interacts with the slope of the speed-accuracy trade-off. Another source of divergence may arise from the method of response: oral in the present study, manual in Pachella and Fisher's.

In order to evaluate more fully the processing of individual stimuli, a detailed examination of response confusions to each stimulus was undertaken. Analysis of the dispersion of responses to each stimulus was made using an information measure, $H_{S_i}(R)$, i.e. response uncertainty conditional upon the individual stimulus. Actually, $H(R)—H_{S_i}(R)$ values have been computed for each S_i, i.e. the maximum variety of responses minus the variety of the same responses when the stimulus S_i is known. This is equivalent to an information transmission measure for each individual stimulus; we shall refer to these values as to the response convergence values. The speed-accuracy relationships for each separate stimulus are reported in Figure 2 for each Subject. As the slopes are in general the same as for the mean curves, the same comments as above can be made. However, Figure 2 clearly shows that the different stimuli are not equivalent: the different curves are not randomly distributed around the mean curve (Figure 1). Some stimuli yield different speed-accuracy trade-off functions than do the others. Indeed, the response convergence is systematically better for some stimuli: extreme stimuli (1 and 10), for example, are more accurately identified than the others, without requiring longer processing time. In reference to the well known ordinal position effects on absolute judgment performance, it could have been foreseen that extreme categories, as objective physical anchors, would be more accurately identified. One possible explanation could be that end points differ from other stimuli on a continuum in that they have fewer neighbors with which to be confused; that is to say, the leftmost stimulus has nothing to the left of it and the rightmost stimulus has nothing to the right of it, which is not true of other stimuli in the array. Another way to make that point is to say that the end points are perceptually distinct in the sense that they do not occur within a context of several potential confusers on either side. The data, however, also illustrate the presence of another privileged position around the middle of the continuum. Although this position cannot be referred to as an objective physical anchor, our data clearly show that it could be used as a subjective central anchor, depending on the Subject's capability of halving a given

