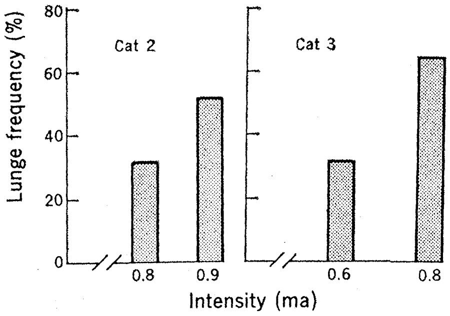

Fig. 2. An increase in the intensity of hypothalamic stimulation for two cats resulted in a significant increase in the number of lunges when the mouse was presented to the ipsilateral eye. All lunge frequency percentages were based on 200 presentations of the mouse at each stimulation intensity. Cat 3 was stimulated at site a. The difference for cat 2 was significant at $P < .05$ on the basis of a χ^2 test. The difference for cat 3 was significant at $P < .001$ on the basis of a χ^2 test.

the case of three cats (cats 1, 4, and 5) the "ipsilateral" eye yielded many responses when the stimulation was switched to a hypothalamic attack site on the opposite side. Neither is the result attributable to olfactory cues alone, since, when both eyes are occluded, the responses are very infrequent.

Furthermore, the differential sensitivity of the two eyes does not appear to be a consequence of a distortion of the optical system of the ipsilateral eye. In two cats (cats 2 and 3) an increase in the intensity of stimulation to the hypothalamus resulted in a significant increase in the number of lunges made when the mouse was presented to the eye ipsilateral to the site of stimulation (Fig. 2). Were distortion of the optical system of the ipsilateral eye the cause of the main result, an increase in the intensity of stimulation should have resulted in less, rather than more, frequent responses on the ipsilateral side.

Thus, the contralateral eye is more effective in mediating attack than the ipsilateral eye, and the effect seems to be due to a facilitation of visual mechanisms related to the contralateral eye and not simply to the exclusion of sensory information from the ipsilateral eye. The mechanisms within the nervous system whereby this effect is mediated are not known at present (*4*). The effect may be related to visual field effects, with the effective visual field of the contralateral eye being larger than that of the ipsilateral eye. This interpretation is suggested by the increased number of lunges to the ipsilateral side with increasing stimulation intensity.

The main result of this study is in accord with a number of other aspects of attack elicited by stimulation of the hypothalamus. The act of biting involves a reflex of head-turning and another of mouth-opening, and these are first discernible on the contralateral muzzle and lip (*1*). The act of striking is similarly accomplished with the contralateral forelimb (*5*). These observations imply that the sensory and motor systems are not simply tools for all occasions at the service of a drive or motive. Instead, they support the general thesis that electrical stimulation of the brain which elicits attack prepares the sensory and motor systems to act in specific ways which reach the level of components of the overt behavior when the environment provides adequate stimulation (*6*).

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1. M. F. MacDonnell and J. P. Flynn, *Science* **152**, 1406 (1966); *Anim. Behav.* **14**, 399 (1966).
2. The term "patterned reflex" was chosen to emphasize not only that the reflex is present during stimulation, but that it plays an integral part in bringing about the total behavioral "pattern" elicited by stimulation. See J. P. Flynn [in *Neurophysiology and Emotion*, D. Glass, Ed. (Rockefeller Univ. Press, New York, 1967), pp. 40–59], and J. P. Flynn, H. Vanegas, W. Foote, S. Edwards [in *Neural Control of Behavior*, R. Whalen *et al.*, Eds. (Academic Press, New York, 1970), pp. 135–173] for a discussion of the hypothalamus as a patterning mechanism.
3. Examination of the histological material for cat 5 failed to indicate why both eyes were equally effective in mediating the lunge during stimulation of site b and the contralateral eye was more effective than the ipsilateral eye during stimulation of site a. In addition, for three cats (cats 2, 3, and 5) during stimulation of other hypothalamic attack sites from which only a weak biting attack could be obtained, the visual presentation of the mouse failed to elicit the lunge and jaw-opening. However, the visual presentation was also ineffective in eliciting the lunge and jaw-opening at all sites shown in Fig. 1 if the stimulation intensity was reduced to a level at which only a weak biting attack could be obtained. After reduction in the stimulation intensity at site b for cat 5, the visual presentation was equally ineffective at each eye.
4. Physiological evidence of a direct effect of hypothalamic stimulation on the visual system is provided by two experiments. C. C. Chi and J. P. Flynn [*Electroencephalogr. Clin. Neurophysiol.* **24**, 343 (1968)] found that stimulation of hypothalamic attack sites prior to stimulation of the optic tract or optic radiations decreased the size of the potential evoked in the visual cortex, whereas similar stimulation of the midbrain reticular formation increased the magnitude of the evoked response. H. Vanegas, W. Foote, and J. P. Flynn [*Yale J. Biol. Med.* **42**, 191 (1969–1970)] reported that the response of some individual cells in the visual cortex to slits of light, moving slits, and moving edges was enhanced by hypothalamic stimulation, whereas the response of other cells was decreased and the response of still other cells was unchanged. Furthermore, in both studies, the hypothalamic effect was still present after the midbrain reticular formation had been destroyed, an indication that there is a pathway to visual structures independent of the midbrain reticular formation.
5. S. Edwards, thesis, Yale University (1970).
6. For a further discussion of this general thesis, see J. P. Flynn, S. Edwards, R. Bandler, Jr., *Behav. Sci.*, in press.
7. Supported by PHS postdoctoral fellowship 2-F02-MH44241 to R.B. and PHS grants 5-R01-MH08936 and 1-K05-MH25466 to J.P.F. We thank F. Gomes and M. Groves for technical assistance.

