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US ARMY MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY 40121

REPORT NO. 817

EFFECTS OF THE INTENSITY OF AUDITORY AND VISUAL READY-SIGNALS ON SIMPLE REACTION TIME

(Interim Report)

by
Captain David L. Kohfeld, MSC

13 March 1969

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UNITED STATES ARMY
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EFFECTS OF THE INTENSITY OF AUDITORY AND VISUAL READY-SIGNALS ON SIMPLE REACTION TIME

(Interim Report)

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ABSTRACT

EFFECTS OF THE INTENSITY OF AUDITORY AND VISUAL READY-SIGNALS ON SIMPLE REACTION TIME

OBJECTIVE

To apply a decision-theory model to the effects of ready-signal intensity on simple reaction time (RT). To investigate whether cross-modal presentation of ready- and response-signals (visual-auditory) would produce effects similar to those obtained when both signals were in the same modality (auditory-auditory).

METHOD

Two experiments were conducted, 16 soldier subjects in each. In Exp. I, Ss were given a RT test on five consecutive days with a different auditory ready-signal condition on each day. In Exp. II, visual ready-signal conditions were presented on four consecutive days.

SUMMARY

The results indicated that a 90-db ready-signal produced the slowest mean RT, a Feedback condition the fastest, while 30-db, 60-db, and a random combination of ready-signals produced intermediate RTs. These results were true for both auditory and visual ready-signal conditions.

CONCLUSIONS

The results were consistent with a decision-theory model which assumes that the rate at which neural impulses accumulate is determined by the intensity of a stimulus input, whereas the number of impulses required for a response is determined by the value of the detection criterion. It was concluded that response-signal intensity determined the slope of the input function, whereas ready-signal intensity influenced the value of the detection criterion. Practice effects and individual differences were assumed to influence the detection criterion. The fact that visual ready-signals influenced the criterion in the same manner as auditory ready-signals indicates that ready-signal effects, and presumably the criterion, are not restricted to peripheral mechanisms, but reflect a process which could be termed central in nature.

EFFECTS OF THE INTENSITY OF AUDITORY AND VISUAL READY-SIGNALS ON SIMPLE REACTION TIME

INTRODUCTION

Previous investigations of simple reaction time (RT) have demonstrated that the stimulus context in which a RT signal is presented is an important factor in determining the speed of response. For example, Grice and Hunter (5) reported larger intensity effects when two signals were presented randomly to the same group than when each signal was presented to a separate group. That is, contextual effects were apparent when Ss received more than one response-signal intensity per session and comparisons were within groups. The role of context was studied further by Murray and Kohfeld (13) and Kohfeld (7) who found that preadapting Ss to various stimuli just prior to participation in an RT experiment significantly modified the resulting intensity functions in accordance with the average intensity of the preadaptation stimulus. Experimental manipulation of other variables, such as the temporal interval between signals (3), the distribution of intensity values (12) and the intensity of the ready-signal (8), also indicates that RT is significantly affected by the relationship of a response-signal to previous experimental events.

One manner of conceptualizing the contextual phenomena observed in RT situations is in terms of adaptation-level (AL) theory. Since the theory predicts that the excitatory strength of a stimulus depends on its distance from AL, Grice and Hunter (5) accounted for large within-S intensity effects by assuming that exposure to two intensities of test stimuli produced an AL between the two values, whereas exposure to only one intensity resulted in an AL at that particular value. Other studies (7,8,13) were also consistent with AL theory, as these experiments collectively indicated that both preadaptation stimuli and RT ready-signals contributed to the effective stimulus context in which the response-signals were presented.

