CONSPEC and CONLERN:
A Two-Process Theory of Infant Face Recognition

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Evidence from newborns leads to the conclusion that infants are born with some information about the structure of faces. This structural information, termed *CONSPEC,* guides the preference for facelike patterns found in newborn infants. CONSPEC is contrasted with a device termed *CONLERN,* which is responsible for learning about the visual characteristics of conspecifics. In the human infant, CONLERN does not influence looking behavior until 2 months of age. The distinction between these 2 independent mechanisms allows a reconciliation of the conflicting data on the development of face recognition in human infants. Finally, evidence from another species, the domestic chick, for which a similar 2-process theory has already been put forward, is discussed. The new nomenclature is applied to the chick and used as a basis for comparison with the infant.

According to one referee of our paper, we are "to be congratulated for [our] temerity in supporting an idea. . . that has been bandied about for over 30 years, and which has been rejected by most in the field of developmental psychology for nearly 20." In general terms, the idea is that some of the visual preferences of the human infant are not merely determined by the extent to which the psychophysical properties of a stimulus match those of the infant's sensory channels. More specifically, we discuss evidence in support of the idea that infants possess some information about the structural characteristics of faces from birth. Our conclusion about the initial state of the infant's mind leads us to adopt a particular view about subsequent development: that subsequent learning through exposure is directed by this early attentional bias. This is in contrast to prevailing views and represents something of a return to the view of an early pioneer of infancy research, Robert Fantz, who argued that

it is. . . reasonable to suppose that the early interest of infants in form and pattern in general, as well as in particular kinds of pattern, play an important role in the development of behavior by focusing attention on stimuli that will later have adaptive significance. (Fantz, 1961, p. 72)

Psychophysical studies of infant vision have suggested that the amount of information obtainable from a face in early infancy is limited. For example, according to Souther and Banks (1979), at normal viewing distance a 1-month-old infant can at best discern only the grossest features of the face: the outer contour defined by the hairline and vague darker areas in the regions of the eyes and mouth.

A related claim about the visual capacities of infants in the first 2 months of life is that with static stimuli they attend to the boundaries of stimuli in preference to the interior—the so-called externality effect (Bushnell, 1979; Bushnell, Gerry, & Burt, 1983; Maurer & Salapatek, 1976). This factor, taken together with the supposed limitations in sensitivity previously mentioned, leads to the expectation of poor face recognition abilities in infants under 2 months.[1] This view has been supported by evidence suggesting that it is not until the second or third month of life that infants can discriminate a schematic facelike configuration from scrambled versions of the same stimulus. For example, Maurer and Barrera (1981) demonstrated that, whereas 1-month-old infants looked equally at intact and scrambled schematic faces, 2-month-olds (61–70 days) looked significantly longer at the facelike configuration.[2] These data contrasted with earlier work, using different techniques, which suggested that not until infants reach 4 months can strong evidence for such a preference be obtained (Haaf, 1974, 1977; Haaf, Smith, & Smitty, 1983). Although the absence of demonstrable preference does not logically imply that a 1-month-old infant cannot *discriminate* a face from other stimuli, it has been generally accepted as a good a priori assumption. In

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[1] There are modifications to the externality effect with respect to whether the internal features are moving, but it is not clear from the literature whether they would affect the responses of very young infants to faces.

[2] For simplicity of exposition, we will from time to time use phrases like *face preference* rather than *preference for facelike stimuli.* Our use of the term *preference* follows the technical literature (e.g., Banks & Ginsberg, 1985) and should not be taken to imply willful preference or motivated interest. Also, note that the term *preference* is commonly used (e.g., by Maurer & Barrera, 1981) to summarize results of experiments using relative looking time at single stimuli as the measure. The term *interest* is used in a similar way: to refer to the behavior of a system.

fact, Maurer and Barrera (1981), using habituation techniques, have also shown that 1-month-old infants cannot discriminate a schematic face from scrambled stimuli.[3]

In the research we have summarized thus far, there is agreement that infants do not respond differentially to faces until they are at least 2 months old. However, more than a decade ago, Goren, Sarty, and Wu (1975) published the results of a study that examined the way newborn infants (median age 9 min) tracked a moving schematic face, scrambled "faces," or a blank head outline. Their results were quite clear: Head and eye movement measurements indicated that there was stronger interest in the face pattern than in the other stimuli.