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Infant Responses to Impending Collision: Optical and Real

Abstract. *Twenty-four infants ranging in age from 2 to 11 weeks responded to symmetrically expanding shadows, which optically specify an approaching object, with an integrated avoidance response and upset. This response did not occur for asymmetrically expanding shadows nor for contracting shadows that specify an object on a miss path and a receding object. The response was observed in all the infants regardless of age, and the addition of kinetic depth information to the displays did not increase the intensity or likelihood of the response. In a second experiment, seven infants defensively reacted to the approach of a real object except when it was on a miss path.*

The perception of an approaching object is of obvious significance to an organism. The approach is a complex spatiotemporal event. To apprehend its significance, the organism must detect object qualities, including relative distance and direction of approach, within a brief period of time. Moreover, if this apprehension is to occur more than once, the organism must act in a fashion appropriate to the event. Recently, Bower (*1*) found that infants respond to symmetrically looming shadows or to real approaching objects with an integrated response that consists of an initial widening of the eyes, a head withdrawal, and a raising of the arms. In addition, the stimulus presentation, particularly in the case of the real object, often produced upset and crying in the infants. Just as other species avoid looming shadows (*2*) or the deep side of a visual cliff (*3*), the infant's response reflects a capacity to respond appropriately to the distal stimulus.

The purpose of this research was to specify further the infant's initial perceptual capacities. The displacement of an object is specified optically by the transformation of a bounded segment of the optic array (*4*). The solidity and shape of the object are specified by the closed contour and by transformations of it that produce kinetic depth (*4, 5*). The path of approach is specified by the symmetrics or asymmetrics of an expanding bounded segment, and withdrawal is specified by its minification. In addition, collision is specified when the bounded segment fills 180° of the frontal visual field. The psychophysics of the infant's capacities requires the assessment of its response to these higher-order, event-specifying stimuli.

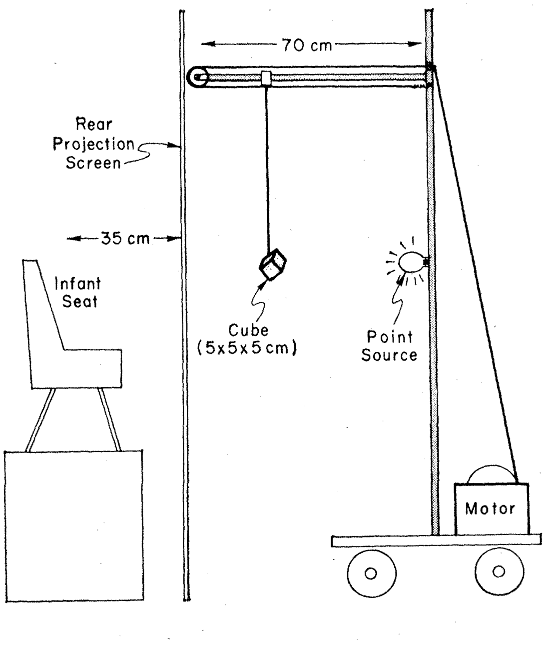
To make this assessment with shadow-casting techniques, 24 infants (eight infants, 2 to 5 weeks of age; eight infants, 5 to 8 weeks of age; and eight infants, 8 to 11 weeks of age) served as subjects. The apparatus (see Fig. 1) consisted of a 100-watt concentrated arc point-source lamp mounted at the end and below a 70-cm track. A Styrofoam cube (5 by 5 by 5 cm) was attached to a 51-cm rod suspended from the track. A motor-operated pulley system moved the rod along the track at a constant speed of 12 cm/sec. A second motor permitted rotation of the rod at a speed of ½ revolution per second. In addition, the point source could be displaced laterally relative to the track, so that the object moved either directly toward it or off to one side.