In spite of the successes of AL theory in accounting for a variety of contextual phenomena (3), some writers contend that AL theory does not contain a specific principle of response evocation (4,12). These writers suggest that certain contextual variables (e.g., within-S presentation of stimuli and preadaptation procedures) can appropriately be viewed as influencing the detection criterion, a concept which is derived from McGill's (10,11) decision-theoretical approach to stochastic latency mechanisms. The strategy employed by McGill was based on the observation that RT distributions tend to be positively skewed. One advantage of describing RT data by an appropriate distribution, e.g., a gamma distribution, is that the parameters of the distribution can provide insights into underlying processes. Thus, the parameter n of the gamma distribution may reflect the number of events which comprise an observed latency, whereas the parameter m reflects the rate at which the hypothetical events accumulate. This reasoning led McGill to postulate that the onset of a RT signal initiates a sequence of neural events which are accumulated over time. The S will respond to the signal when the cumulative impulse count reaches some predetermined number which corresponds to the value of his detection criterion. The latency of S's response is a measure of the time required for the impulse count to reach the criterion value. Since the impulse rate is determined by stimulus intensity and the impulse number is determined by the value of the detection criterion, the model predicts that RT will vary as a function of stimulus intensity and criterion level, respectively. Thus, any experimental manipulation which raises or lowers the criterion will have a corresponding effect on RT. It is in this latter respect that the concepts of AL and detection criterion are analogous, as both theoretical approaches often make similar predictions regarding the effects of contextual variables on reaction latency.

The two experiments reported here dealt with the effects of ready-signal intensity on RT. The primary aims of the research were twofold. First, an attempt was made to apply the decision-theoretical approach to the results. Based on the findings of previous studies (1,8), it was hypothesized that high intensity ready-signals would produce longer mean RT than lower intensity ready-signals. If McGill's model is applicable, the hypothesized differences in RT offer evidence for the assumption that variations in ready-signal intensity produce corresponding changes in the value of the detection criterion. The second purpose of the present research was to investigate whether cross-modal presentation of ready- and response-signals (visual-auditory) would produce effects similar to those obtained when both signals were in the same modality (auditory-auditory). Since the visual ready-signal magnitudes employed in Exp. II were equated with the auditory ready-signals presented in Exp. I, it was possible to determine whether modality was the limiting factor in the identification of ready-signal effects.

EXPERIMENT I

Method:

Subjects. The Ss were 16 soldiers who were assigned to the laboratory after completion of basic training. A medical examination verified their physical health, and all Ss were free of visual and hearing defects. The Ss were assigned randomly to the various experimental conditions.

Apparatus. The experiment was conducted in a double-wall, sound-treated chamber which was totally dark during the entire RT session. The Ss were seated in a desk chair which had a conventional telegraph key clamped on its arm. The ready- and response-signals were three 1,000-cycle tones having intensities of 30-, 60-, and 90-db, SPL. The tones were generated by an audio oscillator, and after appropriate attenuation, were presented through calibrated earphones by means of an electronic switch with a rise and decay time of 10 msec. The durations of the ready- and response-signals were .5-sec and 1.5 sec, respectively. Foreperiods of 1, 2, or 3 sec were given in irregular order on successive trials. There was a 15-sec interval between response-signal offset and ready-signal onset. Timing of events was regulated by interval timers operating in a repetitive sequence. A paper tape reader and a system of shielded relays were used to select the foreperiod and tonal stimuli according to a programmed sequence. RT was registered in msec by an electronic counter.

Procedure. Each S participated in five consecutive RT sessions, one 45-min session per day. Prior to Session 1, the S was read conventional RT instructions. Each session was preceded by a 10 min period of dark adaptation during which the S sat quietly in the darkened sound booth. The S was then instructed over an intercom to adjust his earphones and place his right index finger on the telegraph key. Fifteen unscored practice trials ensued during which the S became familiar with pressing the key as fast as possible to the second of two successive tones. A total of 90 scored trials per session was presented. A short rest period was given between each block of 30 trials. During each session, the Ss were administered the same order of 30-, 60-, and 90-db response-signals, presented in random order with the restriction that there were 10 presentations of each signal in each block.

Four ready-signal conditions were presented to the 16 Ss in a counterbalanced order on the first four consecutive days. For three of the conditions, the same ready-signal (30-db, 60-db, or 90-db) was presented throughout the entire session. The fourth condition (Random) involved presenting each ready-signal an equal number of times within each block of 30 trials. On Day 5, all the Ss were given the same condition (Feedback) in which a 30-db ready-signal was given on all 90 trials and feedback of RT was reported over the intercom after each trial.

