# The Perception of Biological Motion by Human Infants

Abstract. *When a small number of lights are placed on the limbs and joints of a moving human (or animal), the motions of the lights (biological motion) are sufficient to enable adult observers to perceive immediately the activity of the human. This perception of biological motion has been hypothesized to be an intrinsic capacity of the visual system. The results of this experiment, which demonstrate that infants 4 to 6 months of age exhibit a preference for biological motion patterns, support that hypothesis.*

When a small number of luminous dots are attached to the torso and limbs of a moving human, and only the dots are visible, the pattern correctly conveys the human's activity. Walking, running, dancing, and even gender can be quickly perceived (*1*). The perceptions induced by these patterns of motion, dubbed "biological motion" by Johansson, have been taken as evidence that the visual system is sensitive to invariant higher-order stimulus information imbedded in the pattern. Further, this sensitivity has been hypothesized to be an innate capacity of the visual system rather than one acquired through experience (*2*).

As a test of this hypothesis, we investigated sensitivity to biological motion in human infants and found that a visual preference for such motion becomes manifest at 4 to 6 months of age. To gauge this sensitivity we used a forced-choice preferential looking technique, which provides an objective index of an infant's preference for visual stimulation (*3*). In our version of the technique, a pair of stimuli were presented side by side over a series of trials. One member of the pair, the target, consisted of a biological motion pattern, while the other member, the foil, consisted of moving dots that did not meet the criteria for biological motion. The left-right positions of target and foil were interchanged randomly and presented to an infant seated midway between them. An observer who could view the infant, but not the stimuli, was required to make forced-choice judgments about target location based on information obtained from observing the infant (*3*).

In our experiments, target and foil were made from videotapes displayed on a pair of monochrome video monitors placed side by side. Infants seated in the lap of a parent viewed the display from 30 cm; parents were blindfolded to prevent inadvertent cuing. One experimenter observed the infant through a peephole in an opaque screen surrounding the monitors, which concealed the observer from view. In a second experiment, we interchanged spatial positions of target and foil, by an electronic switch, in accord with a predetermined random schedule and gave feedback to the observer about the correctness of his or her responses. The number of trials obtained from each infant varied as a function of alertness and tractability; a minimum of ten trials were required for the retention of an infant in the experiment and no more than 30 trials were obtained from any given infant (*4*). Trials took about 15 seconds to complete and were initiated only when the infant appeared to be in position to view both displays.

In experiment 1, three groups of infants were tested at 2, 4, and 6 months (*5*). The target was a biological motion pattern depicting the profile of a human form running in place. The pattern was composed of ten dots located on the joints of the arms and legs and on the hip. The foil consisted of the same number of dots, each moving in an independent, randomly determined direction. For both patterns, the dots appeared as white disks against a darker background. The patterns were produced by video-recording the appropriate motions; adjustments of contrast and brightness during playback permitted only the dots to be seen (*6*).

The results of experiment 1 are given in Fig. 1A. Performance for the 2-month-old infants did not differ from chance [$t(9) = 0.61$]. Performance for the 4- and 6-month groups was significantly above chance [$t(9) = 9$; $t(9) = 5.25$, $P \leq .001$]. Since the dot size was considerably greater than the visual acuity threshold for 2-month-olds, their performance cannot be attributed to an inability to resolve the dot patterns (*7*). Nor did they appear less attentive than the other groups.

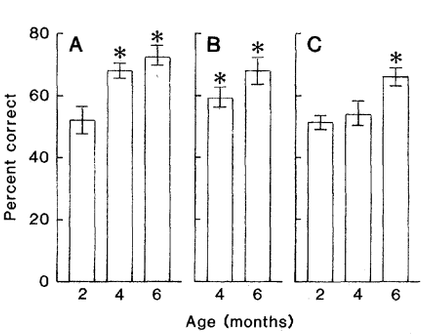


Fig. 1. (A) The results of experiment 1. Means ± standard errors for each age group. The asterisk indicates a significant departure from the chance level of 50 percent. (B) The results of experiment 2. (C) The results of experiment 3.

