function in visual reception and suggested the involvement of porphyrins which are in high concentration in the rat Harderian gland. Although our results do not specifically implicate the porphyrins of the Harderian gland in the enzymic response to light, they do lend some support to Kluver's notion of photoreception by orbital glands.

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Cardiac Responses on the Visual Cliff in Prelocomotor Human Infants

Abstract. *Human infants younger than crawling age yielded reliable cardiac decelerations when placed directly atop the deep side of a visual cliff and generally nonsignificant changes when atop the shallow side. Distress was elicited less frequently on the deep side than on the shallow at these ages, in contrast to the behavior of older infants and other species. Prelocomotor infants thus can discriminate the two sides of the cliff, but not by means of distress at loss of optical support.*

The visual cliff, an apparatus for investigating depth perception in the older human infant, can also be used for testing discrimination capacities in prelocomotor infants. Visual cliff studies have up to now been limited to older infants by relying, as an index of depth perception, on the infant's avoidance of crawling over the "deep" side of the cliff. Only the absence of a suitable dependent variable has prevented the testing of younger infants on the apparatus. Previous studies (*1*) reporting marked emotionality in animals placed directly over the visual cliff's deep side suggested that the autonomic responses of infants placed directly over either side of the cliff might serve to discriminate the deep from the shallow sides, even at ages when the infant is much too young to crawl.

Table 1. Heart rate responses of infants 106 and 55 days old on visual cliff. Results are expressed in beats per minute.

Parameter	Condition: Deep	Shallow	Deep minus shallow
106 days old			
Cardiac highs	−7.80*	−0.90†	−6.90‡
Cardiac lows	−7.40*	−0.80†	−6.60§
Time sample	−6.10*	−0.80†	−5.30§
55 days old			
Cardiac highs	−5.10‡	+4.80†	−9.90‡
Cardiac lows	−2.80†	+6.80‡	−9.60‡
Time sample	−4.70‡	+5.50†	−10.20*

* $P < .001$. † $P > .05$. ‡ $P < .01$. § $P < .03$.

Heart rate is a sensitive autonomic response in even the youngest human infants (*2*, *3*). By measuring heart rate response, we studied visual cliff discrimination in two prelocomotor age samples. The median age of one group (13 males, 7 females) was 106 days (range 75 to 115), and that of the other (seven males, four females) was 55 days (range 44 to 70). Visual cliff model III (*4*, p. 8) was used, with both deep and shallow surfaces consisting of red and white tiles (22 by 22 cm) arranged in checkerboard. Heart rate was recorded on a Grass model 5D polygraph.

The procedure was to assign an infant randomly to one of two conditions, initial deep placement or initial shallow placement. A prestimulus measure of heart rate was obtained before each deep or shallow trial by sitting the infant atop the appropriate side of the visual cliff for 1 minute in the older group, and 30 seconds in the younger group (for whom the longer prestimulus interval often produced crankiness). After the prestimulus period was over, the experimenter placed the infant on his stomach, with his eyes pointed down toward either the deep or the shallow surface of the cliff for the same duration as the prestimulus period. The experimenter had to hold the older infants at a slight angle from the prone position to prevent the child from hitting his head against the glass. The younger infants were placed on foam padding (11 cm thick) to accomplish the same end. Two trials were attempted on each side, except when the infant's state precluded further testing.

Three parameters of heart rate were chosen for study. In one case, heart rate was sampled every 2.5 seconds during the first 30 seconds before the stimulus was administered and during the first 30 seconds of the stimulus period. A simple heart rate difference score was then obtained by subtraction of the mean prestimulus heart rate from the mean stimulus heart rate. The other two parameters, the logic of which is explained by Kagan and Lewis (*2*), were selected to enable comparison with other studies of infant heart rate. One parameter, called "cardiac highs," consisted of sampling the five fastest heartbeats during the 10 seconds just prior to stimulation, and the two fastest beats during each of six succeeding 5-second periods during stimulus presentation. The mean of the cardiac highs during prestimulation was then subtracted from the mean of the highs during stimulation. The analysis of "cardiac lows" was entirely analogous, except for the selection of slowest beats. Regardless of parameter, the index of discrimination of the two sides was simply the heart rate response on the deep side subtracted from that on the shallow.

The hypothesis of the study, that infants would show differential cardiac

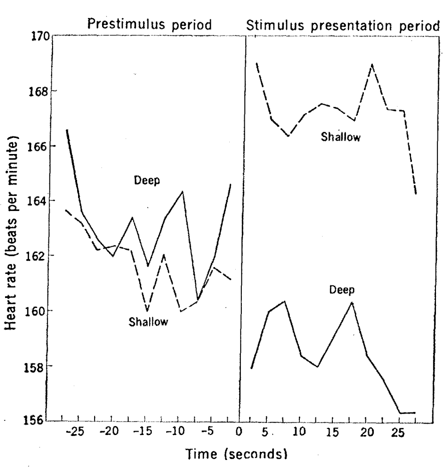

Fig. 1 Heart rates in 55-day-old infants on shallow and deep sides of a visual cliff.

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)