Results and Discussion:

The data were analyzed according to an Orders X Conditions X Intensities analysis of variance. Significant sources of variation were attributed to response-signal intensities, F (2,24) = 130.79, $p < .001$; ready-signal conditions, F (4,48) = 17.52, $p < .001$; and to the Conditions X Intensities interaction, F

(8,96) = 2.55, $p < .025$. The large effect due to response-signal intensity replicated the common finding that RT undergoes a systematic decrease with a corresponding increase in stimulus intensity. The absence of an effect due to Orders (F = 0.19) indicated that counterbalancing procedures were statistically adequate. Mean RTs in msec for the five ready-signal conditions were as follows: 90-db, 304; Random, 289; 60-db, 284; 30-db, 267; and Feedback, 234. In view of the significant Conditions effect, the hypothesis that RT is related to ready-signal intensity was confirmed. It is of additional interest to note the similarity in mean RTs for the 60-db and Random conditions. Further inspection of the data revealed that Ss in the Random condition did not respond differentially to the 30-, 60-, and 90-db ready-signal trials. This finding is consistent with the results of a previous study (8) where random presentation of ready-signals produced RTs that were similar to those obtained when a single ready-signal value at the mean of the stimuli was presented. When ready-signals are presented in an unpredictable order, it appears that Ss maintain an effective reference level which is intermediate among the intensity values. Finally, the significant Conditions X Intensities interaction is meaningful when viewed in conjunction with the finding that RT was shortest for the Feedback condition. Assuming that the ready-signal conditions influenced the detection criterion, these results imply that intensity effects were smaller for a low criterion value (Feedback condition) than for a relatively high criterion value (90-db condition). This implication is discussed more fully below.

Figure 1 presents the results in accordance with a method described by Grice (4) in his evaluation of the decision-theory model. As noted earlier, the model assumes that the number of impulses required for a response is determined by the value of the detection criterion. The hypothetical impulse dimension in Figure 1 serves as an estimate of the relative positions of the criteria. The rationale for determining these positions has been discussed elsewhere (4). Briefly, four steps were followed: (a) the grand means for each of the five ready-signal conditions were calculated; (b) 100 msec was subtracted from each of the means in order to account for the assumed value of the "irreducible minimum" (17); (c) the criterion for the 90-db condition was arbitrarily assigned the index value of 100 impulses; (d) using the values obtained in (b), the other ready-signal criteria were calculated as a proportion of the 90-db index value. The 15 points in Figure 1 correspond to the mean RTs for each of the five RT sessions. The points were plotted along the horizontal criterion lines which represent the five ready-signal conditions. The three linear functions represent the rates at which the impulses were assumed to accumulate for the response-signal inputs. The slopes of the inputs were estimated by least squares fits to the five means for each of the response-signal

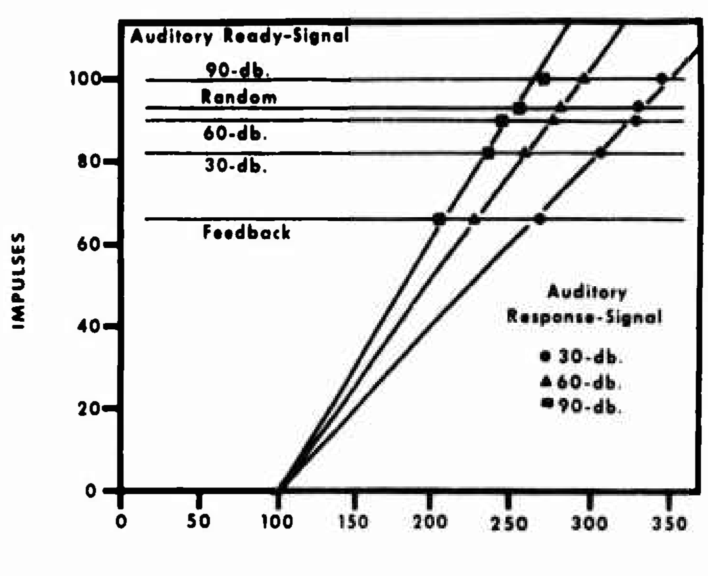

Fig. 1. Decision model applied to the effects of auditory ready-signal conditions and response signal intensity on reaction time.

