may be responsible for the elevation of threshold at 50 msec and for the lowering of threshold when the separation between the two targets exceeds 60 msec.

HAROLD SCHUCKMAN
J. ORBACH

Institute for Psychosomatic and Psychiatric Research and Training, Michael Reese Hospital, Chicago, Illinois

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4. While Bloch's Law refers to the integration of stimulus energy over time, the results of our experiment indicate that the law also holds when the stimulus is a reduction rather than an addition of stimulus energy.
5. With the parameters used, we found that a pair of pulses with a temporal separation up to 60 msec is reported at threshold as a single stimulus. In evaluating our data, it should be noted that a black disc was used as a target whereas Davy's (*2*) and Clark and Blackwell's (*3*) target was a light flash.
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Judgments of Sameness and Difference: Experiments on Decision Time

Abstract. *When asked to judge whether two stimuli (tones) were the "same" or "different," subjects took longer to decide that two identical stimuli were the same than to decide that two dissimilar stimuli were different. Thus these judgments are not equivalent obverse aspects of a unitary judgmental process. While decision theory can be extended to deal with the obtained data, a model based on an analogy with a statistical computer is more directly applicable.*

The fundamental operation by which man obtains knowledge is discrimination—the act of judging whether two given things (for example, colors, symbols, sounds, or events) are the same or different. A problem that frequently arises in psychology is that of determining the transitional points on some similarity–dissimilarity dimension at which the observer changes his judgment from "same" to "different" or vice versa. Several factors, among them sensory acuity, stimulus series characteristics, anchors (reference points), and payoffs (rewarding or punishing outcomes associated with different response choices), are known to affect the transitional points (*1*). But little is known about the nature of the "same–different" judgment *per se*.

While we were attempting to interpret certain data obtained in experiments on decision time (*2*), it occurred to us that the data would make sense if we could assume that, under certain conditions, the judgment "same" takes longer to arrive at than the judgment "different." Though this supposition was contrary to the common view that "same" and "different" are the obverse aspects of a unitary judgmental process, a series of preliminary experiments showed it to be true. We thus had a simple phenomenon that could provide a means of studying the nature of the "same–different" judgment. But decision time is affected by so many factors—for example the nature of instructions, the relative frequency of alternative decisions, the difficulty of the task, the form of the required response—that we first wanted to be sure that our observation was not a result of some experimental peculiarity. The two experiments reported here test the effect of separately varying two conditions—the difficulty of the discrimination to be made, and the instructions (the form of the question to be answered).

Stimuli were two tones, 1000 and 1060 cy/sec, presented through a loudspeaker at about 66 db (relative to the base 0.0002 dyne/cm^2). Tone presentations were arranged in four pairs—1000–1000, 1000–1060, 1060–1000, and 1060–1060—each tone being sounded for 4 seconds. An experimental session consisted of two 32-trial blocks, separated by about 5 minutes; the interval between trials was 5 seconds, and the first tone of each pair was sounded 1 second after a ready signal.

All four tone-pairs and all the sequences in which tone-pairs occurred were presented with equal frequency but in a prearranged scrambled order. The subject indicated his judgment by pressing one of two labeled response keys with the index finger of his preferred hand; between judgments he rested this finger at a point equidistant from the two keys. The labels on the keys were interchanged between subjects so as to balance any effects attributable to unique characteristics of the keys and of direction of finger movement.

Thirty-two college students served as subjects, 16 in each experiment. Each block of trials was preceded by about five practice trials, to insure that the subject understood the task. In both experiments subjects were instructed to decide, as quickly as possible, whether the pitches of the two tones of a pair were the same or different. The interval between the onset of the second tone of the pair and the subject's response was recorded.

In experiment 1, one response key was labeled "Same" and the other "Different," and subjects were instructed to press the appropriate key on each trial. Discriminability was varied by using an intertone interval of 1 second for one block of trials ("easy" discrimination) and an interval of 10 seconds for the other block ("difficult" discrimination). Half the subjects had the 1-second block first, and the other had the 10-second block first. In experiment 2, one response key was labeled "Yes" and the other "No." The instructions were varied by asking a different question before each of the two blocks of trials. For one block of trials, subjects were told to answer the question "Are the tones the same, 'yes' or 'no'?" and for the other block of trials to answer the question "Are the tones different, 'yes' or 'no'?" The order of the two conditions was reversed for half the subjects. The intertone interval remained constant at 5 seconds.

About 90 percent of the 2048 judgments made by the 32 subjects were correct. The means of the times taken (latencies) for the correct responses are shown in Table 1. The latency data of experiment 1 were

Table 1. Mean latencies and total errors for judgments obtained under various experimental conditions. Error data represent the number of times the indicated response was incorrect.

