responsiveness on the two sides of the cliff, was strongly supported. The infants manifested a small, generally nonsignificant, cardiac response on the shallow side, and a large, generally highly significant deceleration, on the deep side (Table 1). The trend of the results is the same regardless of which cardiac parameter is examined or what the age of the subjects is. Figure 1, a detailed presentation of moment-by-moment heart rate in the younger age sample, shows the power of the visual cliff technique to elicit discriminative cardiac responses. During the prestimulus period, heart rate is quite similar in the two conditions. As soon as the subject is placed downward to look at the surface of the cliff, heart rate shows an immediate discrimination which persists for the duration of stimulus presentation (interaction of deep-shallow with prestimulus-stimulus, $F = 18.13$). Consistency of the cardiac responses within the subjects is also evident. Twenty-seven of the thirty-one subjects showed a greater deceleratory trend on the deep side.

The cardiac deceleration obtained on the deep side was not altogether unexpected, in view of the growing body of research on infant deceleratory orienting responses (*5*). Nevertheless, deceleration was not consistent with our initial expectation, nor with what one would expect if an infant were manifesting distress, fear of loss of optical support, or muscular tension—conditions which ordinarily would be associated with cardiac acceleration. Observations collected on the younger sample definitely implicated orienting or attention rather than fear in eliciting the cardiac response on the deep side. A mean of 22.3 seconds per trial of "looking down" was recorded on the deep side, while only 15.7 seconds were recorded on the shallow side ($t = 2.83$, $P < .02$). Similarly, a mean of only 2.1 seconds per trial of "fussiness or crying" was observed on the deep side, while 7.7 seconds were recorded on the shallow side ($t = 2.54$, $P < .05$). The total picture obtained on the deep side is thus one of motor quieting, relatively less fussiness, and highly reliable cardiac deceleration. All of these criteria characterize orienting, rather than fear, and strikingly confirm the expectation of Graham and Clifton (*6*), as well as Kagan and Lewis (*2*) that heart rate deceleration is a component of orienting.

The results of this study are consistent with the view that infants perceive depth at the ages tested, the youngest of which is in the same range as that in which Bower (*7*) found depth discrimination. However, the conclusion that orienting was being manifested, rather than fear, weakens the inferential process by which the presence of depth perception can be derived. Since the orienting response is a nonspecific response to any stimulation, and since depth-specifying stimuli such as are involved in the visual cliff have two-dimensional as well as three-dimensional perceptual correlates, it is not possible to conclude unequivocally that anything more complex was being manifested than attention to the lesser relative motion, or the smaller retinal size, and so forth, in the deep display. Operationally, however, we have demonstrated discrimination of the two sides of the visual cliff at prelocomotor ages. Because any theory of depth perception, learning-oriented or otherwise, must start with the discrimination of those stimuli that ultimately specify depth, it seems plausible to suggest that the visual cliff apparatus, together with heart rate, may be a useful tool for the demonstration of such discrimination in the very young infant, and for the isolation of stimulus parameters discriminable at those ages.

Our results also indicate a significant finding concerning infant emotion. The human infant does not appear to give evidence of much distress at loss of optical support on the deep side at the ages tested. This is in marked contrast to the written and filmed observations of animals (*1*, *8*) and studies of older infants in our laboratory. This suggests that the human infant can discriminate a stimulus and then undergoes a developmental process which allows that stimulus to elicit aversive responses. The increase in negative responding with age to the same stimulus has already been documented with respect to infant responses to strangers (*9*). The infant orients to strangers by 4 months (*10*), but by 12 months, aversive responses are evident. Our possibly analogous finding with the visual cliff shows how the apparatus can prove as useful for the study of the development of human emotion as it is for the study of perception.