intensities. Slope values for the inputs were subject to two restrictions: (a) the position of the criterion lines was based on the arbitrarily assigned index value of 100 impulses for the 90-db condition; (b) each function originated at 100 msec on the time axis because of the assumed irreducible minimum which consists of RT components not under the influence of stimulus intensity. Thus, the observed mean RTs are the points on the time axis which correspond to the intersections of the input functions with the appropriate criterion value. While tests for goodness of fit were not made, it is apparent from Figure 1 that the data points deviate only slightly from the estimated intersections of the input functions with the criteria. Since the model assumes that the input functions fan out from the common origin of 100 msec, larger intensity effects were expected for relatively high criterion values than for lower values. As noted earlier, this prediction received support from the significant Conditions X Intensities interaction. It was concluded from the present analysis that the decision-theory model provides one way to account for the effects of ready-signal intensity.

Grice (4) has suggested that the practice effect typically observed in RT experiments may result from a progressive lowering of the detection criterion. He found that RT data obtained on two consecutive days, when presented in terms of the decision model, supported the assumption that Ss' criterion decreased on Day 2. The data from the present experiment were particularly suitable for further evaluation of this hypothesis, as RT measures from five consecutive days of testing were available. Since the ready-signal conditions were counterbalanced over the first four days, the data from Day 5 were excluded from statistical analyses. A Days X Conditions X Intensities X Ss analysis of variance indicated the following significant effects: Days, F (3,9) = 17.24, $p < .001$; Conditions, F (3,9) = 11.01, $p < .001$; Intensities, F (2,6) = 50.61, $p < .001$; and Days X Intensities, F (6,18) = 6.03, $p < .005$. In view of the nonsignificant Days X Conditions interaction (F = 1.87), the ready-signal means within each day were pooled into daily grand means. For purposes of graphic presentation, the data from Day 5 were also included among the following daily means: Day 1, 308; Day 2, 289; Day 3, 276; Day 4, 269; and Day 5, 234. In a manner similar to that described above, the five daily means were used to obtain estimates of the criterion values for Days 1-5. The input functions were also fitted in the same manner as above. This analysis is presented in Figure 2. It is obvious that the model accounts for nearly all of the variance among the data points.

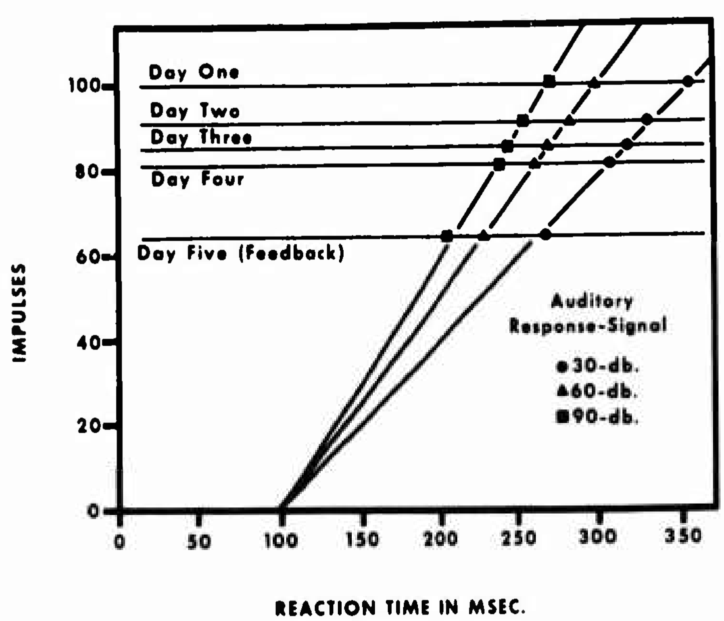

Fig. 2. Decision model applied to the effects of practice (Days 1-5) and response-signal intensity on reaction time.

Furthermore, larger intensity effects were obtained for relatively high criterion values than for lower values of the criterion, a finding which received support from the significant Days X Intensities interaction. The data are consistent with the interpretation that one effect of practice in RT tasks is a progressive lowering of the detection criterion.