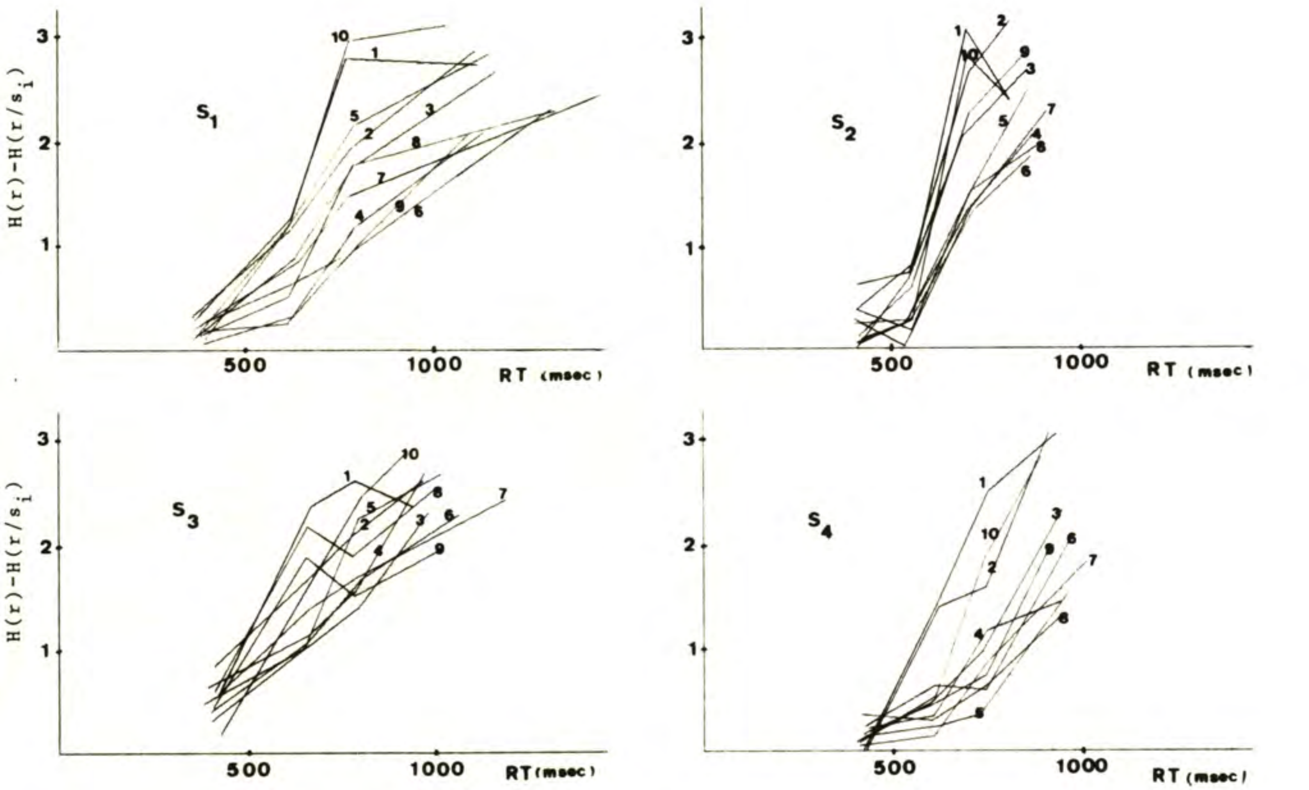

FIG. 2. RESPONSE CONVERGENCE (IN BITS) AS A FUNCTION OF THE RESPONSE LATENCY, FOR EACH STIMULUS AND FOR EACH SUBJECT

visual space. This subjective anchoring appears to be less efficient than the physical anchoring of the end points; this can be explained either by the relative uncertainty related to the halving of the visual field, or perhaps by the time needed for this halving, or both. Finally, stimuli adjacent to the anchored ones may benefit from this proximity, and thus be better identified than the non-adjacent ones. For the reasons already given, it would be hasardous to quantify the differences in slopes of the trade-off functions. Nevertheless, it should be noted that the slopes for stimuli 1 and 10 are very similar for all Subjects: 9.5 and 10.0, 15.0 and 16.0, 7.4 and 8.3, 6.8 and 5.6 bits/sec, and that these values are much higher than the corresponding mean values quoted before. This would indicate a particular processing of these stimuli, or that the central processing of a stimulus depends on the ordinal position of the stimulus to be processed. This is perhaps more distinct in Figure 3, where the response convergence is plotted per stimulus for each new class of RTs. When the Subject has very little time to process the given information, as in condition NC1, all the stimuli are alike, allowing a very low transmission. As more time becomes avilable (from NC2 to NC4), performance improves, but not in the same way for each stimulus. The existence of a strategy selectively promoting some stimuli—corresponding to emerging peaks in Figure 3—seems evident. Furthermore, a certain hierarchy holds even in the easiest condition, NC4: indeed, some stimuli require substantially more time and still result in poorer performance.

GENERAL DISCUSSION

The results of the present investigation confirm and extend previous findings concerning the relationship between the speed and the accuracy of performance. As it is particularly clear from examination of Figures 2 and 3, they also provide evidence showing that processing strategies may be involved in identification performance. Actually, many —perhaps most— psychological investigations show that there are cognitive strategies involved in decision making processes. Yet, the exact nature of these strategies and the question of where in the stage of processing they occur really seem to be the frontier issues. Regarding absolute judgement performance, it has been shown that such strategies may depend on the task and on the amount and type of training (Cuddy, 1970; Hupet & Citta, 1973); it also seems to depend on subjective preferences of the decision maker: one may observe, for instance, differences as regards the choice of a central anchor. However, more precise and quantitative assumptions concerning the nature of such strategies will be needed to advance our understanding of the decision process. Briggs and Shinar (1972), for instance, produced some results suggesting that the speed-accuracy trade-off should be localized in the initial stimulus encoding stage of processing, i.e. in sampling more or less information from a short-term memory store. In this respect,