These findings have remained largely ignored by psychologists despite their far-reaching theoretical implications. It was easy to accept that 1-month-olds did not show a preference and that 2-month-olds did, because one could assume that sufficient learning had taken place over that period to allow a perceptual representation of faces to be formed. The new results, on the other hand, implied that infants enter the world with a degree of innate perceptual "knowledge." Zuckerman and Rock (1957) had earlier argued that "perceptual organization must occur *before* experience . . . can exert any influence" (p. 294). Furthermore, they reasoned that some prior perceptual organization was both logical and a likely product of adaptive evolution. Fantz (1961, 1963) echoed these views and was able to show that neonates looked longer at either schematic faces or bull's-eyes than at a blank, colored field. Fantz's data implied only that infants are born with some form of pattern vision. The Goren et al. (1975) findings suggest that there might be innate[4] perceptual preferences that are quite specific. How, then, can it be explained that infants at 1 month showed no preference for a schematic face over a scrambled face? This pattern of results, with a preference for faces at birth and at 2 months, but not at 1 month, seems to make untenable any account of the development of face preference purely in terms of gradual learning or in terms of the steady maturation of a single neural structure. Conceptual complications such as this may explain why the Goren et al. study has largely been ignored in the literature. Clearly, attempts to replicate and extend this particular study are required.

REPLICATION OF GOREN, SARTY, AND WU (1975): EXPERIMENT 1

Maurer and Young (1983) attempted to replicate the results reported by Goren et al. (1975) and found preferential tracking of the facelike pattern over a severely scrambled face stimulus when they used eye movements as the dependent measure. They found no difference with a moderately scrambled face stimulus and failed to replicate the preferential head turning observed in the original study.

In our own attempt to replicate the Goren et al. (1975) experiment (Johnson, Dziurawiec, Ellis, & Morton, 1991), we included some refinements of data collection and analysis. The sample consisted of 24 normal, healthy newborns who were tested within the first hour after birth. The mean age at the start of testing was 37 min (*SD* = 12.5 min). The stimuli were three head-shaped, head-sized, two-dimensional white forms, about 17 × 19 cm, with black features of a human face, as used by

Goren et al. The stimuli, referred to as *face, scrambled,* and *blank,* are shown in Figure 1.[5] One experimenter was used. She shuffled the stimuli and presented them approximately 18 to 25 cm from the infant's face. Throughout these procedures, the experimenter was entirely unaware of the order of presentation of stimuli because only the identical and unmarked reverse sides of the stimuli were visible to her. Illumination of the stimuli was provided primarily by natural light from a very large window situated above and behind the infant.

Each infant was placed on its back on the experimenter's lap and was surrounded by a large protractor over which the stimuli were to be presented against a light-colored ceiling about 7 ft (2 m) away. The infant reclined on thick toweling, with its neck supported by the experimenter's palm beneath the toweling. The baby's head was aligned midline with the 0° mark on the protractor, and the first stimulus, randomly selected, was positioned directly in front of the baby's face. As soon as the infant fixated it, the stimulus was moved slowly to one side along the arc of the protractor, at a rate of approximately 5° per second. If an infant responded with a head turn, or eye turn, or both that were greater than 60°, the infant was tested to the other side. If the infant failed to turn or turned only minimally, up to seven attempts were made to elicit a satisfactory turn to that side. The procedure was then repeated to the opposite side. The next stimulus, also randomly selected, was then used. Finally, the third stimulus was used. The infant's eye and head turning in pursuit of the stimulus were recorded on videotape for later analysis. As in the study by Goren et al. (1975), the extent of following, measured in terms of degrees of arc, was determined by comparing the final nose position and eye orientation on each trial with the protractor demarcations. For each stimulus, the infant's score for both head and eye turning was the average of the largest turns the infant made to the two sides, with a theoretical maximum possible of 90° for each stimulus.[6]

The video tape recordings were analyzed by two independent

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[3] Note that under certain circumstances, one can find novelty preference instead of familiarity preference. This is the principle behind the habituation technique, where the subject is sated with a repeatedly presented stimulus and thereafter attends more to a stimulus it perceives to be novel.