An important feature of most RT experiments is the wide and consistent individual differences among the mean RTs of various individuals. In terms of the decision model, it seems possible that individual differences in performance may reflect characteristic differences in the detection criteria of various individuals. In other words, Ss with longer mean RTs may adopt a relatively higher or more conservative criterion than Ss with shorter mean RTs. In order to evaluate this hypothesis, the 16 Ss in the present sample were divided into eight fast and eight slow responders, as indicated by their grand mean RT scores. The data were then analyzed according to a Fast vs. Slow X Conditions X Intensities analysis of variance. Significant sources of variation were attributed to fast vs. slow Ss, F (1,14) = 13.47, $p < .005$; ready-signal conditions, F (4,56) = 17.50, $p < .001$; response-signal intensities, F (2,28) = 245.33, $p < .001$, and to the Fast vs. Slow X Intensities interaction, F (2,28) = 12.41, $p < .001$. Since the Fast vs. Slow X Conditions interaction was not significant (F = 0.62), the ready-signal means were pooled into grand means for the slow and fast responders. Figure 3 presents the data in accordance with the method outlined above. Note again how the three linear input functions originate at 100 msec and pass through the grand means for the two groups. The significant Fast vs. Slow X Intensities interaction supports the model's prediction that the slope of the RT-intensity function is steeper for a relatively high criterion value. In terms of the decision model, the results support the hypothesis that individual variation in mean RT reflects corresponding variation in the values of Ss' detection criteria.

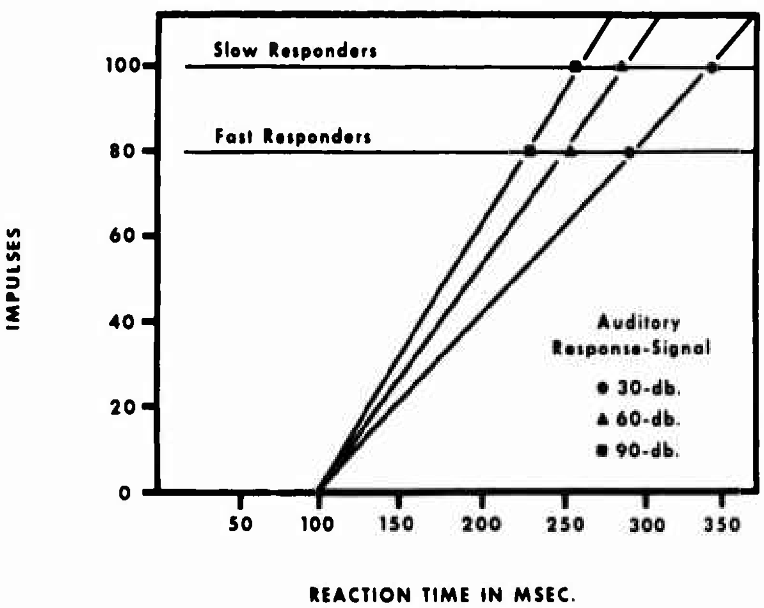

Fig. 3. Decision model applied to the effects of individual differences (fast vs. slow responders) and response-signal intensity on reaction time.

EXPERIMENT II

Method:

Subjects and Procedure. The Ss were 16 soldiers who were selected in the same manner as in Exp. I. The procedure was essentially the same as in Exp. I, with two exceptions: (a) a visual ready-signal was utilized; (b) the Day 5 (Feedback) condition was omitted because of scheduling difficulties.

Apparatus. The apparatus was the same as that used in Exp. I except that visual ready-signal were programmed in the trial to trial sequence. The ready-signals were three intensities of white light which were presented to the dark-adapted S through a 15 X 15 in. window of 1/8-in. milky Plexiglas. The window was situated in the front panel of a light box which was mounted at eye level approximately 3 ft from the S. During RT trials, S was instructed to look straight ahead and keep his eyes open. The three light levels were set at 100 ml, .10 ml, and .0001 ml, as calibrated by a dark-adapted O with a Macbeth illuminometer. These light levels were chosen because they correspond in subjective magnitude to 90-db, 60-db, and 30-db tones, respectively (15). In accordance with Stevens' (14) suggestion that a decibel scale is appropriate for both sound intensity and light intensity, the ready-signals employed in Exp. II shall be referred to as 30-db (.0001 ml), 60-db (.10 ml), and 90-db (100 ml) light levels.

