Applying RT deadlines to discrimination reaction time*

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Five Ss discriminating differences between a fixed standard line length and five comparison line lengths performed under three randomly presented RT deadlines. Analyses of response measures, conditional upon the RT deadline of a preceding trial, showed that on a trial-to-trial basis, S could shift both accuracy and RT performance to meet the demands of a new RT deadline. There was no influence of the RT deadline used on Trial n − 1 on performance on Trial n.

Placing RT deadlines on a discrimination RT task provides a method for interrupting an ongoing process at E-contrived times. The method has been used by numerous Es (Fitts, 1966; Pachella & Pew, 1968; Yellott, 1967, 1971; Link & Tindall, 1971) in order to change response accuracy in both discrimination and choice RT experiments. Yellott (1971) has suggested that the effect of an RT deadline in CRT experiments is to alter a mixture of fast guess and choice RT distributions. On the other hand, Link & Tindall (1971) showed that in discrimination RT, the effect of changing an RT deadline could not be interpreted as simply producing a change in the probabilities defining a mixture of two distributions. However, within an RT deadline, changes in stimulus similarity produced RT results consistent with a two-state mixture theory of discrimination RT. With a fixed RT deadline, latency distributions associated with states of the model remained invariant as stimulus similarity decreased. But changes in the RT deadline produced changes in the latency distributions associated with states of the model. The results suggested that in order to meet the demands of an RT deadline, Ss exert control over their discriminative RT distributions.

Since Ss control their RT distributions in order to meet an E-imposed RT deadline, it is possible for the E to track the temporal development of a perceptual discrimination by imposing RT deadlines on the experimental task. In each RT deadline condition, mean results can be computed so that increases in accuracy performance can be compared across increases in RT in order to examine the trade of speed for accuracy. To obtain adequate data, the E may find trial-to-trial changes in the RT deadline a convenient means of avoiding statistical difficulties produced by gathering data in blocks of trials where mean RT may be influenced by practice, fatigue, or other systematic effects. But the use of trial-to-trial changes in RT deadlines may introduce a collection of undesired results. For example, a change from one RT deadline to another may not influence RT performance immediately. A series of trials, at the new RT deadline, may be required before a state of responding uninfluenced by the shift in RT deadlines is reached. If so, more complications would be introduced than would be avoided and a careful E would not randomize RT deadlines over the trials of an experimental session. Alternatively, the results obtained by Link & Tindall (1971) indicate that Ss have a much greater degree of control over discrimination RT than had previously been known, and RT control may be sufficient to allow one-trial shifts in performance when RT deadlines are presented at random. Ss may, for example, choose a critical count for a temporally correlated counter and simply respond when the critical count is reached. If several RT deadlines result in S choosing several critical counts, then changes from trial to trial in RT deadlines may simply produce trial-to-trial changes in S's critical count. In the latter case, trial-to-trial changes in RT deadlines would be a convenient method for tracking the speed accuracy tradeoff.

The experiment reported here was designed to determine if there was any influence on mean RT by RT deadlines which were varied from trial to trial. It was found that Ss could immediately shift performance to meet demands of the RT deadline on Trial n. No systematic effect of the RT deadline of Trial n − 1 on the response measures for Trial n was found.

METHOD

Five right-handed university students were each paid $24.00 to participate in 12 experimental sessions. A session, lasting approximately 50 min, consisted of two blocks of 250 trials each, separated by a rest period of 5 min. On each trial, S initiated a sequence of trial events by depressing a trial initiation key (TIK). During the depression of TIK, a ready signal, the character R, together with an RT deadline in milliseconds were presented for 500 msec on a computer-controlled oscilloscope (Tektronix 602 with P4 phosphor) placed 1 m in front of the S. Immediately following the ready-signal/deadline display, the first of two horizontal line segments was presented for 200 msec, followed by an interstimulus interval of 200 msec during which the oscilloscope display screen was blank. The second line segment was presented until S made a "same" or "different" response by releasing TIK and then, with the same hand, depressing one of two (80-g) microswitches. After responding, S could be informed via the oscilloscope whether or not the response was correct (YES or NO) and whether or not the RT deadline was exceeded (SPEED OK or TOO SLOW). Each feedback display lasted 500 msec and was followed by a new trial when S next depressed TIK. If, during any trial, S released TIK before the presentation of the second line segment, the trial was aborted but restarted with the next depression of TIK. The RTs were measured from the onset of the second line segment to the depression of one of the two choice response microswitches.

