A decision model based on that of McGill (1963) relating stimulus intensity to response latency is applied to conditioning and reaction-time data. Points of similarity and identity between this model, Hull-Spence behavior theory, and the theory of signal detection are indicated. It is suggested that the concept of a variable, experimentally manipulable detection criterion or reaction threshold is a principle of considerable potential power in behavior theory. The difference between within-S and between-S stimulus-intensity effects is deduced from the model. The effects of motivational, reinforcement, adaptation, and practice variables and their relations to stimulus intensity are analyzed.

While stimulus intensity has been the classical problem of psychophysics, this variable has played a rather minor role in theory and research in the areas of learning and response evocation. The one exception to this is in the area of reaction time (RT), where at least a moderate literature exists dealing with the effects of variation in signal intensity. It is interesting that, even here, writers have tended to think of such data in the context of sensory psychophysics rather than in that of response evocation. However, the results of a number of recent experiments from the writer's laboratory (Beck, 1963; Grice & Hunter, 1964; Grice, Hunter, Kohfeld, & Masters, 1967; Grice, Masters, & Kohfeld, 1966; Kohfeld, 1968; Murray, 1968; Murray & Kohfeld, 1965; Walker, 1960) suggest that it is time for behavior theory to take a new look at intensity variables. The chief reason for this is the discovery that within-subject manipulation of CS intensity or RT signal intensity produces substantially enhanced intensity effects when compared with situations in which the subject (S) receives only a single intensity and comparisons are between groups. The mere fact that large CS intensity effects have been obtained in human conditioning when earlier studies showed only small or inconsistent effects is in itself reason for renewed interest in the problem. However, the particular manipulations resulting in these effects suggest that there may be a class of variables of which traditional behavior theory has not taken adequate cognizance. This problem certainly lies at the border of learning theory and sensory psychology, and it is possible
that new theoretical efforts and re-
search in the area may produce small
steps toward greater unity in psycho-
logical theory.

**WITHIN-S AND BETWEEN-S' INTENSITY EFFECTS**

Grice and Hunter (1964) originally
proposed that the large within-Ss in-
tensity effects could be interpreted in
terms of adaptation level theory. If
the significant intensity variable were
distance of the stimulus from adapta-
tion level rather than absolute stim-
ulus intensity, they showed that the
obtained results would be expected.
In further support of this view, it
was subsequently shown in RT ex-
periments (Kohfeld, 1968; Murray
& Kohfeld, 1965) that preadapting
Ss to stimuli of particular intensi-
ties significantly and persistently af-
fected Ss' RTs to a wide range of stim-
ulus intensities. However, in spite
of these successes and the obvious need
for concepts of this general type, adap-
tation level theory does not contain a
principle of response evocation and is
rather difficult to integrate into behav-
ior theory when one gets to the details
of how it might work. Therefore, it
is proposed to turn to other conceptual-
izations which may ultimately deal
with these mechanisms in more specific
terms and provide the basis for the
analysis of a wider class of experi-
mental variables.

The point of departure of the present
discussion is the decision-theory ap-
proach of McGill (1961, 1963) in his
stochastic model of latency mecha-
nisms. Of immediate concern is his
discussion of the relation between sim-
ple RT and stimulus intensity. Ac-
cording to this view a sensory input
may be regarded as a series of im-
ulses. When the cumulative count
reaches some predetermined number,
that is, the detection or decision cri-
terion, S will respond. The time re-
quired for the count to reach the cri-
terion is the reaction latency. Since
the impulse rate is probabilistic rather
than constant, latencies are variable
from trial to trial. Furthermore, the
impulse rate increases with stimulus
intensity, producing the inverse rela-
tion between latency and stimulus in-
tensity.