[4] We use the term *innate* to refer to specific abilities that arise without prior specific postnatal input from the environment. Our use of the term is not intended to imply absolute genetic determination, and we are fully aware that such a mechanism would be sensitive to many aspects of the developmental context. We use the term more in a descriptive sense—to label the development of mechanisms that are dependent on aspects of the "species-typical" environment and not on the "individual-specific" environment (see Johnson, 1987; Johnson & Morton, in press).

[5] Note that these stimuli did not include the one with which Maurer and Young (1983) failed to replicate Goren et al. (1975). This stimulus had the eyes and the eyebrows bilaterally located and could therefore satisfy some protofacial description.

[6] Note that Maurer and Young (1983) found that this was a less sensitive measure than taking the mean of the first three attempts on either side. In our procedure, we stopped testing on one side as soon as the infant gave a satisfactory response, even on the first attempt. We could not, then, use the Maurer and Young measure. Our data should be seen as, if anything, more conservative.
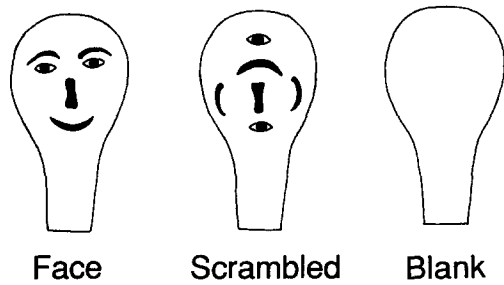
Face   Scrambled   Blank

Figure 1. The three stimuli used to test newborn infants' preferences in Experiment 1. (All stimuli were white, life-sized head outlines.)

observers who were unaware of either the purpose of the study or the patterning on the stimuli. The concordance between the judges was 0.87. The mean head- and eye-turning responses to the three stimuli are shown in Figure 2. On a Tukey test, the extent of the eye turns to the face (48°) were significantly greater than those to the scrambled face (40°), which, in turn, were greater than those to the blank (21°). The same differences were also found with the head-turning measure.

The results of this study replicated the findings of Goren et al. (1975) with respect to one of the scrambled faces they used. A moving facelike pattern elicits greater following behavior than does a nonfacelike pattern. In addition, neonates attend much more strongly to patterned stimuli than to a head shape with no internal features.

REPLICATING THE ONE- AND TWO-MONTH-OLD DATA: EXPERIMENT 2

Like Goren et al. (1975) and Maurer and Young (1983), we found that newborn infants will follow a schematic face farther than a thoroughly scrambled face control stimulus. We now move to the next piece of the puzzle. Is it really the case that infants around 1 month old do not discriminate between intact and scrambled schematic faces? Only Maurer and Barrera (1981) have succeeded in finding any preference for faces compared with scrambled faces prior to 4 months.[7] These authors showed that 2-month-olds looked significantly longer at a schematic face, but they also failed to demonstrate such a preference with 1-month-old infants. Maurer (1985) attributed their success with 2-month-olds, compared with the failure of earlier work, to their use of an "infant control procedure," which they considered more sensitive than the preference techniques used by other workers. We decided to replicate the Maurer and Barrera experiment using the same technique, because this would give us the best chance of finding an effect with 1-month-old infants. We also tested a group of 5-month-old infants using the same technique. To our knowledge, only one other study has used an infant control preference procedure around this latter age. This was by Fantz (1966), who found no advantage for a schematic face over an asymmetrical scrambled face with infants aged 4–6 months.