These results suggest that preference for biological motion appears by 4 months of age. Yet that conclusion must be qualified since there were differences between target and foil not confined strictly to the dimension of biological motion. The foil dots varied somewhat from the target dots in the rate and magnitude of their movement, and unlike the target dots, they were not periodically occluded by the limbs crossing the axis of the torso.

Experiment 2 was performed to determine if preference for biological motion was present when target and foil were more comparable. In this experiment the target was a human running in place (as in experiment 1), while the foil was the same form inverted 180°. For adult observers, such inversion severely impairs veridical perception of the human form. These stimuli were presented to two groups of infants (ten in each group) at 4 and 6 months of age (*5*) according to the same procedures used in experiment 1. Performance of both groups was significantly above chance [for the 4-month-old group, $t(9) = 4.64$, $P \leq .001$; for the 6-month-old group, $t(9) = 4.59$, $P \leq .001$]. These data indicate that the infants preferred the target even when the physical conditions of stimulation were identical for target and foil.

It is possible, however, that this preference is based on some unique attribute of the target. To test that possibility, a new biological motion pattern was constructed and used in experiment 3. This pattern was a pair of hands that appeared to come together to clasp an invisible glass and then withdraw. To produce this target pattern 15 dots were placed on the joints of the fingers and wrists of an actor and the hands video-taped as in the preceding experiments. For the foil stimulus, the same number of dots was placed on the hands at off-joint positions, a procedure known to impair the veridical perception of a biological motion pattern (*8*). These patterns were shown as in experiments 1 and 2 to three groups of infants 2, 4, and 6 months of age. Performance of the 2-month-olds [$t(9) = 0.952$, $P > .05$] and 4-month-olds [$t(9) = 0.5$, $P > .05$] did not differ from chance. The performance of the 6-month-olds, however, was significantly above chance [$t(7) = 3.02$, $P = .02$]. These data indicate that the 6-month-old infants preferred the biological motion pattern. The absence of a significant pattern for the 4-month-old group may have been due to the reduced salience between target and


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foil for that particular pattern. Adult observers who rated the relative perceptual difference between the target and foil used in the experiments found the difference between target and foil in experiment 3 to be less than for the stimuli used in experiments 1 and 2. Taken together, the results of all experiments indicate that sensitivity to biological motion patterns becomes manifest in infants between the ages of 4 and 6 months. The comparability of the target and foil patterns used in experiments 2 and 3 suggest that the critical difference mediating this sensitivity is the presence or absence of the complex motion pattern that defines uniquely biological motion. The critical dimensions of stimulation that define such motion are not yet known, yet the results of experiments 2 and 3 suggest that sensitivity to it is not confined to a specific pattern.

These data force us to conclude that young infants are sensitive to biological motion. This supports the hypothesis that the mechanism responsible for such sensitivity is largely intrinsic rather than acquired slowly through experience. Yet it is not obvious why the youngest infants did not exhibit this sensitivity. Perhaps a postnatal period of growth is required before such a mechanism becomes functional. A similar growth period has been proposed as a requisite for the emergence of stereoscopic depth termination (*9*).

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### References and Notes

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3. D. Y. Teller, *Infant Behav. Dev.* **2**, 135 (1979). The forced-choice preferential looking method incorporates the same logic and methodology as the two-alternative forced-choice method used in contemporary psychophysical research. A statistically significant departure from chance (50 percent) implies both discrimination between the stimulus pair and a preference for one stimulus over its partner.
4. The number of infants with fewer than ten trials because of sleepiness, fussiness, or equipment failure were: experiment 1, one from each age group; experiment 2, one from each age group; experiment 3, one 2-month-old and two 6-month-olds.
5. Experiment 1: 2 months, $N = 10$, range 68 to 79 days; 4 months, $N = 10$, range 111 to 130 days; 6 months, $N = 10$, range 164 to 190 days. Experiment 2: 4 months, $N = 10$, range 125 to 136 days; 6 months, $N = 10$, range 187 to 192 days. Experiment 3: 2 months, $N = 10$, range 63 to 70 days; 4 months, $N = 10$, range 122 to 132 days; 6 months, $N = 8$, range 190 to 210 days.
6. The target pattern was produced by video-recording a darkly garbed human running in place. Dots made of highly reflective tape were attached to limbs and torso. The foil pattern was produced by video-recording the motions of dots clustered in approximately the same area encompassed by the human runner. To facilitate clustering, each dot was attached to the end of a long wand; to provide motion the wands were moved manually by assistants, in apparently random directions. The background luminance of both video monitors was 25 cd/m$^2$; dot luminance was 51.3 cd/m$^2$; contrast (maximum − minimum/maximum + minimum) was 36 percent. Dot size in experiments 1 and 2 was 3.82° visual angle; in experiment 3 it was 1.15° visual angle.
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## (+)-Amphetamine Binding to Rat Hypothalamus: Relation to Anorexic Potency of Phenylethylamines