One manner of conceptualizing this
model is indicated in Figure 1, in which
the number of hypothesized impulses
is plotted as a function of time since
stimulus onset. The two linear func-
tions indicate the expected number of
impulses for two stimulus inputs—
for example, tones differing in in-
tensity. The constant delay before the
start of the count is the so-called "ir-
reducible minimum" RT, or at least
those components of RT not under
the influence of variations in inten-
sity. This delay is regarded to be
of the order of 100 milliseconds. The
criterion is indicated by a horizontal
line of fixed ordinate. The expected
mean RTs are at the intersections
of the two lines with the criterion.
Trial-to-trial variability in the num-
ber of impulses is indicated by the
probability functions associated with
each input. Since at each point in
time, the means of these distributions

![Fig. 1. Graphic representation of latency model with variable input.](image-url)
are on the input line, the distributions erected above the criterion line indicate the cumulative probability that the count will be above the criterion by time $t_i$. In other words, these are the predicted cumulative distributions of reaction latency. The illustrative normal distributions with equal variance drawn here are not intended to represent McGill's hypotheses concerning their form. However, it is interesting to note that the model as presented here does predict the precise linear relation between mean RT and the standard deviation discovered by Chocholle (1945). The $SD$ of the RT distribution is equal to the $SD$ of the impulse distribution multiplied by the reciprocal of the slope of the input function. Mean RT is also linear with respect to the reciprocal of the slope.

In spite of the appeal of this simple model, the writer has difficulty taking it seriously in exactly this form as a general model for latency mechanisms. The distributional phenomena so elegantly deduced by McGill (1963; McGill & Gibbon, 1965) are dependent upon the criterion's remaining constant for large blocks of trials under constant experimental conditions. This seems unlikely. Various considerations, including data to be presented here, strongly suggest that the criterion may be readily and strongly influenced by a variety of experimental and individual difference variables. It is difficult to conceive of a psychological process of this kind which would not be subject to extensive moment-to-moment fluctuations. On the other hand, it is relatively easy to think of a sensory input as a rather stable process, determined by the stimulus energy, temporally dense and uniform on the rather gross time scale in which reaction latency displays its variability. In other words, it is being suggested that we may alternatively regard all of the variability as residing in fluctuation of the criterion rather than in the input rate. Parenthetically, it is suggested that this argument also has merit when applied to the essentially identical concepts of the criterion of the theory of signal detection (TSD), the category boundary of the law of categorical judgment, and the reaction threshold of Hull-Spence learning theory.2

Now it must be admitted that this revised model often makes no difference in prediction or methods of data analysis. However, it does lead to a somewhat different way of thinking, and it may lead to different research and, possibly, to differential prediction. Figure 2 indicates this scheme, showing the probability functions associated with the location of the criterion.3 Here, it is more natural to speak of the probability that the criterion is below the input at $t_i$ than that the count is above the criterion. The criterion line is shown at its mean loca-

\[\text{FIG. 2. Graphic representation of latency model with variable criterion.}\]

2 Hull at one time utilized the assumption of an oscillating threshold rather than the concept of $\theta$. (Hull, Hovland, Ross, Hall, Perkins, & Fitch, 1940).

3 The ordinate in Figure 2 and in following similar figures is labeled "Impulses"; however, it is not essential to the present analysis that this dimension be conceived in terms of discrete units.
The linear relation between mean RT and the SD also holds for this arrangement.

A word may be added here concerning the relation of this model to Hull’s theory. The input functions presented here are essentially similar to the rise of reaction potential with the input segment of the stimulus trace. The criterion is the same as his reaction threshold. Thus, latency as a function of stimulus intensity is deducible from Hull’s theory, although he did not actually make this deduction. Had Hull assumed that the threshold was responsive to experimental manipulation, as is suggested here, other deductions would have followed. The present development may be viewed either in the context of decision theory or within the general framework of Hullian behavior theory. These two approaches are much more alike than is commonly recognized.

This model may be applied not only to RT responses but to conditioning as well, at least in situations where the CR is of short latency. Here, the usual measure is probability of response rather than latency. To understand how the model applies, one should imagine in Figure 1 or 2 an ordinate erected at the end of the interstimulus interval (ISI) or of the scoring interval. Responses may occur only before this time. Thus, the predicted probability of response is that portion of the cumulative distribution above criterion by t₁. The model predicts that, for a constant criterion or a criterion fluctuating around a constant mean, probability of response will be an increasing function of stimulus intensity.