Test condition	Response	Mean latency of correct judgments (sec)	No. of errors
		Experiment 1: Discriminability varied	
Easy*	Same	0.87	4
Easy	Different	0.78	14
Difficult†	Same	1.10	17
Difficult	Different	0.90	45
		Experiment 2: Instructions varied	
". . . same"	Yes	1.11	10
". . . different?"	No	0.96	40
". . . same"	Yes	1.30	15
". . . different?"	No	1.14	39

* One-second interval between tones. † Ten-second interval between tones.

subjected to a three-way analysis of variance: judgment ("same" vs. "different") × discriminability (1-second vs. 10-second intertone interval) × subjects. This analysis showed that subjects consistently took longer to reach the decision "same" than to reach the decision "different" (judgment effect, $F = 9.68$, $df = 1/15$, $p < .01$), and had longer response latencies in the 10-second condition than in the 1-second condition (discriminability effect, $F = 49.46$, $df = 1/15$, $p < .001$). The interaction between judgment and discriminability was significant ($F = 15.73$, $df = 1/15$, $p < .01$); the judgment effect was greater in the 10-second condition, although the 1-second condition also generated a reliable judgment effect of its own ($t = 2.19$, $df = 15$, $p < .05$).

The latency data of experiment 2 were similarly subjected to a three-way analysis of variance: judgment ("same" vs. "different") × instructions (question "same?" vs. question "different?") × subjects. Again, subjects took longer to reach the decision "same" (judgment effect, $F = 18.35$, $df = 1/15$, $p < .001$). In addition, they took longer to respond to the question "different?" than to the question "same?" (instruction effect, $F = 10.30$, $df = 1/15$, $p < .01$).

The total number of errors made under each of the various conditions of the two experiments is also shown in Table 1. As expected, in experiment 1, significantly more errors were made when the intertone interval was 10 seconds than when it was 1 second (Wilcoxon matched-pairs, signed-rank test, $T = 8$, $N = 13$, $p < .01$). No consistent differences in errors were associated with the instruction variable in experiment 2. In both experiments, most of the errors consisted in judging two identical tones to be different; seldom were two different tones judged to be the same.

The results show clearly that subjects took longer to decide that two identical stimuli were the same than to decide that two dissimilar stimuli were different. This was true whether they indicated their judgment directly by pressing keys marked "Same" and "Different" (experiment 1) or by "translating" the judgment into a "yes" or "no" response (experiment 2). That some such translation of judgment to fit the required response mode may be involved in experiment 2 is suggested by the fact that response latencies obtained in this experiment were generally higher than those obtained in experiment 1; but since the intertone intervals differed in the two experiments, this point requires confirmation. In experiment 2, latencies were longer in response to the question "different?" than in response to the question "same?"; this indicates that the judgments "same" and "different" are more easily translated into the responses "yes" and "no," respectively, than into the responses "no" and "yes," respectively. The main point, however, is that the latencies were longer for the judgment "same" whatever the form of the response.

The data on errors can be readily interpreted in terms of decision theory (*3*) by assuming that the subject adopts a more stringent definition of sameness than of differentness. In the terminology of decision theory, this means that his criterion point lies closer to the mean of the "same" distribution than to the mean of the "different" distribution on the decision axis (Fig. 1). If so, the area of the "same" distribution that falls on the "different" side of the criterion would be larger than the area of the "different" distribution that falls on the "same" side of the criterion. Hence the error of calling identical stimuli "different" would be expected to occur more frequently than the error of calling dissimilar stimuli "same." This is what happened.

In order to account for the observed differences in latency within the framework of decision theory, one might assume that latencies are maximum at the criterion point, the point of greatest uncertainty, and that they decrease progressively on both sides of it, as shown in the lower graph of Fig. 1. Though lacking a theoretical rationale, this assumption has factual support (*4*), and it would explain higher average latencies for the judgment "same" than for the judgment "different."

There is, however, a different way of looking at the present results; this arises from the type of choice-time model proposed by Stone and elaborated by McGill and Sekuler (*5*). One might conceive of the subject's decision-making mechanism as a sta-

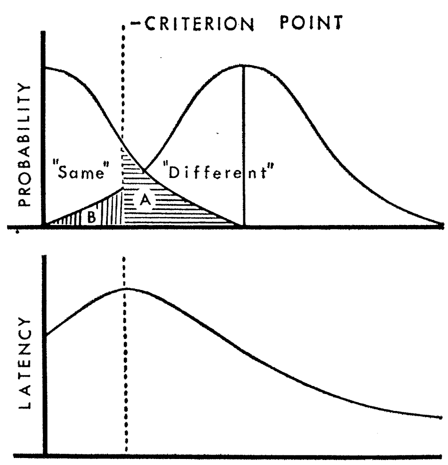

Fig. 1. The probability and latency functions of "same" and "different" judgments. The decision axis here describes the hypothetical neural datum, representing the amount of difference between the two comparison stimuli, on which the judgment is based. The criterion point separates the values of the neural datum (stimulus differences) that will be judged "same" from those that will be judged "different." The distributions in the upper graph describe the likelihood of obtaining the two judgments. Area *A* represents the probability of the error of calling identical stimuli "different," and area *B* the probability of the error of calling dissimilar stimuli "same." The lower graph describes the hypothesized relation between the criterion point and response latency.

tistical computer which receives a stream of information about the stimuli, accumulates this information, or some transformation of it, in an "adder," and matches a running total of this accumulated information against some predetermined criterion value. For example, the information might represent dissimilarity of the two stimuli, so that the subject would judge "different" if the running total accumulates beyond the criterion within a certain interval, determined by task requirements of speed and accuracy. In this case, the judgment "same" would occur only if the criterion value for the judgment "different" is not reached within the allotted interval; thus, on the average, "different" judgments would be reached earlier than "same" judgments. The reverse would be true if the information represented similarity of the two stimuli.