Abstract. *Saturable and stereospecific binding sites for (+)-[$^3$H]amphetamine were demonstrated in membrane preparations from rat brain. The density of these binding sites varies among brain regions and is highest in the hypothalamus and brainstem. Specific (+)-[$^3$H]amphetamine binding in hypothalamus is largely confined to synaptosomal membranes, rapidly reversible, and sensitive to both heat and proteolytic enzymes. Scatchard analysis of the equilibrium binding data revealed two distinct sites with apparent affinity constants of 93 and 300 nanomoles per liter, respectively. The effects of various psychotropic drugs as well as a number of putative neurotransmitters and related agonists and antagonists in displacing specific (+)-[$^3$H]amphetamine binding demonstrate that these binding sites are not associated with any previously described neurotransmitter or drug receptors, but are specific for amphetamine and related phenylethylamine derivatives. Furthermore, the relative affinities of a series of phenylethylamine derivates for (+)-[$^3$H]amphetamine binding sites in hypothalamic membranes is highly correlated to their potencies as anorexic agents. These results suggest the presence of specific receptor sites in hypothalamus that mediate the anorexic activity of amphetamine and related drugs.*

Amphetamine and related phenylethylamine derivatives have psychostimulant, hyperthermic, vasoconstrictor, and anorexic properties (*1*). Although biochemical studies have revealed potent effects of amphetamine on the neuronal release (*2*), reuptake (*3*), and metabolism (*4*) of biogenic amines, it is unclear which of these effects, if any, is responsible for the multiple pharmacologic actions of this class of drugs.

The use of radiolabeled psychotropic drugs of high specific activity has proven valuable in delineating the membrane (neuronal) sites of action for such drugs as opiate alkaloids (*5*) and benzodiazepines (*6*). We have examined the binding of (+)-[$^3$H]amphetamine to membrane preparations from rat brain. We now report the presence of stereospecific and saturable binding sites for (+)-[$^3$H]amphetamine that are located mainly in synaptosomal membranes, sensitive to heat and proteolytic enzymes, and regionally distributed within the central nervous system. The affinities in vitro of a series of phenylethylamine derivatives for (+)-[$^3$H]amphetamine binding sites in hypothalamic membranes were compared with their behavioral potencies as anorexic agents. The results suggest that these sites may be pharmacologic receptors mediating the anorexic action of these compounds.

Male Sprague-Dawley rats (100 to 150 g) (Taconic Farms, Germantown, New York) were killed and their brains were quickly removed and dissected on ice. In each experiment, hypothalami (*7*) from 8 to 12 animals were pooled and disrupted in 40 volumes (weight to volume) of ice-cold buffer (50 m*M* tris-HCl, containing 500 m*M* NaCl and 5 m*M* KCl, *p*H 7.4), with a Brinkman Polytron (setting 5 for 20 seconds). The homogenate was centrifuged at 30,000*g* for 10 minutes, and the resulting pellet was suspended in an equal volume of buffer. The binding of (+)-[$^3$H]amphetamine sulfate (specific activity, 15.7 Ci/nmole; New England Nuclear) was carried out on ice (0° to 4°C) for 20 minutes. A standard incubation contained 200 μl of membrane preparation, 50 μl of (+)-[$^3$H]amphetamine (5 to 500 n*M*) and 50 μl of buffer or drug. After incubation, the samples were quickly diluted with 5 ml of assay buffer and filtered through glass fiber filters (Whatman GF/B). Filters were washed three times with 5 ml of ice-cold buffer and air-dried; the radioactivity retained by the filters was measured in a liquid


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