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Temporal Summation Phenomena at Threshold: Their Relation to Visual Mechanisms

Abstract. *Threshold energies were determined for brief flashes as a function of their duration in order to determine the maximum duration for which the flash intensity and duration could be varied reciprocally without affecting detectability (the Bunsen-Roscoe effect). A pair of threshold-level flashes for which reciprocity obtained in the determination of threshold were shown to be discriminable from each other at several imperfectly detectable energy levels. Thus equal detectability of flashes of equal energy does not imply identical neural responses to such stimuli. It is suggested that the summation reflects primarily the operation of the detection mechanism rather than of the peripheral visual mechanism. Some general implications for the interpretation of threshold measures are also discussed.*

Temporal summation phenomena have been investigated extensively in studies of sensory systems because they seem to reflect important properties of the underlying sensory mechanisms. The best-known summation phenomenon in vision is Bloch's law (also known as the Bunsen-Roscoe law)

(*1*), which describes the fact that flashes less than some critical duration are equally detectable when their total energies are equal. Intensity and duration can be traded to keep detectability constant. This reciprocity has also been demonstrated in the performance of a variety of other visual and cognitive tasks (*2*). The duration at which reciprocity failed depended in part on the nature of the task. Kahneman and Norman were led to conclude from task-dependent differences in the critical duration that critical duration "does not represent the duration of an early 'sensory' phase of the visual process." However, their argument does not reject the possibility that the critical duration for a simple detection task, where the critical duration is shortest, might reflect the limits of an early, sensory phase of the visual process.

One reason why, over some range, equal-energy flashes are equally detectable, might be that equal-energy flashes produce essentially identical neural responses. This would occur, for example, if the flash durations were very short with respect to the duration of the impulse response for the system (*3*). Some writers have suggested this kind of explanation of Bloch's Law (*4*). The experiments described below were designed to test this hypothesized explanation more directly. If equal-energy stimuli are believed to be equally detectable because they elicit the same neural responses, then they should also be indiscriminable from each other. It will be shown that this is not so, thus rejecting the argument that all stimuli within the range of Bloch's Law are very short with respect to the duration of the impulse response of the visual system.

The first experiment constituted a replication of Bloch's finding with a specific set of arbitrarily chosen parameters. Thresholds were measured for a dark-adapted observer (J.L.Z.) with a test stimulus 5′ of arc in diameter, centered 20′ to the left or right of the fixation point.

Thresholds were measured for flashes of from 2 to 512 msec. The psychophysical method used was a double-random, spatial forced-choice staircase with feedback (*5*). Threshold energy is shown as a function of flash duration in Fig. 1. Equal-energy flashes were equally detectable up to durations of about 100 msec.

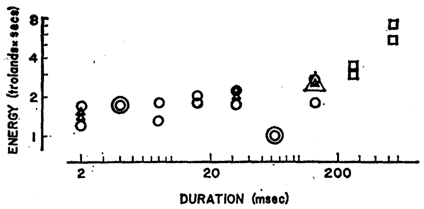

Fig. 1. Threshold flash energy as a function of flash duration. Each data point is the median of the last 40 trials from a 60-trial staircase. Stimuli were presented every 10 seconds. Data represented by the same symbol were collected on the same day.

To ascertain more accurately that a given pair of stimuli (4 and 81 msec) were equally detectable when they were of the same energy, psychometric functions were estimated for each, using a two-choice spatial forced-choice psychophysical method and the same stimulus geometry as in experiment 1. There is no indication that the detectability of the short flash is different from that of the long flash of the same total energy (Fig. 2A).