The difference between within-S and between-S intensity effects can readily be explained in terms of this theory. First, it is assumed that the value of the criterion will be determined to some degree by the stimuli to which S is exposed. At least it is intuitively reasonable, and the Grice and Hunter (1964) data suggest, that Ss receiving only a weak stimulus will adopt a lower criterion than those receiving only a strong stimulus. This will account for the fact that a 50-decibel difference in CS intensity provided only a slight, and statistically nonsignificant, difference in number of CRs, a finding typical of previous between-S experiments. The Ss in the within-S condition received both stimuli in an irregular, unpredictable order. Presumably, the value of their criterion was also determined by the stimuli received, but it was necessary for them to respond to both stimuli with a single criterion, and this turns out to be the crucial point. If the value of the criterion is influenced by the level of stimulation in the manner suggested above, Ss responding to stimuli of two or more intensities on the basis of a single criterion will usually show a greater intensity effect than that between groups, each responding to a single stimulus. Figure 3 describes the data of the Grice and Hunter eyelid-conditioning experiment in terms of the McGill variable input model. The distributions associated with the Loud and Soft input function indicate the trial-to-trial prob-
ability density of the number of impulses by \( t_i \), the end of the ISI. The horizontal lines indicate the hypothetical location of the criteria for Group L, receiving only the loud tone; Group S, receiving only the soft tone; and Group L-S, receiving both tones. Areas of each distribution above each of the criteria indicate the appropriate response probability. This figure is so constructed that the areas correspond exactly to the four proportions of CRs in the Grice and Hunter data. It may be seen that the area of the Loud distribution above the Loud criterion is approximately the same as the area of the Soft distribution above the Soft criterion. However, the area of the Loud distribution above the L-S criterion is substantially greater than the area of the Soft distribution above this same criterion. Note that this would have been true for any location of the L-S criterion so long as both probabilities were not near either zero or one.

At this point it is desirable to point out additional relationships of this model. The vertically erected pair of distributions with intersecting criteria is essentially the decision axis of the TSD. The distance between the intersections of the input functions with \( t_i \) if expressed in SD units is \( d' \), or it may be regarded as a Thurstone scale value. Furthermore, in Hullian terms, this difference between the two input functions at \( t_i \), also scaled in SD units, is the difference in reaction potential between the Loud and Soft tones (\( E_L - E_S \)). The supra-threshold reaction potential, as used by Spence (1956), is the normal deviate corresponding to the area of a distribution above one of the criterion, or threshold, lines. Spence's theory will not account for the Grice and Hunter finding, however, since he assumes the threshold to have a constant location. The remarkable similarity between the Hull-Spence approach and TSD may be seen especially in Spence's theory of choice behavior (Spence, 1956, pp. 203-205 and Appendix A, pp. 237-242).

The purpose of Figure 4 is to show how the variable criterion or oscillating threshold model explains or describes the Grice and Hunter data. The input functions and the criteria have the same locations as in Figure 1. Now, however, the criterion lines are regarded as located at their mean value. The three distribution functions indicate the hypothetical trial-to-trial probability density of the location of the criteria. Horizontal lines are drawn through the functions at the ordinates of the inputs at \( t_i \). Areas below these lines indicate the proportions of the times the criterion is below the input by \( t_i \), thus resulting in response evocation. The figure is again so constructed that the four shaded areas exactly equal the corresponding percent CRs in the Grice and Hunter data. This model is equivalent to the fixed criterion, variable input theory in describing the data.

Grice and Hunter (1964) also compared between- and within-S intensity effects for signal intensity in simple RT. Here, again, a larger intensity difference was obtained for the within condition, but Ss receiving two stimuli
were slower in response to both stimuli than were the single stimulus groups to the corresponding stimuli. What may have been going on here, according to the model, is indicated in Figure 5. Here the irreducible minimum RT is taken as 100 milliseconds. The single criterion for the L-S group was assigned an arbitrary value of 100 units. The RTs for the L-S group to the two stimuli were plotted on this line and the input functions passed through them. The mean RTs for the L and S groups were then plotted on these functions. The resulting vertical locations of these points indicate that apparent level of their respective criteria. The model in this way suggests that the S group did have a somewhat lower criterion than the L group, but that the criterion for the group responding to either was considerably elevated. This may have been the result of stimulus uncertainty. The difference in relative location of the L-S criteria in the two types of experiments is possibly due to differences in the nature of S's set. In the RT experiment, he has a set to detect the stimuli and respond, while in the conditioning experiment his set is the traditional "neutral" one.