Results and Discussion:

Figure 4 presents the results in accordance with the decision model. The procedures for positioning the detection criteria and fitting the input functions were identical to those described in Exp. I. Of particular interest was the similarity between the present results and those of Exp. I. That is, mean RT was fastest for the 30-db ready-signal, slowest for the 90-db ready-signal, and intermediate for the 60-db and Random conditions. An analysis of variance indicated that the effects of ready-signal intensity were significant, F (3,36) = 4.14, $p < .025$. In addition, the effects of practice and individual differences were analyzed in the same manner as in Exp. I. While not presented here, the results of these analyses were consistent with those presented in Figures 2 and 3. In general, the results of Exp. II indicated that ready-signal effects were not restricted to a single modality; rather, psychophysically matched visual and auditory ready-signals had similar effects on the RT-intensity functions.

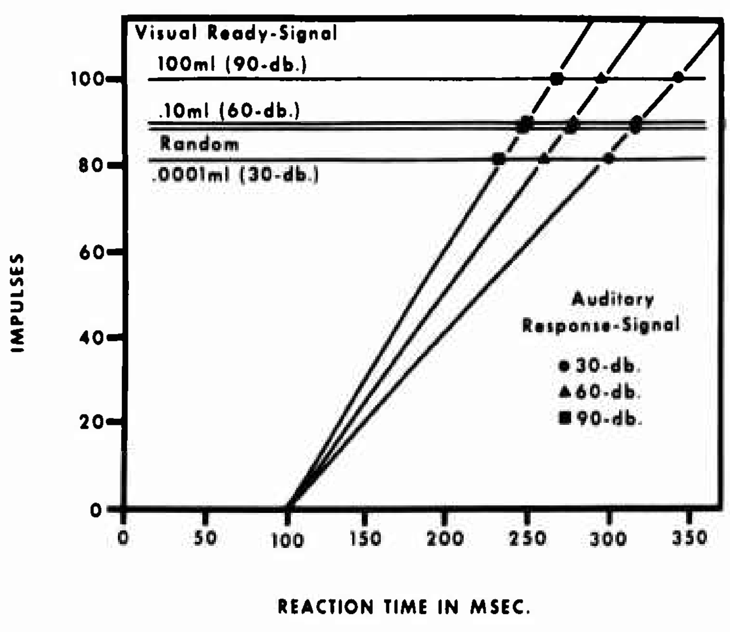

Fig. 4. Decision model applied to the effects of visual ready-signal conditions and auditory response-signal intensity on reaction time.

One difference in the findings of the two experiments is worth mentioning. In Exp. II, the interaction between ready-signal conditions and response-signal intensities was not statistically significant (F = 0.41). This appears to contradict the model's assumption that larger intensity effects result from relatively high criterion values than from lower values of the criterion. Moreover, two other experiments also resulted in nonsignificant interactions between stimulus intensity and adaptation (criterion) conditions (7,13). While the data from Exp. II appear to be consistent with the model, as shown in Figure 4, the data from Exp. I suggest that relatively wide manipulation of the criterion (Day 5, Feedback condition) is necessary in order to statistically confirm the predicted interaction.

DISCUSSION

The main finding of the present experiments was that mean RT systematically increased with a corresponding increase in ready-signal intensity. A major purpose of the research was to relate this finding to McGill's (10) and Grice's (4) decision-theoretical approach to response evocation. As described above, the decision model assumes that the rate at which neural impulses accumulate is determined by the intensity of a stimulus input, whereas the number of impulses required for a response is determined by the value of the detection criterion. The present results are consistent with the model if one assumes that response-signal intensity determined the slope of the input function, whereas ready-signal intensity influenced the value of the detection criterion.