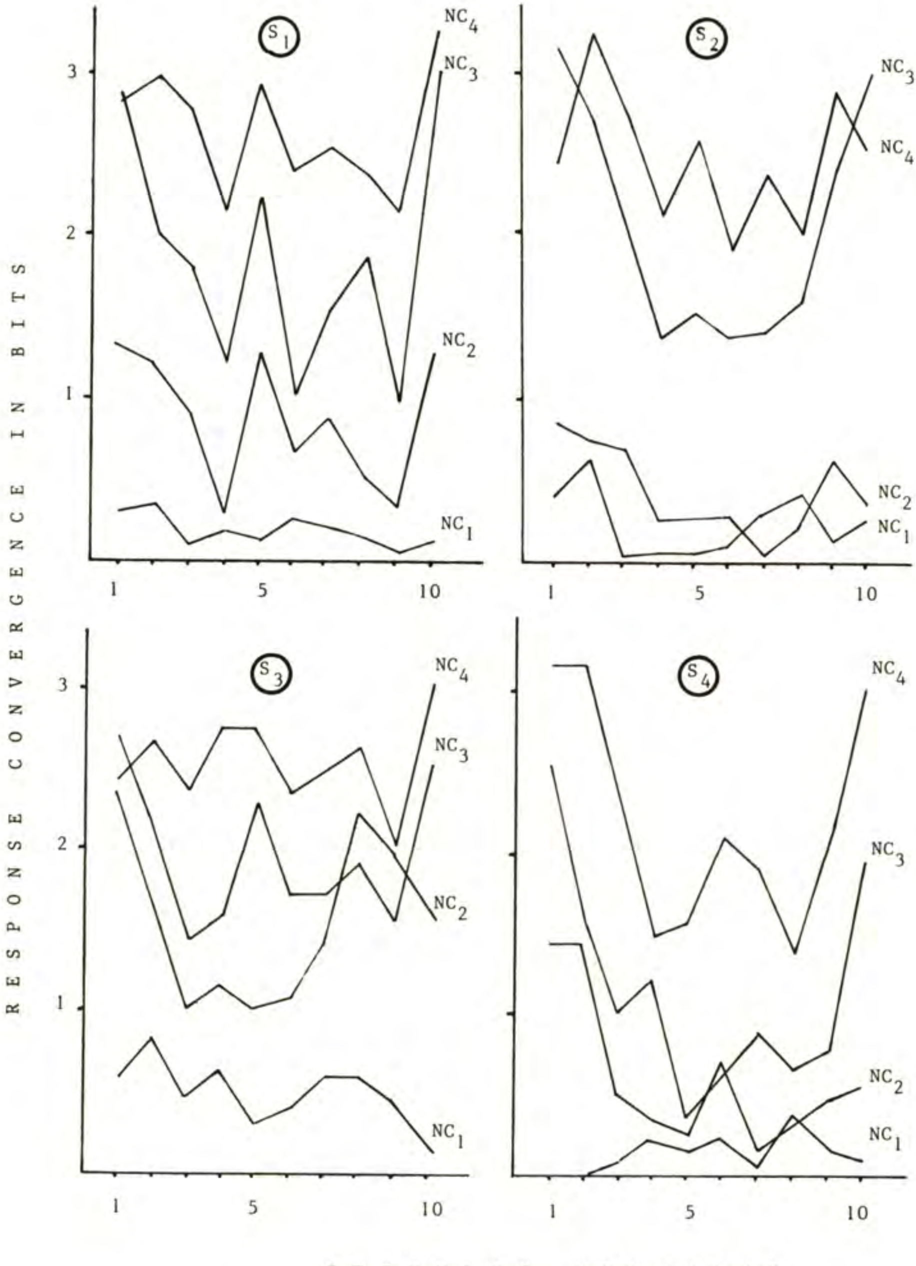

FIG. 3. RESPONSE CONVERGENCE (IN BITS) AS A FUNCTION OF THE STIMULUS POSITION, FOR EACH NEW CONDITION (NC) AND FOR EACH SUBJECT

a detailed analysis like that reported in the present study, might help to state more precisely and, perhaps to solve, fundamental questions such as: 1. Is the sampling rate equal for each stimulus? This would imply equal slopes in the trade-off curves; 2. Does every stimulus require exactly the same sampling time before transfer to further stages as classification and decoding? This would imply equal intercepts of the trade-off functions. It would be hazardous to squeeze the present data and to use them to check different models or strategies. Indeed, it is, first, difficult to reach good estimates of the "random" level and of the "perfect" performance level; second, there is an actual lack of definite rationale for grouping RTs one way over another, and this may introduce a possible bias due to a given partitioning. Nevertheless, the present data suggest that using a detailed analysis of responses might allow a sharper testing of some decision models. For instance, as concerns the sequential processing model (e.g., Hick, 1952; Welford, 1971), a detailed analysis per stimulus would permit tracking off the structure of the sequence; indeed, at a given moment of the decisional process, this analysis should show how some stimuli are still confused while others are already distinguished.

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