Five horizontal line segments, 2.0, 1.9, 1.8, 1.7, and 1.6 cm, were used throughout the experiment. For three Ss the 2.0-cm line segment was always the standard, and was presented as the first of the two line segments. For the remaining two Ss, the 1.6-cm line segment was the standard. The differences between the standard and comparison stimuli will be referred to as 0ΔS, 1ΔS, 2ΔS, 3ΔS, and 4ΔS, representing 0- to 4-mm differences. On each trial, the RT deadline was selected at random from a set of three deadlines: 260 or 460 msec, or accuracy (acc). The instructions to S indicated that both the RT deadline and difficulty of the task would vary from trial to trial and that the S was to "beat the time" while being as accurate as possible. For both the 260-msec and the 460-msec deadlines, Ss were given feedback on both speed and accuracy, while in the accuracy case only accuracy feedback was provided, but, in this case, a blank display replaced the usual RT deadline feedback display.

Each session yielded a total of 500

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Table 1
Estimates of the Probability of a Correct Response (P_c), the Mean Correct RT (M_c), and the Mean Error RT (M_e) for Each S and Averages Across Ss

S	Stimulus Difference	RT Deadlines 260 Msec P_c	M_c	M_e	460 Msec P_c	M_c	M_e	Accuracy P_c	M_c	M_e
BT	0Δ	.519	242	212	.793	399	340	.379	423	427
	1Δ	.545	224	214	.620	406	389	.570	456	414
	2Δ	.685	239	213	.895	394	371	.935	422	373
	3Δ	.675	241	203	.965	382	276	.975	398	310
	4Δ	.585	244	192	.970	374	284	.980	403	353
IC	0Δ	.455	227	215	.801	456	372	.801	588	546
	1Δ	.570	221	211	.500	421	416	.740	578	620
	2Δ	.620	214	206	.845	414	315	.935	483	442
	3Δ	.620	246	199	.925	389	246	.995	456	223
	4Δ	.575	248	205	.935	369	266	1.000	430	—
SJ	0Δ	.524	181	211	.809	452	360	.866	545	503
	1Δ	.545	194	173	.565	410	436	.610	558	578
	2Δ	.460	176	176	.945	416	417	.915	509	553
	3Δ	.470	201	191	.930	377	371	.985	467	752
	4Δ	.435	189	172	.960	374	322	.995	429	152
MB	0Δ	.480	174	175	.819	414	338	.929	538	627
	1Δ	.555	175	171	.585	400	412	.600	621	621
	2Δ	.550	191	177	.890	394	363	.960	524	560
	3Δ	.605	176	178	.965	393	352	.995	466	990
	4Δ	.615	198	166	.980	376	302	1.000	445	—
IT	0Δ	.339	231	207	.621	388	319	.916	566	681
	1Δ	.595	220	240	.680	357	370	.650	675	584
	2Δ	.675	222	205	.860	357	327	.940	538	642
	3Δ	.715	223	198	.960	350	329	1.000	496	—
	4Δ	.645	220	213	.955	345	246	.995	479	466
Average	0Δ	.463	210	204	.769	424	341	.878	531	541
	1Δ	.562	207	201	.590	397	407	.634	580	556
	2Δ	.598	211	192	.887	396	348	.937	495	511
	3Δ	.617	219	193	.949	378	312	.990	457	502
	4Δ	.571	221	188	.960	368	279	.994	437	338
Standard Errors	0Δ	.008			.007			.005		
	1Δ	.016			.016			.015		
	2Δ	.016			.010			.006		
	3Δ	.015			.007			.001		
	4Δ	.016			.006			.001		

observations. The first two sessions were ignored as practice sessions and in the remaining sessions the first 10 trials of a block were treated as practice trials and ignored. Within the 240 remaining trials of each block there were 120 0ΔS presentations and 30 presentations of each of the remaining four stimulus differences. Since the RT deadline was varied from trial to trial, equiprobably and at random, each RT deadline occurred on 80 trials. Thus, within each block, any combination of a particular RT deadline and KΔS (K = 0, 1, 2, 3, 4) yielded 40 observations for K = 0 and 10 observations for each of the four remaining values of K. Since two blocks constituted an experimental session and since there were 10 sessions and 5 Ss, there were 8,000 trials at each of the three RT deadlines split into 4,000 0ΔS observations and 1,000 observations for each of the stimulus differences greater than 0. In all, 24,000 observations enter into the analysis of the experiment.