In our experiment (Johnson, Dziurawiec, Bartrip, & Morton, 1991), the stimuli were life-size white head outlines on a gray background. They are shown in Figure 3. The nonface stimuli are *config,* corresponding to two eyes and a mouth; *linear,*

where the features are intact but in an inappropriate location; and *scram,* where the elements of all features are scrambled but the symmetry is retained. The babies sat on their mothers' laps about 90 cm from a rear-projection screen. The method involved attracting the infant's attention and then showing one of the four stimuli on the screen, terminating the presentation once the infant looked away from the stimulus. This is the infant control procedure recommended by Cohen (1976) and Maurer (1985). For the entire experiment, the infant's face and the timer were recorded on videotape, and the length of time that the infant had looked at each slide was later assessed by a judge blind to the experiment. If the judge thought the experimenter had terminated a trial prematurely, that infant's data were discarded. We used three groups of infants, with mean ages of 5 weeks ($n = 14$), 10 weeks ($n = 15$), and 19 weeks ($n = 15$).

In Figure 4 we show the mean score for each of the four stimuli at each age group. On a Friedman test, there were no significant differences among the times spent looking at the four stimuli for the 5-week-olds, $\chi^2(3, N = 14) = 0.75$, $p > .8$. In contrast, for the 10-week-olds, a Friedman test gave $\chi^2(3, N = 15) = 10.28$, $p < .02$. On a Wilcoxon test, *face* was significantly preferred to the other stimuli ($p = .05$ for *config;* $p < .01$ for *linear* and *scram*). With the 19-week-old infants, there were significant differences among the four stimuli, $\chi^2(3, N = 15) = 10.28$, $p < .02$, but these were not in the expected direction. In this subject group, 12 of 15 infants preferred *face* less than each of the other three stimuli ($p < .05$). Note that this was the age group for which Fantz (1966) found no face preference. We explore this finding further in the Models of Face Preference section.

In common with Maurer and Barrera (1981) and other experimenters, we were unable to find any evidence that 5-week-old infants possess information about the general characteristics of faces. The mean looking times of about 20 s correspond closely to those found previously in the Maurer and Barrera study. The 10-week-old group showed significant preferences among the four stimuli, looking most at the intact face. Again, this result replicated the findings of Maurer and Barrera. We also extended the earlier work by showing that for 10-week-olds, the preference is not just for a facelike configuration, but that there must be the features of a face present in their correct locations.

EXPLORATION OF THE CONFLICT

We have been able to replicate both the finding that 1-month-old infants show no face preference with the infant control procedure and the finding that newborn infants prefer faces when a tracking response was elicited. Thus, there appears to be a real paradox to be resolved. The conflict between the two sets of experiments could be accounted for by one of the following explanations:

1. Although newborn infants show a preference for faces, this preference declines after the first few days of life but emerges again at 2 months. Under this account, the two tasks call upon

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[7] Dannemiller and Stephens (1988) have recently shown a preference in 12-week-olds for a schematic face with black features on a white background over the same stimulus with white features on a black background. They found no such preference with 6-week-olds.

the same mechanism, and it is the functioning of this mechanism that fluctuates over time.

2. The tracking technique is a more sensitive measure of preference than the infant control procedure (which we refer to as a *looking task*). Under this account, the two tasks call upon the same mechanism. The U-shaped function up to 2 months is an artifact of having used a different measurement technique with the newborns.

3. There are two independent mechanisms. The tracking technique is a sensitive measure of a propensity for the newborn to attend to faces. This propensity declines, and its time course is largely independent of the mechanisms that underlie the emergence of face preference in other tests at 2 months.

The activity levels of the various mechanisms in these three accounts are illustrated in Figure 5. They are all consistent with a face advantage in tracking for newborns, a face advantage with looking for 2-month-olds, together with no advantage in looking for 1-month-olds. The three accounts make different predictions with respect to performance in a tracking task by 1- and 2-month-olds. On the first account, performance will simply follow the single curve. The choice of task would make no difference. On Account 2 (Figure 5, center panel), both 1- and 2-month-olds will show a face advantage in the tracking task. By Account 3 (Figure 5, right panel), it is clear that 2-month-old infants will not show a face advantage in the tracking task. Whether there will be a face advantage in this task for the 1-month-olds would depend on exactly where the tracking curve (see Figure 5, right panel) crossed the threshold value. The three accounts thus give rise to different predictions. In Experiment 3 we examined the time course of the tracking of facelike stimuli over the first 5 months in an attempt to decide among these possibilities.