The shadow caster was placed on one side of a rear projection screen (1.8 by 1.8 m). The infant was seated approximately 35 cm away from the opposite side of the screen in an infant chair. The chair had no head support or waistband and thus allowed free head, arm, and leg movements; but the infant was supported by an adult holding him around the waist. To the left of the infant, a television camera and microphone recorded the infant's responses to the various displays. The room itself was darkened except for the light from the point source, light from an overhead bulb, and light from a lamp on the floor to the infant's left. This combination of lights was intense enough for efficient operation of the television camera but was dim enough not to interfere with the clarity of the shadow transformations.

Movement of the static cube toward the point source (flat hit) produced a symmetrical growth in the shadow and the visual experience of an approaching object for an adult observer. Shifting the point source laterally produced an asymmetrically growing shadow that appeared to be an object coming toward an observer but on a miss path (flat miss). Movement of the cube away from the point source after an approach appeared to be an object moving away from the observer (flat recession). Rotation of the cube in front of the point source prior to and during its movement along the track resulted in the visual experience of a solid object. The rotating cube went through the same sequence as the static cube; that is, it was driven directly toward the point source (solid hit), toward the laterally shifted point source (solid miss), and away from the point source (solid recession).

A trial consisted of an approach followed by a withdrawal of the object from the point source. Two of the infants in each age group started with one of the four possible conditions. After three trials, if they were still alert and attentive, they continued through the other three conditions in a predetermined Latin square order.

In a second experiment, seven infants 3 to 6 weeks of age were exposed to a 30 by 30 cm object approaching on a collision or miss path (Fig. 2). Its rate



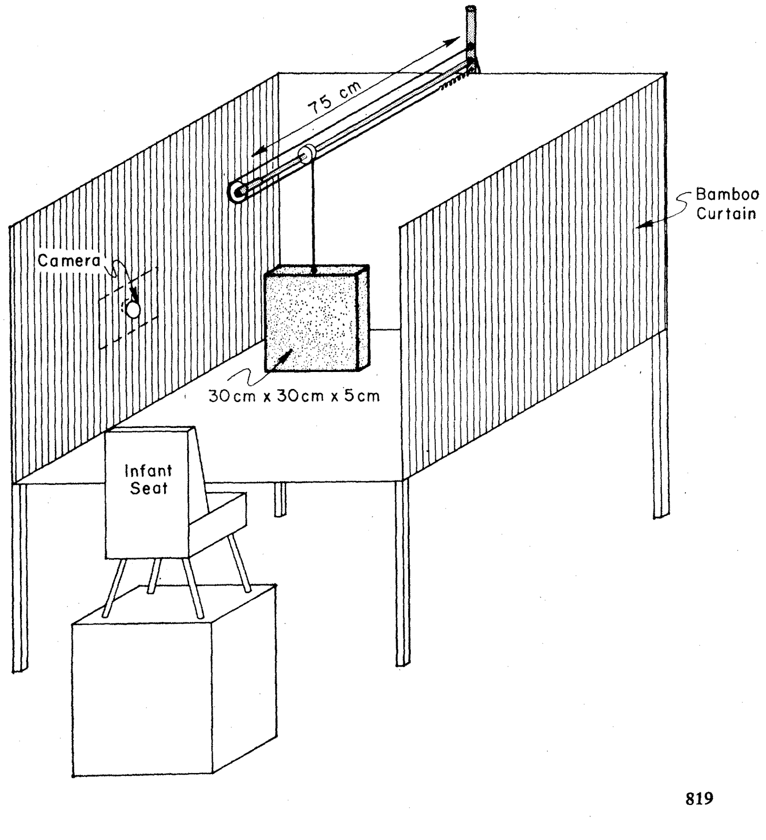


Fig. 1 (above). Shadow-casting apparatus.