**RELATION OF CS INTENSITY TO OTHER VARIABLES**

Of course the ultimate utility of this theory will depend upon the range of experimental phenomena to which it can be extended, providing useful methods of analysis, accurate prediction, and sensible interpretation. The eyelid-conditioning experiment of Beck (1963), which gave the first information concerning the large within-S CS intensity effect, lends itself especially well to analysis in these terms. She manipulated two presumed motivational variables, UCS intensity and anxiety (MA scale score), as well as CS intensity. There were two levels of each variable, manipulated orthogonally, resulting in eight cells. Anxiety and UCS intensity were between-S effects based on separate groups, while CS intensity was within S with each stimulus occurring equally often in an irregular order. Beck's data, presented in Figure 6, are based on the total number of anticipatory blinks. In this figure, the average probability of a blink to the Loud CS is plotted as a function of the probability of a blink to the Soft tone for each combination of the other two variables. The plot is on normal-normal coordinates. This figure is recognizable as a receiver-operating characteristic (ROC) func-

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**Fig. 5.** Representation of Grice and Hunter (1964) RT data.

**Fig. 6.** Between-conditions ROC function for Beck's (1963) CS intensity data.
tion as used in TSD, although the application is somewhat different than in the detection situation. Here the application should be regarded as a scaling operation in which scale separations are to be inferred between two readily detectable stimuli rather than between two noise distributions with a signal present and absent. It is appropriate to think of overall responsiveness in the dimension parallel to the positive diagonal, and the scaled difference in response to the loud and soft tones in the dimension parallel to the negative diagonal. The straight line drawn through the points, which obviously fits quite well, has a slope of unity. This is of especial interest because it implies that the distance between the loud and soft tones is approximately constant for all levels of responsiveness. This is quite contrary to Hull's theory that the stimulus intensity dynamism (V) has a multiplicative relation with motivational variables. According to that view, the loud-soft distance should increase with responsiveness, and the slope should be markedly greater than one.

Considerably greater understanding of the relation of these data to the present model may be gained by an inspection of Figure 7. Actually, this figure is fully redundant with the preceding figure, which implies that it can be drawn. This is the TSD decision axis in a different setting. Following the variable input model, the two normal distributions represent the probability densities of the loud and soft stimulus inputs at the end of the scoring interval. Equal variance for the two distributions is assumed. The abscissa is scaled in SD units, and is appropriately labeled "Reaction Potential," which is scaled in the same manner. The vertical lines represent the locations of the four groups' criteria, or reaction thresholds. These were obtained from Figure 6, by using the "Soft" coordinate of the projection of each point on the ROC function. Zero is set at the mean of the "Soft" distribution. The distance between the means of the two functions is $E_L - E_S$ or $d'$ and was read graphically from the "Soft" intercept of the ROC function. Its value is .57. The areas of the two distributions which lie above (to the right) of the group criteria indicate the two percentages of CRs for each group. Remarkably, these areas simultaneously describe the eight cells of Beck's experiment with a maximum error of one percentage point. In behavior theory terms, these data are consistent with the view that the effect of increasing drive is to lower the reaction threshold rather than to increase reaction potential in a multiplicative fashion. This is not a new view (e.g., see Campbell & Sheffield, 1953), but it has never been thoroughly explored. It is suggested that this conception should receive renewed attention.

If one wished to describe the data of Figure 6 with the single, fixed-threshold model of Hull and Spence, it would be necessary to use eight distributions, each with the appropriate area above the threshold. If this were done, the
distance between the Loud and Soft distributions for each of the four motivational groups would be essentially constant. This would be contrary to the multiplicative assumption, and would imply an additive relationship instead.