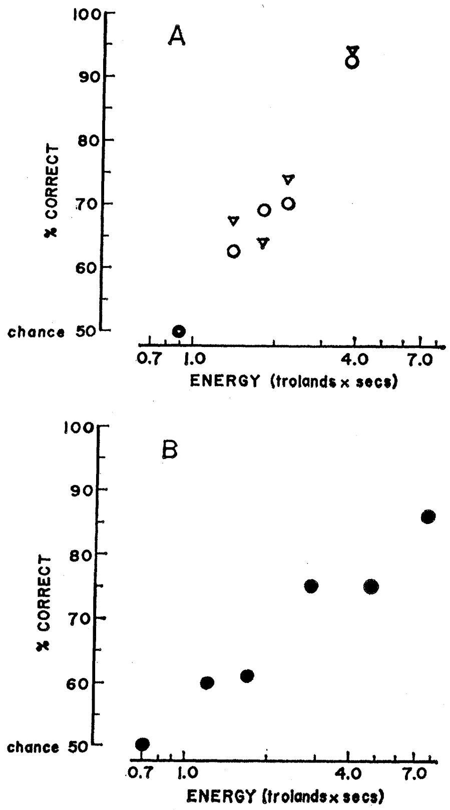

Fig. 2. (A) Correct detection as a function of flash energy. There is no significant difference in the psychometric functions for the 4- and 81-msec flashes. Results for 4-msec flashes are shown by circles, for 81-msec flashes by triangles. (B) Correct discrimination between 4- and 81-msec flashes of the same energy. Note also, by comparison with (A), that discrimination between the flashes is nearly as good as detection of the flashes.

Having demonstrated that the 4- and 81-msec flashes were equally detectable when they were of the same energy, I measured their discriminability from each other. In this experiment the stimulus always appeared to the left of the fixation point. The task of the observer was to indicate, on each trial, whether the 4-msec or the 81-msec flash had been presented. He was given trial-by-trial feedback. In any block of 50 consecutive trials all flashes were of the same energy, and each flash occurred 25 times. Two blocks of trials were run at each energy level. The results (Fig. 2B) show that the flashes are at least partially discriminable from each other over the entire range of energies for which they are imperfectly detectable. In fact they are almost as discriminable as they are detectable (compare Fig. 2B with 2A).

These results thus force the rejection of the hypothesis that equally detectable, equal-energy flashes are of the same detectability because they evoke identical neural responses. Furthermore, because the stimuli are virtually as discriminable from each other as they are detectable, it is unreasonable to believe that discrimination is based upon the slight differences in the responses that would be expected from a linear system with a long time constant. It seems more plausible to argue instead that the summation observed in the detection results reflects a property of the detection mechanism, not just the visual system. The present results say nothing directly about the psychological dimension along which the long and short stimuli were distinguished (*6*).

That the long summation time is a property of the detection mechanism is supported by the fact that similar summation phenomena have been observed in auditory detection. Under some conditions the detection of a tone burst depends only upon the energy for durations up to 200 msec (*7*), in a sensory system known to have very good temporal acuity. Similarly, a human observer, hearing the responses of cat retinal ganglion cells as trains of clicks, also finds that equal-energy flashes of up to 100 msec produce equally detectable modulations in the click trains near threshold flash energies (*8*).

Thresholds have been widely used to

characterize various aspects of sensory functioning. Their use reflects in part the apparent similarity of thresholds to "null measures." Adjusting the stimulus parameters to produce a constant effect (some criterion level of detectability) appears to minimize the need to make assumptions about the properties of the metric used by the observer to measure his sensation. The experiments described above emphasize the caution one must exercise in the interpretation of the results from this kind of null experiment. The situation is no different, in principle, from an experiment in which Krauskopf and Srebro (*9*) demonstrated that equally but imperfectly detectable flashes of different wavelengths were nearly perfectly discriminable. The empirical data attest only to the similarity of the *measured* effects of the assorted stimuli. If it is desired to determine that two or more stimuli produce identical effects in all respects it is necessary to demonstrate that the stimuli cannot be discriminated from each other. Where stimuli are discriminable from each other, but equally detectable, it requires a stronger model (more assumptions) to be able to conclude which aspects of the neural responses to the various stimuli are the same (if any) when the stimuli are equally detectable. Thus total temporal summation in the determination of the detectability of brief flashes implies only that those aspects of the responses to brief flashes which determine their detectability are equivalent.