Fig. 2 (right). Real object apparatus.

of approach was 17 cm/sec. The object was hung from the shadow-casting apparatus and displayed in a three-sided visual corridor made of bamboo curtains. Its run was 75 cm in length and ended about 15 cm in front of the infant. The object was not rotated but remained frontal parallel to the infant seated at the end of the run, in the same fashion as in the shadow-casting procedure. Infants started with either hit or miss sequences in a balanced design across subjects. Three trials of each sequence were again attempted, and a video tape recording was made of the sessions.

Because the form of the infant's response is fundamental to the experiment, a qualitative description will be given before the quantitative results. Infants generally began the session slumped in the chair with their arms down. During a hit sequence, the infant moved his head back and away from the screen and brought his arms toward his face. This was the full avoidance response. Sometimes the infant finished by facing toward the ceiling. The coming back of the head was usually observed only after the shadow had begun to fill the field or when the object came close. It was never observed before the transformation began. The person holding the infant often reported a "stiffening" of the infant's body during looming phases, followed by a relaxation during the recession phase. The response during the miss trials was dramatically different. There was commonly a slow turning of the head and eyes along the path of the shadow or object. The arms tended to come up, but the head did not come back as it did in hit trials, nor did the infant stiffen. Strikingly, visitors with no knowledge of the stimulus conditions, who observed the tapes, commented that the baby seemed to be either avoiding or following something in the respective conditions.

For the quantitative analysis, counts were made of the movement of the head backward, of the arms upward, and of the head tracking to the side; counts were also made of fussing (primarily vocalizations from low cries to wailing). Each of these events was scored and analyzed separately, and a combined measure of two out of three components produced a tracking or upset index. The quantitative results support the qualitative descriptions.

In the shadow-casting experiment, hit and miss trials were significantly different ($\chi^2 = 16.8$, d.f. $= 1$, $P < .001$) for the combined upset measure. The difference was accounted for by a significant difference between the movement of the head (movement backward versus tracking) in the two conditions ($\chi^2 = 82$, d.f. $= 1$, $P < .001$). There were no differences in any of the measures for the different age groups or for the solid as compared with the flat sequences. The recession trials did not produce the above components at all. The results in the case of the real object were similar. Hit versus miss was significantly different on the combined upset measures (Fisher exact test, $P = .003$), and the difference was accounted for by the head-movement measure.

The qualitative and quantitative results support the interpretation that infants can detect object qualities of direction and relative depth of approach and collision for both real objects and their optical equivalent. Neither kinetic depth in the optical displays nor the real display appeared to produce a stronger response than the simple expansion pattern. It may be that the infants are unable to process all the information available simultaneously or that expansion alone is a sufficient elicitor of the response with or without additional information. The lack of age differences over the age range studied indicates that learning (either to detect the event or, in the shadow-casting case, to detect that it is *not* a real object) does not play a major role in the phenomenon.

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Competition between Species: Frequency Dependence

Abstract. *Whether two species competing for the same limited resources can stably coexist has been subject to controversy for several decades. The relative fitnesses of two species of* Drosophila *under competition in laboratory populations are shown to be inversely related to the relative frequencies of these species. This frequency-dependent fitness leads to a stable coexistence of the two species in spite of their competition for limited resources.*

The question of whether two or more related species competing for the same limited resources—such as food, places to live, or places to nest—can coexist has long been debated among ecologists. The "principle of competitive exclusion," or Gause's principle, postulates that no two species are likely to be exactly identical in their efficiency to exploit any given resource; one species or the other will be at a relative advantage. If the two species compete for the same resource existing in limited supply, no matter how small is the difference between the two species in their efficiency to exploit it, the less efficient species will eventually be eliminated. For as long as the competition continues, the more efficient species will gradually increase in number relative to the less efficient species, until the latter becomes extinct (*1*).

This reasoning ignores, however, the complexities of the process of ecological competition. Physical and biotic environments of organisms are heterogeneous both in the spatial and in the temporal dimension. Species are not monolithic entities composed of identical copies of the same model; rather, in species that experience sexual outbreeding, no two individuals, with the trivial exception of monozygotic twins, are likely to be genetically identical. Moreover, the frequencies of genes and genotypes of a population are continually changing through natural selection which promotes adaptation of the population to its environment. For these reasons, it can be argued that species competing for the same limited resources may, under certain conditions, coexist in a more or less stable equilibrium (*2*). The proponents of this position failed, however, for many years to obtain decisive and convincing evidence from either observations or experiments. But, recently, it has been demonstrated in an experimental system that two species of *Drosophila* coexisted at equilibrium frequencies while competing for limited resources of food and space (*3*).