RESULTS

Estimates of the marginal probability of a correct response, P_c, and the mean correct and error response times, M_c and M_e, are given in Table 1. Mean values, computed across Ss and standard errors are presented in the lower part of Table 1. From the average results, it is clear that in two conditions (460 msec and acc) mean RT varies as a function of ΔS, while for the 260-msec condition mean RT remains relatively constant across all values of ΔS. The probability of a correct response is, in general, smallest for a 1ΔS discrimination, larger for the 0ΔS case, and then increasingly large for 2, 3, and 4ΔS.

The major result from this experiment is pictured in Fig. 1. To obtain these results, the probability of a correct response and the mean correct and error response times were obtained for each RT deadline-ΔS combination, conditionalized on the RT deadline of the preceding trial. These results were then averaged across values of ΔS to provide a large number of observations. As can be seen in Fig. 1, shifts in performance, as measured by either probability or reaction time, are not dependent upon the RT deadline of the previous trial. It is particularly impressive that Ss faced with a task of responding within a 460-msec RT deadline can shift to the 460-msec deadline from either a 260-msec RT deadline or the acc condition and perform the same as when no change in the RT deadline occurred. Moreoever, the results in Fig. 1 are consistent in terms of correct response probability and mean correct and error response times.

The marginal results for the 460-msec RT deadline trials were expanded so that a detailed study of performances across the five levels of discriminable difference could be compared for cases where the RT deadline on the preceding trial was 260 msec, 460 msec, or acc. These results are shown in Table 2. It can be seen that within stimulus differences, the maximum range of differences in probability of a correct response is .044, while between stimulus differences, the maximum range is .397. We can be confident that the major source of variability can be attributed to stimulus differences, while for a particular stimulus difference the RT deadline of the preceding trial has little, if any, effect.

Similar conclusions can be drawn concerning the mean correct RTs where the largest difference in mean RT within stimulus differences is 15 msec (with a standard error of the difference of 10.0), while for between stimulus differences, the maximum difference in mean RT is 58 msec (with a standard error of the difference of 3.2 msec). Using the Studentized range based on within-S variances, it was concluded that

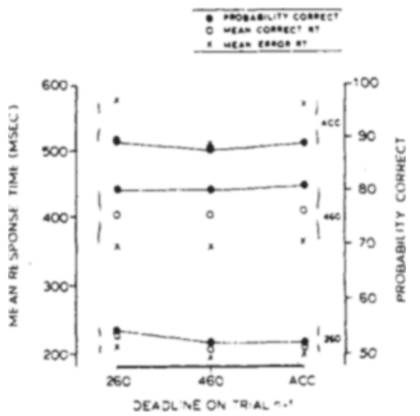

Fig. 1. Within brackets are placed results for each RT deadline on Trial n conditionalized on the RT deadline of Trial n − 1. Xs are estimates of mean error RT, and filled circles are estimates of correct response probability. Open circles represent estimates of mean correct response time.

Table 2
Results for the 460-msec RT Deadline Conditionalized Upon the RT Deadline of the Preceding Trial

Stimulus Difference	Estimates: P_c 260	P_c 460	P_c Acc	M_c (msec) 260	M_c 460	M_c Acc	M_e (msec) 260	M_e 460	M_e Acc	N 260	N 460	N Acc
0Δ	.762	.773	.771	428	425	428	353	330	348	1337	1241	1422
1Δ	.614	.581	.576	401	393	408	396	415	421	326	384	290
2Δ	.891	.892	.877	393	398	405	336	360	352	284	399	317
3Δ	.929	.943	.973	381	379	383	308	292	368	336	298	366
4Δ	.959	.952	.970	373	367	372	294	273	273	390	311	299