In Figure 8, the oscillating criterion model for Beck's data is presented. While not ordinarily discussed in the TSD context, this model is equally implied by the ROC function of Figure 6. Here, the assumed fixed location of the two stimuli are indicated by vertical lines separated by the distance \( d' \). The four distribution functions located at the criterion means now represent the probability densities of criterion values. Areas indicating the criterion below the inputs (to the left) are the predicted response percentages. If one is thinking in these terms, the positive and negative signs of the \( z \) values of Figure 6 should be reversed. These eight areas describe the actual values in the same manner as those of Figure 7.

It is also of interest to examine and compare the individual \( S \) data plotted in the same manner as the group means of Figure 6. Such a plot is presented in Figure 9, omitting a few \( S \)'s who made no response to one or both stimuli. The relation between two such arrays has been previously discussed by the writer (Grice, 1966). The ROC function of Figure 6 is a "between-conditions" regression line. It was pointed out in the previous paper that such relations are frequently both very high and quite illuminating because the covariation is introduced by known, systematically manipulated factors. The linear correlation in this instance is .994, a value not unrepresentative of other examples previously given. The scatterplot of Figure 9 is a "Total" correlation including both manipulated and individual difference sources of correlation. The correlation coefficient is .82. The best fitting mutual regression line drawn through the points has a slope of .985, suggesting that the same model applies to the individual \( S \) data. In psychometric terms, each point, in either figure, may be regarded as a two-element vector, each element consisting of five primary components plus possible interactions. (Interactions are disregarded since Beck's analysis suggested they were not significant.) The components are Anxiety (A), UCS, CS, Individuals (I), and within-\( S \) variability or error.

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**Fig. 8.** Variable criterion model for Beck's (1963) data.

**Fig. 9.** Individual \( S \) scatterplot for Beck's (1963) data.
For any given point, the elements differ only in the CS and within-S error components. Variation along the Loud-Soft axis consists of the CS effect (d') and within-S variability. Figures 7 and 8 represent alternative ways of conceptualizing this variability. In the between-conditions relation of Figure 6, the variability contributes less to the location of the points by a factor of 1/n, because it is based on means. However, the same underlying within-S distributions are involved. The individual difference component (I), producing variability along the responsivity axis, also contributes less variability in Figure 6 for the same reason. The "within-conditions" correlation (Grice, 1966) for the four groups plotted together in Figure 9 is, as to be expected, somewhat lower, .78. It still indicates a substantial linear trend within conditions, due to individual differences in responsivity. The slopes of the within-conditions regression lines are somewhat variable, ranging from .86 to 1.24. Their mean is 1.01.

A different basis for the understanding of the present analysis may be gained from a consideration of the effect of a 45° rotation of the axes of either Figure 6 or Figure 9. The coordinates of each point on the new axes now become:

\[ I = .707 (s_L - s_S) \]
and
\[ R = .707 (s_L + s_S). \]

It is now obvious that the rotated axes may appropriately be labeled the Intensity Effect and the Responsiveness Effect. The difference between the Loud and Soft coordinates is the intensity effect, and their sum is their joint responsiveness effect. In Figure 10, the data for Figure 6 have been replotted on the rotated axes. For convenience, after rotation, the data have been rescaled by multiplying by 1/.707. The correlation between these dimensions is of zero order, and the regression line, parallel to the Responsiveness axis, is of zero slope. Its intercept is d'. The spacing of the points along the Responsiveness axis is proportional to the spacing of the locations of the criteria on the decision axis. The relation is simply \((s_L + s_S)/2\). This estimates the locations of the criteria from the point midway between the two stimulus distributions. For the variable threshold model, similar reasoning applies to the location of the criterion means. The graphical method of estimation used in the original construction of Figures 7 and 8 is a way of obtaining these same values.

In general, the picture is one of considerable consistency, suggesting that the scaled difference in reaction potential does not vary in any systematic way with the level of responsiveness produced either by the manipulation of motivational variables or by individual
FIG. 11. Between-conditions ROC function for Beck's (1963) data including stage of conditioning (habit strength) as an additional variable.

differences. Furthermore, the data are consistent with the model which assumes that the effect of drive manipulation is to influence S's reaction threshold or detection criterion. While this is certainly not the only possible interpretation, it is indeed a hypothesis of considerable promise for further theoretical analysis and for the guidance of future research.