EXPERIMENT 3: THE ROTATING CHAIR

We were particularly interested to see whether 5-week-olds would preferentially track faces, this age being the one where all
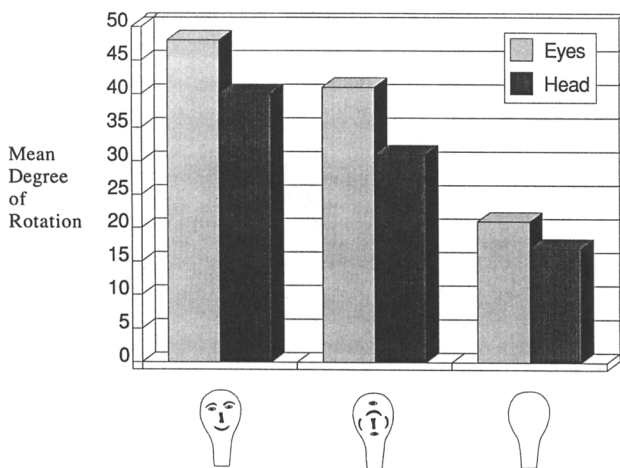

Face   Config   Linear   Scram

Figure 3. Stimuli used in Experiment 2. (The second stimulus was intended to possess the configuration of a face without the features; the third stimulus maintains the features but with the wrong configuration.)

previous investigators have failed to find a face preference using standard visual preference techniques. Following pilot studies, we decided to keep the test stimuli in a fixed location and to slowly rotate the infant rather than moving the stimuli around the infant, as in Experiment 1. The effect of this was that the babies had to turn their heads and eyes to keep the stimulus in view. This makes the technique into a tracking task that is equivalent to that used successfully with newborns.

The babies sat on the lap of a trained holder about 90 cm from a rear-projection screen. In this experiment, we used the same four stimuli that had been used in Experiment 2 (see Figure 3). These stimuli were presented twice, initially in random order and then in the reverse order. The procedure that followed was similar in some respects to that used in Experiment 1. Briefly, this involved showing one of the four stimuli on the projection screen. After 5 s, a motor that rotated the chair was switched on. The infants frequently turned their heads and eyes to keep the stimulus in view. After the chair had rotated through 90°, it returned to the starting position, ready for the next trial. After four stimuli had been tested in this way, the process was repeated with the chair rotating in the opposite

Figure 2. Data from Experiment 1 showing the extent of newborn eye and head turns in following the stimuli in Figure 1 (from Johnson, Dziurawiec, Ellis, & Morton, 1991). (Newborn infants follow the face farther than the other stimuli.)
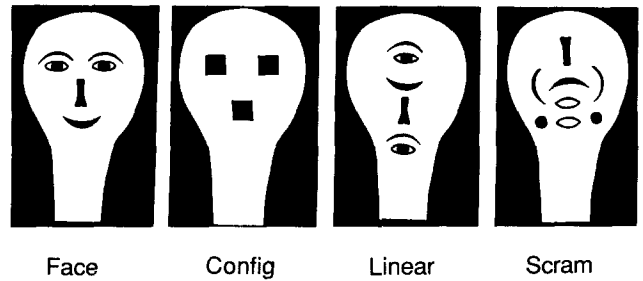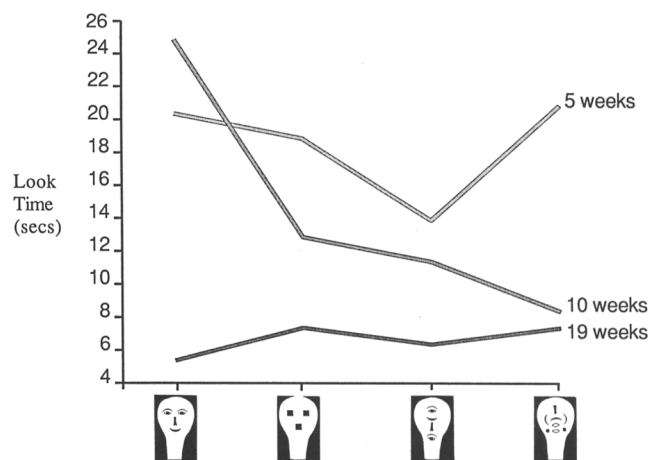