Stimulus Difference	Standard Errors: P_c 260	P_c 460	P_c Acc	M_c (msec) 260	M_c 460	M_c Acc	M_e (msec) 260	M_e 460	M_e Acc
0Δ	.012	.012	.012	3.4	3.7	3.4	8.4	5.4	6.6
1Δ	.027	.025	.029	8.2	6.6	10.0	8.2	7.7	8.7
2Δ	.019	.016	.018	7.8	5.6	6.5	13.5	12.8	14.4
3Δ	.013	.013	.010	5.2	5.6	3.9	13.7	17.9	23.4
4Δ	.010	.012	.010	4.2	5.7	6.0	15.6	15.8	24.7

Note—The number of observations, N, refers to the number of transitions from the specified deadline on Trial n − 1 to a 460-msec deadline on Trial n. The total number of transitions per block of trials will include a transition from Trial 10 to Trial 11 of each block.

differences between mean RTs existed between stimuli, but not across means conditionalized on the preceding trial RT deadlines. Similar results were not obtained for the mean error RTs largely because of small numbers of observations. In one case, only 9 observations were available, and, in another case, only 10 were available. Considering the large number of observations entering into the analyses of correct response probability and mean RT, it appears safe to conclude that response measures on Trial n are not systematically influenced by the RT deadline of the immediately preceding trial.

DISCUSSION

The major experimental result shown in Fig 1 indicates that trial-to-trial changes in E-imposed RT deadlines are immediately adjusted to by S. Whether the RT deadline was changed from 460 msec or acc to 260 msec, Ss can perform equally well. This result may not seem surprising given the extremely low mean RT for 260-msec deadline trials. Since S was required first to release a trial initiation (or home) key and then make a choice response by moving his hand approximately 10 cm forward to depress the choice key, the mean RT of approximately 200 msec is very fast indeed. Were it not for the slight differences in response probability as a function of ΔS given in Table 1, it might be concluded that all responding on the 260-msec deadline trials represented guessing from a state of minimum response time and minimal stimulus information. It appears more likely that performance on the 260-msec deadline trials is a mixture of trials associated with guessing and other trials where at least some discriminative performance occurs. Thus the fact that preceding a 260-msec deadline by a 460-msec or acc trial produces virtually identical results suggests that whatever mixture may exist is adopted on the basis of the E-imposed RT deadline and not on the basis of the deadline of the preceding trial.

A more interesting case of responses uninfluenced by the preceding trial's RT deadline is when a 460-msec deadline is imposed on S. In this case, if the deadline of a preceding trial was 260 msec, then S's RT and acc are both increased. If an acc trial preceded the 460-msec deadline trial, then both RT and acc decreased. The fact of interest is that from a 260-msec deadline, S pushes performance up to the same level that he pushes his performance down to from an acc trial. Furthermore, the change from a 460-msec deadline to a 460-msec deadline produces results identical to those obtained when the deadline on the prior trial was either 260 msec or acc. This strongly suggests that performance under an RT deadline may be dominated by the temporal constraints of the task and supports conclusions drawn from previous experiments (Link & Tindall, 1971).

Conclusions similar to those drawn from 260- and 460-msec deadline results can be obtained from acc trial results, although there is a significant compromising result. Since the mean error RT for an acc trial preceded by a 460-msec deadline is substantially, and significantly, different from other mean error RTs, it is conceivable that S sometimes fails to shift into a mode of responding determined by only maximal acc. If so, the argument that RT deadlines produce S-controlled RT distributions is not damaged, since the inability to switch from a 460-msec deadline trial to unrestricted RT responding implies that RT is somehow controlled on the preceding 460-msec deadline trial. Finally, measures of correct response probability and mean RT are not affected by the deadline of the preceding trial. Thus even results from acc trials support the notion that RT deadlines on Trial n − 1 have little, if any, influence on performance on Trial n.

From the results shown in Fig. 1, together with the results in Table 2, we may conclude that the presentation of an RT deadline has an immediate effect and is sufficient to promote a marked change in S's responding. Naturally it is the nature of the change that is most interesting.