A further assumption of Hull was that the stimulus intensity dynamism \( (V) \) combined multiplicatively with the associative factor—habit strength. This implies that the CS intensity effect should increase with training. In one sense this must be true. At zero habit strength, no response would be evoked by any stimulus and difference would be zero. However, Hull's position implies that intensity difference should increase continuously until asymptote, that is, \( E_L - E_S = H(V_L - V_S) \). There are a number of difficult problems involved in the analysis of this problem. These include possible changes in the underlying distributions with practice and the determination of a meaningful zero for reaction potential. However, without facing up to these problems, a preliminary, and, at least illustrative, analysis of this problem has been attempted here. For this purpose, two blocks of trials at different stages of training were selected from Beck's data. The blocks were Trials 11–40 and 51–80. Percentages of anticipatory responses were then obtained for each of the eight conditions for each trial block separately. These data are presented in Figure 11 with \( P_L \) plotted against \( P_S \) as in Figure 6. The filled circles are for the late trial block and the hollow circles are for the early trial block. Within each block the UCS and A points arrange themselves in the same order along the responsiveness axis as in Figure 6. The two squares are the mean values for the two trial blocks, summed over the other variables. The between-conditions linear correlation is .989. The regression line is arbitrarily drawn with a slope of one in order to assess the reasonability of this hypothesis. The best fitting regression line has a slope of 1.08 and would hardly be perceptibly different. There is little evidence here that the scaled intensity distance increases systematically with practice.

**Effect of Stimulus Preadaptation**

Based on the original Grice and Hunter (1964) adaptation level interpretation of within-S intensity effects, Murray and Kohfeld (1965) studied the effect of brief prior exposure of Ss to auditory stimuli before a series of RT trials to tones varying in intensity. They found that a group of Ss with 12 1.5-second presentations of a 40-decibel tone, at the lower end of the series, produced consistently faster RTs to all stimuli than groups without such preadaptation, or with similar presentations of a 100-decibel tone, at the upper end of the series. RTs of the 100-
decibel group were slower than those of the control group. More recently, Kohfeld (1967) has confirmed and extended these findings. In one of his experiments, Ss received a series of 75 RT trials to tones of 35-, 50-, 65-, 85-, and 100-decibel sound-pressure level. Prior to the session, separate groups listened, without responding, to 12 presentations of a tone of either 35, 65, or 100 decibels. A control group received no preliminary tones. Functions were presented showing typical within-S intensity effects, RT being inversely related to signal intensity. Functions for the different adaptation groups were vertically displaced, the 100-decibel adaptation group responding considerably slower than the 35-decibel group. The other groups were intermediate. Twenty-four hours later, Ss received another similar session, but without additional adaptation presentations. Somewhat surprisingly, to the writer at least, the effects of the 12-tone presentations, 24 hours before, were still consistently and significantly present.

Kohfeld discussed these findings in terms of adaptation level theory. However, it is a bit difficult to think of an adaptation effect based on such a brief experience persisting, not only through a series of trials to other intensities, but over a 24-hour delay and through another series. On the other hand, the effects are readily understood in terms of the present model, if one assumes that S's detection criterion is determined at least in part by the intensity of the adapting stimuli. It was suggested in the discussion of the Grice and Hunter data that hearing weak stimuli apparently leads S to adopt lower criteria, while more intense stimuli lead to higher criteria. This explanation lies in the general domain of set phenomena rather than in that of sensory adaptation. The persistence is, perhaps, somewhat less surprising in this context.

