What these data do indicate is that the growth function of trace strength may not be as simple as is currently believed or, alternatively, that the relationship between different indices of trace strength (degree of correctness, subjective certainty, and response latency) is more complex than has as yet been imagined.

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Probability and expectancy in two-choice reaction time*

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RTs were measured to two stimuli which were presented in a 2 : 1 ratio. The mean RT was inversely related to the probability of stimulus presentation, but no difference was found when the mean RT was calculated conditional on Ss' predictions of stimulus presentation. The probability effect in choice RT was interpreted as depending upon a weighted combination of fast RTs to correctly predicted stimuli and slow RTs to incorrectly predicted stimuli.

Two recent theories of choice reaction time (RT) have been proposed which use expectancy concepts (i.e., states of preparedness or subjective probability) to account for various effects commonly found in choice RT experiments (Falmagne, 1965; Laming, 1969). In these theories the expectancy state is hypothetical and is not directly observable. One possible way to assess the expectancy of the S is simply to ask him to predict which stimulus will be presented next.

Several experiments have demonstrated that the RT to correctly anticipated stimuli is shorter than to incorrectly anticipated stimuli (e.g., Bernstein & Reese, 1965). Hinrichs & Krainz (1970) have shown that the difference in RT to correctly and incorrectly predicted stimuli is due to a stimulus-expectancy effect rather than to differential preparation to execute the associated responses. The purpose of the present study was to extend the application of expectancy effects to stimulus probability effects in two-choice RT experiments.

The probability effect, also called the frequency or uncertainty effect, refers to the relationship between RT and the probability of stimulus occurrence: as the probability of a stimulus increases, the RT to that stimulus decreases (see Smith, 1968, for a recent review). Because Ss tend to match their predictions of stimulus presentations to the a priori probability of occurrence (e.g., Estes, 1964), a possible interpretation of the probability effect in two-choice RT is that the difference in RT is a function of the probability of a correct anticipation. As the probability of occurrence increases, the probability of predicting that stimulus also increases and, correspondingly, the probability of a correct prediction increases. Therefore, the difference in mean RT to stimuli with different frequency might be attributed to the relative proportion of RTs to correctly and incorrectly predicted stimulus occurrences.

Bernstein & Reese (1965) have already shown, in an experiment which varied stimulus uncertainty across blocks of trials, that when RTs are partitioned into correct and incorrect predictions, a frequency effect is found only for incorrectly predicted stimuli. Across levels of stimulus uncertainty, as the stimulus information increased, the mean RT to incorrectly predicted stimuli increased; the mean RT to correctly predicted stimuli did not change. In the present experiment, the probability effect was examined within a single probability level rather than across levels. The primary goal of the study was to assess the adequacy of stimulus predictions as a measure of subjective expectancies and to examine the extent to which the frequency effect in two-choice RT may be explained as the weighted combination of expected and unexpected stimulus presentations.

SUBJECTS

Twenty-four University of Iowa undergraduates, 12 males and 12 females, served as Ss, fulfilling an introductory psychology course requirement. The Ss were randomly assigned to two groups, each group containing six males and six females.

MATERIALS AND APPARATUS

The stimuli were the digits 1 and 2, presented by an Industrial Electronic Engineers Bina-View self-decoding display cell (Model KA-12/12-093-E-1886) which has a 5.8 x 4.6 cm display screen. Each S was tested on eight blocks of 30 trials per block. Within each block one stimulus occurred twice as often as the other. The assignment of 1 or 2 as the more-frequent (MF) or less-frequent (LF) stimulus was counterbalanced across Ss but maintained across all eight blocks of trials for each S.

The presentation of the stimuli was controlled by prepunched paper tapes.

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Table 1
Conditional Predictions and Reaction Times (in Msec) for Group P

Measure	Condition (Stimulus Presented/Stimulus Predicted)			
	MF/MF	MF/LF	LF/MF	LF/LF
Number of Observations	1148	701	522	391
Theoretical Proportions	.444	.222	.222	.111
Observed Proportions	.416	.254	.189	.142
Mean of Median RTs	424	474	486	422

Response latencies were measured to the nearest millisecond by a Hunter digital readout timer (Model 1520) and manually recorded by the E. The S was separated from E and the programming equipment by a black partition. The Bina-View display screen on the S's side of the partition was mounted at eye level, approximately 30 cm from the seated S. Two identical thumb-operated response buttons, 2.5 cm in diam, were mounted 32 cm below the Bina-View cell and labeled as Button 1 and Button 2. Assignment of Button 1 and Button 2 to the left or right hand was counterbalanced across Ss.