The marginal results in Table 1 provide corroborative evidence for two different views of discrimination RT performance. In particular, the marginal probabilities indicate that across stimulus difference greater than zero there exists a virtually constant difference between correct response probability on 460-msec and acc trials. These data are shown in Fig. 2 and support a similar finding (also shown in Fig. 2) reported earlier (Link & Tindall, 1971). Although differences in the level of responding may depend upon Ss, experimental design, stimulus differences, and RT deadlines, the differences between measures of

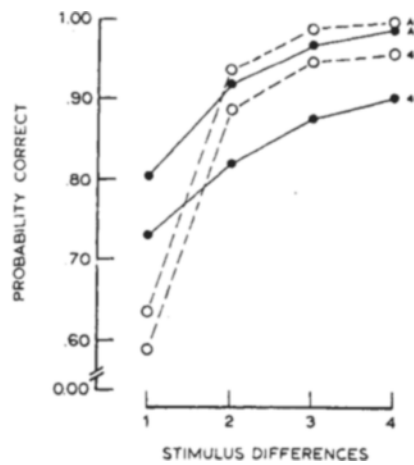

Fig. 2. Estimates of correct response probability across stimulus differences for each of two RT conditions in two similar experiments. Filled circles represent results from Link & Tindall (1971); open circles represent results from the present experiment.

probability of a correct response are not influenced by these factors.

The interpretation of the result depends upon differences in probability correct between stimulus differences. For example, the difference between correct response probabilities for 1ΔS and 2ΔS stimulus differences on a 460-msec deadline trial is the same as the difference on an acc trial, although the value of probability correct on acc trials exceeds that of the 460-msec deadline trials. Consequently, the constant difference between correct response probabilities for any two stimuli exists long before asymptotic responding is reached.

In a sense, this result argues in favor of a view of discrimination RT similar to the sequential sampling scheme for choice RT proposed by Laming (1968). In Laming's theory, S places constraints on Kullback's (1959) discrimination information statistic, so that over time the information statistic, in performing a random walk on the dimension of posteriori choice probabilities, eventually reaches one of two choice probability bounds. S then makes the choice response corresponding to the boundary reached by the discrimination information statistic. In the present experiment, where S judges stimuli to be either the same as or different from a standard, only two boundaries are necessary to determine the choice response. As increasingly stringent RT deadlines are placed on S, a constant reduction in correct response probability could occur by a simple change in the boundary set for the information statistic. In addition, S would need no more than one pair of boundaries for each RT deadline in order to perform adequately under trial-to-trial changes in RT deadlines.

Although the results are not incompatible with a form of sequential analysis RT theory, neither are they incompatible with a simple alarm clock model of RT. In this theory, it would be assumed that S controls a parameter of his RT distribution so that only a small number of long RTs exceed the RT deadline. By using only three parameters, S could perform trial-to-trial shifts in RT distribution and thus meet the RT deadline constraints. However, the nature of the decision theory needed to account for constant increases in correct response probability as the RT deadline changes from 460 msec to acc is unknown.

It has been suggested by Audley & Mercer (1968), Thomas (1971), and others that discrimination RT is related to the absolute distance of an evoked sensory representation of a stimulus from a S-controlled decision criterion. Assuming the usual signal detection model, the assumption is simply that the nearer a sensory value is to the S's decision criterion, the more difficult the decision and (consequently?) the longer the RT. If, in the present experiment, we assume that for any fixed RT deadline there exists a single sensory distribution for the standard and a series of sensory distributions for the comparison stimuli, and a single decision criterion, then the response "same," given a difference between the standard and comparison, can be thought of as a miss. According to the Audley and Mercer and the Thomas notion, median RT for misses should increase as the probability of a miss decreases. The results from the present experiment do not confirm this rather general prediction.

In summary, it has been shown that trial-to-trial changes in RT deadlines can be tracked by the S and that the influence of the RT deadline used in Trial $n - 1$ on the S's performance on Trial n is, if existent, minimal. The marginal probability results indicate that S could operate in a manner consistent with Laming's (1968) theory for choice RT. But the data are also consistent with an alarm clock view of RT control. Future experiments designated to distinguish between the different views of discrimination RT can benefit from the empirical results that, on a trial-to-trial basis, Ss can alter performance to meet the demands of randomly presented RT deadlines.

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