In terms of this model, the different adaptation groups are assumed to differ only in their criteria, the same stimulus input functions applying to all groups. Since the stimuli are unpredictable, each group must be regarded as operating with a single criterion, or, in the case of the oscillating criterion model, a single criterion distribution. In order to assess the degree to which Kohfeld's data fit these assumptions, they have been analyzed in a manner suggested by Figures 1, 2, and 5. This analysis is presented in Figure 12. Because of somewhat lower variability, the data analyzed are those for the second day. Here, "Impulses" are plotted as a function of time. Since the impulse dimension is hypothetical, only the relative positions of the criteria can be indicated. These relative positions were inferred from the general means of the four groups. The criterion for the 100-decibel adaptation group was arbitrarily assigned the index of 100. The other criteria were then located in proportion to the ratios of the general mean RTs minus 100 milliseconds, the assumed irreducible minimum. (This analysis is not very sensitive to the exact value assumed for this.) This
means that an input function starting at 100 milliseconds would pass through the four-group general means, its slope being determined by the choice of the index of 100 for the 100-decibel group. The five mean RTs for each of the stimuli for each group were then plotted along the four criterion lines. As explained earlier, these points are estimates of the intersections of the input functions with the criteria. Estimates of the slopes of the five input functions were made by least-squares fits of straight lines to the four points for each of the stimulus intensities. Fits were made with the restriction that each function originate at 100 milliseconds. These are the five lines drawn in Figure 12. The adequacy of the model in accounting for the data may be evaluated by examining the discrepancies of the data points from the intersections of the criteria and the input functions. While not perfect, it is obvious that the fit is very good. The model does, in fact, account for 99.5% of the variance among the 20 data points. Since the general means of the groups were used in locating the criteria, the proper basis for a statistical test of goodness of fit is “Intensities within Groups.” In addition, there were 5 degrees of freedom used in estimating the slopes of the input functions. Eleven degrees of freedom remain after fitting the model. A test of “departure from model” is not significant; $F = .53$, $df = 11/144$. This analysis clearly indicates that the data are consistent with the interpretation that the effect of the adaptation conditions was to affect $S$s' detection criterion or reaction threshold, and that the stimulus inputs were unmodified by these operations. Methods for estimating the relative values of these parameters are also indicated.

As is typical of RT experiments with unpracticed $S$s, Kohfeld’s data show a practice effect from Day 1 to Day 2. The present kind of thinking leads naturally to the hypothesis that the effect of practice is a progressive lowering of the criterion. An analysis similar to the preceding one has been made of this hypothesis and the result is presented in Figure 13. The data have been analyzed for each group separately. In each case the Day 1 criteria were assigned a value of 100 and the Day 2 criteria were located on the basis of the relation between the daily general means. Input functions were fitted in the same manner as above. In each case, 3 degrees of freedom remained

Fig. 13. Latency model applied to Kohfeld data for Days 1 and 2, assuming practice influences criterion.

Fig. 14. Loudness as a function of slope of fitted input functions.
after the fit. While tests of goodness of fit have not been made, it is obvious the fit here is even better than in the previous example, the model accounting for nearly all of the variance among the points. It is reasonable to assume that the somewhat closer fit is due to the fact that the different criterion levels here are within-S differences rather than involving separate groups as in the previous example. In any case, the data are consistent with the suggested interpretation that the level of S's detection or response criterion decreases with practice.

In one of his early presentations of this type of model, McGill (1961) suggested that the impulse rate (slope) should provide the basis for subjective loudness. In accord with this suggestion, the Stevens (1956) sone transformation of the five stimuli has been plotted as a function of the fitted slopes of Figure 12. This is presented in Figure 14. The curve fitted to the points is exponential. The writer has, so far, been unable to arrive at any rational derivation of this relationship, but the figure is presented for the benefit of those who may wish to speculate further along these lines.

**DISCUSSION**

While the approach presented here stemmed most directly from McGill's decision model of latency and stimulus-intensity effects, it has large areas of overlap with TSD, Hull-Spence learning theory, and the scaling approaches of Thurstone and Torgerson. The major departure from McGill and Hull and Spence is the intent to view the criterion or threshold as a more dynamic concept in the theory, subject to experimental manipulation and to variability from individual differences and from random fluctuation. It is suggested that a number of variables having effects of considerable psychological interest may profitably be viewed as influencing the response threshold. Thus, this approach has implications for learning theory considerably wider than the stimulus-intensity problem with which this paper is primarily concerned. An extreme view that all of the motivational, training, and set variables which influence the probability of response work in this way is even conceivable. The predictive, heuristic, and analytic value of such theory can only be evaluated on a long-term basis.