It is noteworthy that McGill's primary concern has been to deduce mathematically a multistage process which adequately describes various input functions (11). Since he assumes that the criterion remains relatively stable over trials, trial to trial variation in RT is attributed to the variable rate at which neural impulses accumulate. On the other hand, Grice (4) has argued that variability in reaction latency can more appropriately be attributed to fluctuations in the S's detection criterion. Since the criterion appears to be readily influenced by a variety of experimental and individual difference variables, Grice's position has theoretical value. The present findings, for example, indicated that ready-signal intensity, degree of practice, and individual differences were significant determinants of RT, and presumably, S's detection criterion. While the present research leaned heavily on McGill's assumptions regarding sensory inputs, it is clear that the primary emphasis was on the role of criterion variation in reaction latency.

The present results appear to be consistent with an adaptation-level approach to contextual phenomena. AL theory states that the experience of a given intensity can be described in terms of its contrast with some reference level of stimulation. Assuming that the ready-signal served as a reference against which the response-signals were compared, the 90-db ready-signal produced the longest mean RT because the response-signals were all at or below AL, whereas the 30-db ready-signals resulted in shortest mean RT, the response-signals all being at or above AL. Similarly, the 60-db and Random conditions produced intermediate levels of responding, the effective AL being close to the mean of the response-signals. While it appears that the concepts of AL and detection criterion have analogous properties, the latter concept provides a more specific description of the mechanism of response evocation, at least for studies of stimulus intensity effects in RT (4). Furthermore, Murray (12) has pointed out that AL theory provides no way to account for the fact that relatively high criterion values (high ALs) produce larger stimulus intensity effects than when lower criterion values (lower ALs) are assumed. The decision model, on the other hand, predicts an interaction between signal intensity and criterion level, an assumption which was supported by Murray's results and by those reported in Exp. I.

Another advantage of the decision model is that it may account for Behar and Adams' (2) finding that RT was inversely related to ready-signal intensity, a result which contrasts with the present findings, and with those of previous RT studies (1,8). Three aspects of Behar and Adams' study are worth mentioning. First, they employed a conditioning-like methodology in which only one response-signal was presented on all trials, and little within-session variation in foreperiod interval was utilized. Second, the ready-signal overlapped temporally with the response-signal, both signals being terminated simultaneously. Third, and perhaps most noteworthy, they concluded that the ready-signal in their experiments had properties which are analogous to those of the CS in classical conditioning. In this vein, it is noteworthy that Grice, Hunter, Kohfeld, and Masters (6) reported that a relatively intense CS produced shorter latency CRs than a weaker CS. The analogous nature of Behar and Adams' and Grice et. al.'s results is especially significant in view of recent proposals that classical conditioning variables can be studied within the context of decision theory (4,16). For example, Grice (4) has suggested that the intensity of the CS in classical eyelid conditioning determines the slope of the input function. With respect to Behar and Adams' RT design, if one assumes that ready-signal intensity determined the rate of impulse accumulation, whereas other variables (e.g., trace vs. delayed presentation) influenced the S's detection criterion, then the results are not only consistent with the decision model, but also support their conclusion that the ready-signal behaved like a CS.

In Exp. II it was found that visual ready-signals influenced the detection criterion in the same manner as when auditory ready-signals were used. This finding has at least two implications. First, it demonstrates that ready-signal effects, and consequently the criterion, are not restricted to peripheral mechanisms, but reflect a process which could be termed central in nature. The second implication of Exp. II is that the concept of a detection criterion may provide an explanation for inter-sensory effects, at least for cases in which an interval of 1 sec or longer separates the stimuli. Inter-sensory effects are said to occur when responses are either facilitated or inhibited by the presentation of stimuli in two or more modalities. The fact that the latency of a response to an auditory stimulus depended on the intensity of a preceding visual stimulus, along with the inference that this effect was mediated by criterion variation, suggests that future study of sensory interaction may profit from a decision-theoretical approach.

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13. ABSTRACT

The effects of auditory (Exp. I) and visual (Exp. II) ready-signal intensity were investigated in a simple reaction time (RT) task. Mean RT to three auditory response-signals was found to systematically increase with a corresponding increase in the intensity of either auditory or visual ready-signals. The results were analyzed according to a decision model of stimulus intensity effects. It was concluded that ready-signal intensity influenced the value of the detection criterion. Practice effects and individual differences were also significant determinants of the criterion level. (U)

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