Another possibility is that there are two adders, one accumulating dissimilarity information and the other accumulating similarity information. Assuming that, correspondingly, there are also two criteria, the judgment reached would depend upon whether the "different" input accumulates to the level of the "different" criterion before the "same" input accumulates to the level of the "same" criterion, or vice versa. Response latency would then depend upon (i) the input rates of dissimilarity and similarity information—that is, on the relative preponderance of similarities or dissimilarities in the comparison stimuli; and (ii) the stringency of the criterion—that is, the magnitude of the cumulative total an adder must reach before the corresponding judgment would be given. Errors would be a function only of the stringency of the criterion; the greater the stringency the fewer the errors. To account for the longer latencies and greater frequency of error for "same" judgments, it is again sufficient to postulate that the "same" criterion is more stringent than the "different" criterion.

What factors determine the adoption of a more stringent criterion of sameness than of differentness? The significant interaction between judgment and discriminability in experiment 1 suggests that the difficulty of the discrimination may be one such factor; as discrimination difficulty decreases, the stringency of the "same" criterion is lowered relative to that of the "different" criterion. This implies that the latency differences observed in our experiments could be made to disappear, and possibly even reverse, by the use of more discriminable stimuli. Other task conditions, such as payoffs, could also be used to manipulate the relative stringency of the two criteria, and hence the relative latencies of "same" and "different" judgments. A systematic study of these factors should elucidate the nature of the "same–different" judgment.

DALBIR BINDRA
JUDITH A. WILLIAMS
JACK S. WISE
Department of Psychology, McGill University, Montreal, Canada

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Square Root Variations of Reciprocal Graphing of Enzyme Kinetic Data

Stutts and Fridovich (*1*) make a general criticism of the mathematical treatment of enzyme kinetic data which we have used extensively in recent years (*2–6*). They point out that it is difficult to distinguish between a reciprocal plot ($1/v \times 1/S$) (*6*) of data fitting the usual Michaelis-Menten formulation and a plot of $1/v^{1/2} \times 1/S$. On these grounds they suggest that the square root variation is limited in usefulness. However, in their treatment of ideal data from the Michaelis-Menten equation they do not show what data would look like if they did not fit the Michaelis-Menten relationship and yet could be made to do so by extraction of the square root.

This omission is here corrected. Table 1 and Fig. 1 correspond to table 1 and figure 1 of Stutts and Fridovich (*1*) but provide the additional data and plot of $1/v^2 \times 1/S$ which permit the proper comparison. That is, since the square root of the data had to be extracted to adjust them to the usual curves, the ideal data are here squared for purposes of comparison. The data have also been "normalized" by using V_m/v instead of $1/v$ so that the ordinate intercept is the same in all cases and it is easier to make a direct comparison.

To further clarify the differences between Stutts and Fridovich's ideal data (*1*) and the experimental data obtained by ourselves and collaborators (*2, 5, 6*) some of these experimental data have been recalculated (from the published curves) and plotted as V_m/v in Fig. 1. The recalculation was made by measuring the points on the graphs and squaring to reconvert to "raw" data. The $1/S$ values so obtained were multiplied by the Michaelis constant (K_m) determined from the curves, and the $1/v$ values were multiplied by the maximum velocity to convert V_m to 1.0. This is a general method for standardizing enzyme data to a K_m and V_m of 1. All data which can be expressed by a simple Michaelis-Menten relationship will fall on the same line passing through the points 0,1 and 1,2, with a slope of 1.0. If this procedure were always followed, there would never be difficulty in distinguishing between the possible cases shown. The results of these operations, shown in Fig. 1, should leave no doubts as to the internal consistency of the criticized data and as to the usefulness of the square root variation of the Lineweaver-Burk plot when it is properly applicable.

In Fig. 2, which corresponds to figure 2 of Stutts and Fridovich (*1*), a plot is made of the data obtained at sub-

Table 1. Idealized data of Stutts and Fridovich (*1*, table 1) converted to $(V_m/v^n$ to "normalize" the ordinate intercepts.

$1/S$	V_m/v	$(V_m/v)^{\frac{1}{2}}$	$(V_m/v)^2$
4.0	5.0	2.23	25.0
2.0	3.0	1.74	9.0
1.33	2.3	1.53	5.3
1.00	2.0	1.41	4.0
0.667	1.67	1.29	2.79
.500	1.49	1.22	2.22
.400	1.40	1.18	1.96
.333	1.33	1.15	1.77
.250	1.25	1.11	1.56
.167	1.16	1.08	1.34
.125	1.12	1.06	1.25