The proposed departure from McGill's model, attributing random variability to fluctuations of the criterion, is, for the present at least, merely a preference of the writer based on logical rather than mathematical grounds. It seems unrealistic to assume that a psychological state, so apparently labile in the sense of ready manipulation, could remain literally constant for the duration of an experimental session. If this reasoning is sound, it has the unfortunate implication that McGill's derivation of RT distributional phenomena is based on an inappropriate assumption. It may be desirable to seek another approach to the derivation of response distributions based on criterion variability. It is, of course, recognized that the two conceptions are not necessarily mutually exclusive. If both sources existed, they would be additive. The present preference is expressed for the sake of simplicity, and reflects the belief that criterion variability is likely to be large with respect to sensory variability. In the case of TSD, it is well to keep in mind, at this point, that the noise distributions refer to actual noise, physically present in the stimulus. The
extension of the model to noise-free stimuli and the treatment of psychometric variability as "noise" is a subsequent development. Obviously, a variable input model does apply, if the stimulus is, indeed, variable. In this context, the writer prefers to consider psychometric variability in the criterion.

Grice and Hunter (1964) suggested an interpretation of their intensity effects in terms of adaptation level theory. Decision theory as an alternative deserves a word of further comment. It is suggested that there are at least two qualitatively different classes of adaptation phenomena. Sensory adaptation should be treated as a modification of sensory processes. Other kinds of adaptation effects may more properly be regarded as modifications of judgmental or response processes. These effects may be expected to be more persistent. The present interpretation may be regarded as a theory of this latter class of adaptation phenomena. The notion that adaptation procedures have their effects on the criterion is certainly applicable to judgmental and psychophysical situations as well as to response evocation.

In this paper, the terms detection criterion, decision criterion, and reaction threshold have been used interchangeably. This has been done to emphasize the mathematical identity of these terms and the range of phenomena to which the concept may be applied. It is possible that in the future there may arise a need for more than one such concept. So far, this has not been necessary. There is one paper which superficially seems to imply that detection theory will not account for the intensity effect in conditioning, but upon analysis this implication turns out to be false. In an eyelid-conditioning study using weak auditory CSs, Fishbein and Engel (1966) also had Ss give verbal reports of stimulus detection. There was no evidence of conditioned eyelid responses on those trials when S reported no stimulus. However, on those trials when S did report a stimulus, the percentage of CRs still increased with intensity. This is readily understood in terms of the latency model. Their CS was on for 775 milliseconds, the airpuff beginning after the first 525 milliseconds. For detection, defined by the verbal report, the entire time (775 milliseconds) was available for the input to reach the criterion. For a CR to occur, however, detection would have had to occur sufficiently before 525 milliseconds for the response to be evoked before that time. The stronger the CS, the earlier in this interval detection would begin, and the greater would be the number of anticipatory CRs. When detection occurred after the critical interval before 525 milliseconds, no CR would occur. While it is also possible that different criteria apply to different response systems, this explanation need not be invoked here.

One area of potentially interesting application of this model with its latency implications is to ISI phenomena in conditioning. For example, if one could assume a constant criterion, there is an implication that CS intensity effects should decrease with increasing ISIs. For example, Grice et al. (1967) have found suggestive evidence that the latency distributions for loud and soft stimuli are similar, but that the loud distribution reaches its maximum earlier in the ISI. Walker (1960), in a study complicated by being a between-S experiment, found that CS intensity significantly affected the frequency of blinks early in a .5-second interval, but not late in the interval. Perhaps, the notion of an optimum ISI for association formation is incorrect, and these functions depend upon latency phenomena and interactions with
other variables, such as stimulus intensity. The writer doubts that unraveling this area will be simple, because it is suspected that the ISI may influence the criterion. Within-S manipulation of the ISI may be an aid to the solution of this problem.

This analysis of the difference between within-S and between-S intensity effects has a rather interesting methodological implication not previously mentioned. In one sense, the early independent-groups investigations of CS intensity actually represented a methodologically inappropriate way to investigate the problem. This is simply because one could not assume a common criterion. It is suggested that there are many instances, both in psychophysical and behavioral research, where, if one wants to assume a common criterion, stimuli should be administered in an unpredictable order rather than in blocks or to independent groups.

In the analyses presented here, this model has achieved considerable initial success. The possibilities for further application and the exploration of additional implications are extensive.

REFERENCES


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