While statistically significant, the differences obtained among stages of sleep were relatively small from a physiologic standpoint. This apparent low order of change is probably due to the fact that shifts in metabolic level with variation in stage of sleep are superimposed upon the overall nightly trend in $\dot{V}_{O_2}$. Oxygen consumption rate decreases during the early hours of sleep and rises toward morning (*5, 7*). Comparison of stages that are averaged throughout the night might therefore be expected to minimize existing differences.

To take into account the changing slope of $\dot{V}_{O_2}$, contiguous sleep stages were compared. Thus, the difference in $\dot{V}_{O_2}$ between a given stage and that which immediately preceded or followed it could be obtained. The results of these comparisons are presented in Table 2. The data confirmed the findings in Table 1, and the differences were generally of greater magnitude. Indeed, there were significant differences even if only the last 5 minutes of a given stage were compared with the first 5 minutes of the next stage.

Thus, perusal of the analogues and computations derived from the data make it clear that differences in rate of oxygen metabolism parallel the level of sleep as defined by EEG. If one wishes to define level of sleep in terms of metabolic activity, then these data confirm the equivalence of depth of sleep and EEG stage.

The differences reported have been calculated from pooled data on all subjects. While these differences generally held for each individual, not every shift within a given night was of significant proportions. Table 3 shows the frequency with which significant and nonsignificant changes in $\dot{V}_{O_2}$ occurred with a transition in stage of sleep. A number of factors may bear upon the large number of changes which do not reach the level of significance, and the occasional change in the direction opposite to that expected. An increasing number of body movements before a REM period (*11*) could at times obscure differences by increasing oxygen utilization prior to the change in stage. Acting in the opposite direction, periods of apnea during stage I REM (*12*) could also be responsible for the occasional lack of significant differences. Interindividual variation in patterns of metabolism during sleep (*5*) might also contribute to the lack of uniformity in results.

It could conceivably be argued that body movements throughout the night are responsible for all differences in $\dot{V}_{O_2}$ observed. While the relationship between physical activity and other variables during sleep is indeed little understood, it is our impression that such activity has not significantly affected the data. Major body movement artifact has been avoided by omitting sections in which more than two changes in stage occur, for example, awake going to descending I and then stage II. Additional bases for this impression are that differential variations with stage of sleep have been reported for other physiologic parameters when episodes of body movement were removed from comparisons (*3*), and that gross cyclical changes in $\dot{V}_{O_2}$ were noted in REM sleep when little evidence of body movement was present (see Fig. 1).

D. ROBERT BREBBIA
KENNETH Z. ALTSHULER
Respiration and Metabolism
Laboratory, Research Center,
Rockland State Hospital,
Orangeburg, New York

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Detection Thresholds as a Function of Interval Separation between Two Successive Targets

Abstract. *Detection thresholds for two successive targets varied systematically with the interval between the two pulses. At intervals of 10 to 30 milliseconds, and again at 80 to 200 milliseconds, the threshold was lowered as compared to that for a single target, while at a separation of 50 to 60 milliseconds, the threshold was raised.*

The relative energy required to attain threshold when two successive light flashes are used has been shown to be equivalent to that necessary for one light flash provided that (i) the integral, intensity × time, is the same for two as for one light flash and (ii) that the flashes occur within a certain critical period. These factors are embodied in Bloch's Law which states that for short pulses of light the Bunsen-Roscoe law of photochemistry applies to the human visual system (*1*). The changes in target detectability when the separation of two stimuli exceeds the critical period are presented in this report. The available evidence is conflicting. On the one hand, Davy (*2*) reported that threshold energy rises when two flashes are separated by intervals greater than the critical duration and, at a temporal separation of 0.5 sec, it is the same for each of the two flashes as it is for one flash. On the other hand, Clark and Blackwell (*3*) have reported that double-pulse targets separated by intervals exceeding the critical duration are more detectable than are the corresponding single-pulse targets. We have attempted to determine, in greater detail, the functional relationship between target detectability and the temporal separation between two targets.

Four adult males served as subjects. All were personnel of the laboratories and had normal or corrected vision. The apparatus consisted of a two-field mixing tachistoscope providing a distal stimulus at a constant illumi-

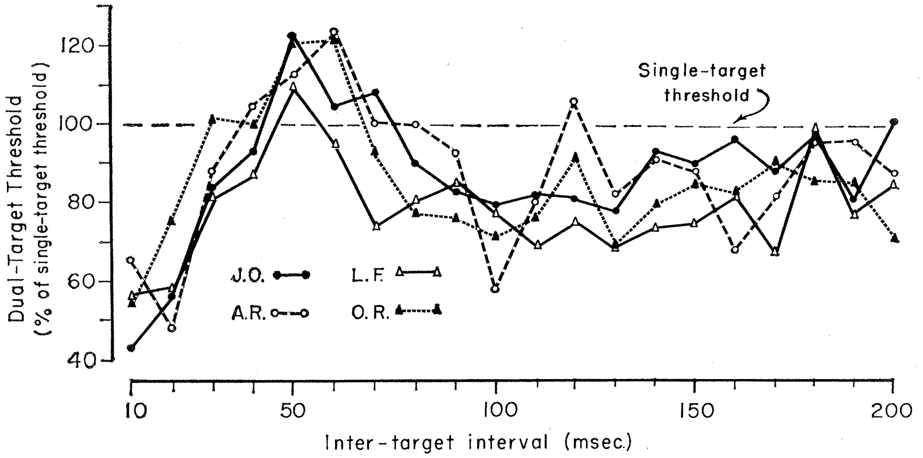

Fig. 1. Dual-target threshold as a function of intertarget interval.