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3. This assumes, as many have, that the visual system can be characterized as a linear system for near-threshold intensities. Thus the response to a temporally extended stimulus can be derived, knowing the impulse response, by decomposing the stimulus into a series of impulses of heights proportional to the amplitude of the stimulus at that time, computing the response to each impulse, and summing these responses. If the stimulus duration is short with respect to the duration of the impulse response, the response to the brief stimulus will be only slightly longer and slightly lower in peak amplitude than the response to an impulse of the same energy.
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Tektite Glass Not in Apollo 12 Sample

O'Keefe (*1*) has reported the supposed discovery of tektite glass in lunar sample 12013 on the basis of information from the Apollo 12 preliminary examination (*2*) and other communications. This report is based on faulty data and assumptions, and the major conclusion is incorrect. Although portions of the sample might appear to be vitreous by cursory examination, neither fragment of sample 12013 analyzed during the preliminary examination was glass. X-ray diffraction analyses of both fragments (Fig. 1) were performed prior to chemical analysis and gave the following mineral identi-

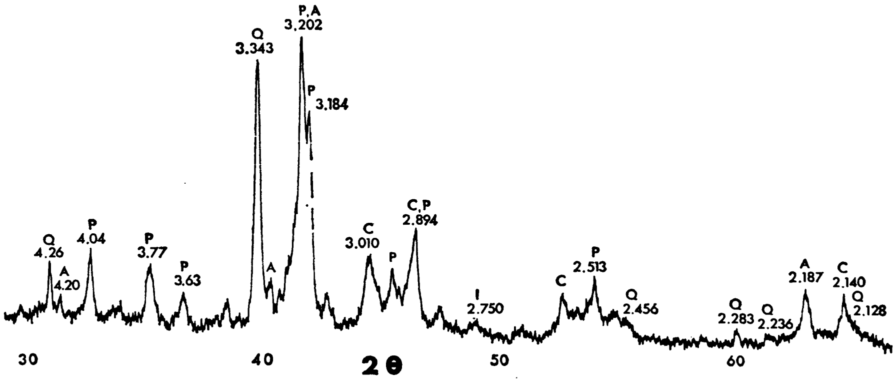

Fig. 1. A portion of the x-ray diffractogram of one of the analyzed fragments of lunar sample 12013. The fragment is obviously not glass. Peaks are identified as follows: *A*, alkali feldspar; *C*, clinopyroxene; *I*, ilmenite; *P*, plagioclase; *Q*, quartz. This diffractogram is approximately the same as the one obtained for the second fragment. (CrKα radiation).

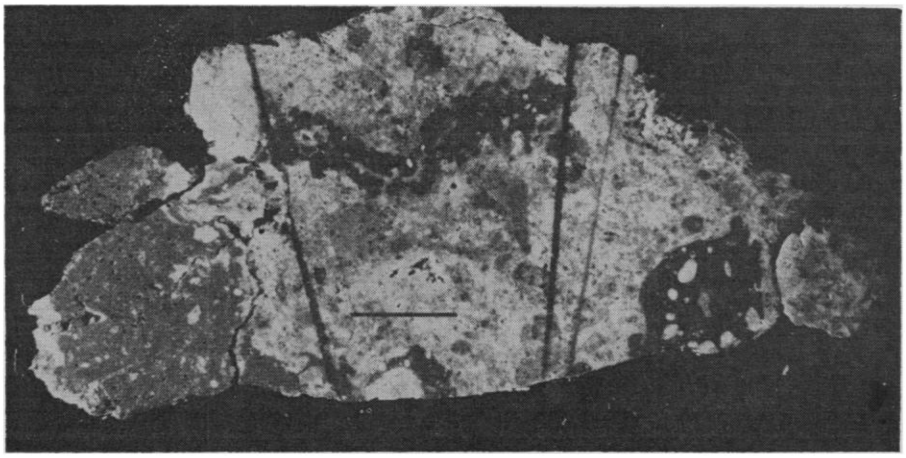

Fig. 2. Sawed slab of lunar sample 12013, in which the heterogeneity and complex petrography of the sample are illustrated. The scale is 0.5 cm [NASA, Manned Spacecraft Center photograph No. S-70-40833, sample No. 12013,9].