PROCEDURE

All Ss were instructed to respond to the presentation of the stimulus as accurately and rapidly as possible by pushing the appropriate response button. The Ss were informed about which stimulus would occur more often and that it would occur approximately twice as often as the other stimulus. The 12 Ss in the predict (P) group were further instructed to attempt to guess which stimulus would occur on each trial. The Ss in the no-predict (NP) group were not so instructed. Each trial was initiated by E without knowledge as to which stimulus would be presented after the S made his prediction (Group P) or verbally indicated that he was ready for the next trial (Group NP). Each S received a 10-trial practice tape before beginning the experimental sequence.

RESULTS

Each S contributed 240 observations for a total of 2,880 observations in each condition. A total of 73 response errors were observed, 45 in Group P and 28 in Group NP, for an overall error rate of 1.3%. An additional 105 E errors occurred (clock failures, recording errors, etc.), 73 in Group P, 32 in Group NP. The remaining responses were partitioned into categories according to the stimulus predicted (in Group P) and the stimulus presented (in both groups). A mean and median RT were calculated for each S in each response category. The same pattern of results was observed with both the mean and the median measures. Consequently, only the results based on the medians will be considered, and the means reported below are based on the individual S medians.

When Ss' predictions were disregarded, the frequency effect was found for both groups. In Group P, ignoring Ss' predictions, the mean RT to the MF stimulus was 446 msec and the mean RT to the LF stimulus was 463 msec. In Group NP the mean RTs to the MF and LF stimuli were 440 msec and 473 msec, respectively. The difference between the RT to the MF and LF stimuli was reliable, $F(1,22) = 27.49$, $p < .001$, but neither the difference between groups $[F(1,22) < 1]$ nor the Groups by Stimulus Frequency interaction $[F(1,22) = 2.75, p > .05]$ was significant.

Within Group P, when the observed RTs were sorted into categories conditional upon the Ss' predictions, a very different pattern of results emerged. As shown in Table 1 and as confirmed by an analysis of variance, RTs to correctly predicted stimuli were faster than to incorrectly predicted stimuli, $F(1,11) = 47.32$, $p < .001$, with a mean RT of 423 msec to correctly predicted stimuli and 480 msec to incorrectly predicted stimuli. However, the difference between the mean RT to the MF stimulus and to the LF stimulus was not significant, $F < 1$. The magnitude of the effect was reduced, from a mean difference of 17 msec in the unconditionalized data to a mean difference of 5 msec, when the RTs were conditionalized on stimulus predictions. The interaction of Stimulus Frequency by Prediction Correctness was significant, $F(1,11) = 5.17$, $.025 < p < .05$, showing a tendency for a greater MF-LF difference with incorrect predictions than with correct predictions.

As shown in Table 1, the Ss closely matched their predictions to the proportions to be expected on the basis of probability matching. The observed proportion of predictions of the MF stimulus of .605 was a slight undershooting of the presentation probability of .667. The observed probability of a correct prediction, .558, closely approximated the expected probability of .556. In order to account for the observed probability effect in choice RT, the important observation is the proportion of correct predictions within each stimulus presentation condition. For the MF stimuli, 62.1% of the RT scores were responses to correctly predicted stimuli, but only 42.8% of the LF stimuli were correctly anticipated.

DISCUSSION

The results show that when RTs are averaged only over the stimulus presented, the usual probability effect is found. However, when the correctness of the S's prediction is taken into account, the probability effect virtually disappears. No probability effect is found within the set of correctly predicted stimuli or within incorrectly predicted stimuli. The occurrence of the probability effect in the first analysis and not in the second can be attributed to the differential weighting of the scores in the two analyses and to the tendency of the Ss to match their predictions to the observed probability of occurrence of each stimulus. When the Ss' predictions are disregarded, the RTs to the MF and LF stimuli are based upon different proportions of correctly and incorrectly predicted stimuli. Due to the tendency of Ss to probability match, the MF stimuli have a greater relative proportion of correct predictions than do the LF stimuli. Because RTs to correct predictions are faster than to incorrect predictions, a greater proportion of correct predictions in the MF condition than in the LF condition would produce an apparent faster mean RT to MF stimuli.

The generality of the present results must be limited to instances of moderate probability differences; a probability effect within correct or incorrect predictions may become evident with more extreme differences in stimulus-presentation probabilities (cf. Bernstein & Reese, 1965). However, even if probability effects do occur after adjustment for Ss' predictions, the magnitude of the effects are likely to be greatly reduced. A large portion of the probability effect in two-choice RT experiments may be attributed to the relative proportions of correctly anticipated stimuli in each experimental condition, as indicated by Ss' verbal predictions.

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