nation (Scientific Prototype Model GA). One field was used to expose the target, and a second the adapting field. The target was a small black disc which subtended 15 minutes at the retina. The waveform of the stimuli was monitored and indicated a risetime of 24 μsec and a decay time of 28 μsec. The target appeared in the center of a white rectangular adapting field which had a luminance of 18 millilamberts and subtended an angle of 26 by 42 degrees at the retina.

At the beginning of each test session, the subject looked at the adapting field binocularly. After a signal from the experimenter, a single or dual target was presented. A dual-target presentation consisted of two black targets separated by intervals of 10 to 200 msec (in steps of 10 msec). Regardless of whether a single or dual target was exposed, the subject's task was simply to report the perception of just one target. In order to obtain the threshold exposure for this perception, the psychophysical method of limits was used; target duration was either increased until the subject reported its presence (ascending series) or decreased until he reported its absence (descending series). Incremental changes in target duration were made in steps of 0.25 msec, and the two targets in a dual-target presentation always had identical exposure durations. If the subject was uncertain, the same target, or targets, was presented repeatedly until a judgment was made. During each daily test session, one single-target threshold and two dual-target thresholds at two intertarget intervals were determined. Each threshold determination was based upon two ascending and three descending series. Since a single-target threshold varied somewhat from day to day, all dual-target thresholds were expressed as percentages of the single-target threshold obtained during the same session.

Separate curves for the four subjects are plotted in Fig. 1. Relative detectability, expressed as a percentage of single-target threshold, varied as a function of the temporal separation between dual targets. The curves reveal three distinct periods which are consistent between subjects: first, an enhancement, followed by a depression, then a second enhancement. The first enhancement, at 10 and 20 msec, conconforms almost exactly to Bloch's Law (*4*). The second enhancement beyond 80 msec or thereabouts has been reported previously by Clark and Blackwell (*3*). It should be noted that between these two periods all four curves rise above the single-target threshold. The peak appears to be at about 50 msec. Thus, with a 50-msec temporal separation between paired targets, it is apparently more difficult to detect the dual targets than the single one. Specifically, each pulse of the dual target must be presented with a duration about 20 percent longer to reach threshold than the equivalent single target (*5*). The difference in the threshold for single- as opposed to dual-target detection at 50-msec separation was analyzed and found highly significant [$t = 4.21$, df (degrees of freedom) $= 58$, $P < .001$].

Facilitation or neural summation is usually offered to account for the lowering of threshold for successive visual stimuli (*6*). In the case of the second enhancement, probability summation may be contributory (*7*). This means that, with the longer temporal separations, the visual system may be acting as a detector of two independent events, such that the probability of reporting at least one of these events is greater than the probability of reporting one single event. There is some evidence to support this view (*3*, *7*).

Inhibition might account for the depression of threshold but its mode of operation in this case is unclear. It is not merely that the first stimulus inhibits the second, a not uncommon event, but rather that the two stimuli mutually inhibit one another. Thus the first masks the second, and the second, in turn, masks the first. A case of mutual inhibition of retinal ganglion cell discharge has been reported in the past, but, in this case, the stimuli were presented together (*8*).

That a visual stimulus can produce an effect upon another visual stimulus which preceded it has been reported many times (*9*); but the second stimulus has usually been markedly supraliminal, and it is not unreasonable to assume that it initiates neural events which overtake and interfere with the events generated by the weaker liminal stimulus. This explanation cannot be applied to our data since the two targets had equal exposure durations. However, a backward inhibition can be accounted for if it is assumed that the second neural event interferes with the elaboration of events initiated earlier.

It has generally been postulated that a system arising from the mesencephalic tegmentum and projecting by way of the intralaminar nuclei may exert a regulatory influence over cortical excitability (*10*). This system may contribute to an understanding of the mechanism for forward inhibition. Specifically, the first stimulus acting through this system may trigger the start of a cerebral excitability cycle which then determines the phase of the cycle when the second stimulus arrives. The precise moment of arrival determines the relative perceptual effectiveness of the second stimulus. These shifts in excitability may be related to the cyclicity of the alpha rhythm (*11*).

In summary, it appears that the function in Fig. 1 may be reflecting three distinct processes occurring at one or more levels within the visual system. Although the early facilitation (10 to 40 msec) probably reflects the influence of photochemical and neuroretinal events, cerebral mechanisms 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