Figure 4. Data for Experiment 2. (Mean look times for each of the three stimuli for 5-, 10-, and 19-week-old infants. For both the 10- and 19-week-old groups, there was a significant effect of stimulus on mean look time. From Johnson, Dziurawiec, Bartrip, & Morton, 1991.)
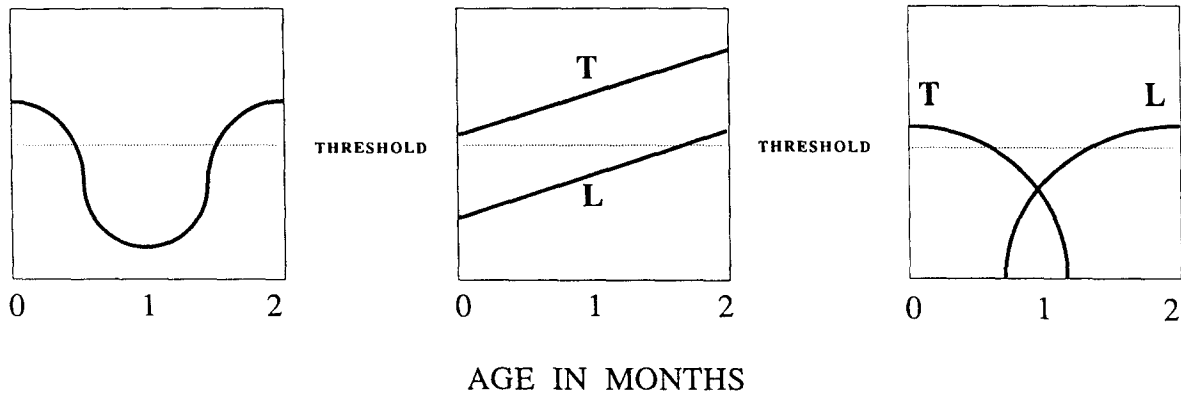
AGE IN MONTHS

Figure 5. Illustration of the activity of the mechanisms responsible for controlling behavior in the three possible accounts of the conflict. (If the activity is above threshold, the behavior, face preference, is found. Left: There is a single mechanism that is active at birth and at 2 months but that declines between the two ages. Center: There are two functions for a single mechanism, one being tapped by the tracking [T] experiment and the other, less sensitive, tapped by the infant control, or looking [L], procedure. Right: There are two mechanisms: T controls tracking behavior and is active at birth and then declines. The other, L, controls looking and does not become fully active until 2 months.)

direction. For the entire experiment the infant's face and the timer were recorded on videotape, and the length of time that the infant had looked at each slide was later assessed by a judge who was blind to the stimulus being shown. Further details of the experimental procedure can be found in Johnson, Dziurawiec, Ellis, and Morton (1991, Experiment 3).

We used three groups of subjects, aged 5, 10, and 19 weeks. The mean angles of the chair at which infants stopped looking at the slides for the three age groups are shown in Figure 6. For the 10- and 19-week-old groups of infants, there was no effect of stimulus on chair angle when the infant looked away, $F(3, 60) = 1.37$ and $F(3, 60) = 0.23$, respectively. With the 5-week-old infants ($n = 38$) the analysis of variance gave a significant result, $F_{3, 111} = 2.80$, $p = .043$. When individual t tests were carried out with these infants, *face* was preferred to *config* ($t = 2.56$, $p = .015$), *linear* ($t = 2.79$, $p = .008$), and *scram* ($t = 2.28$, $p = .029$).
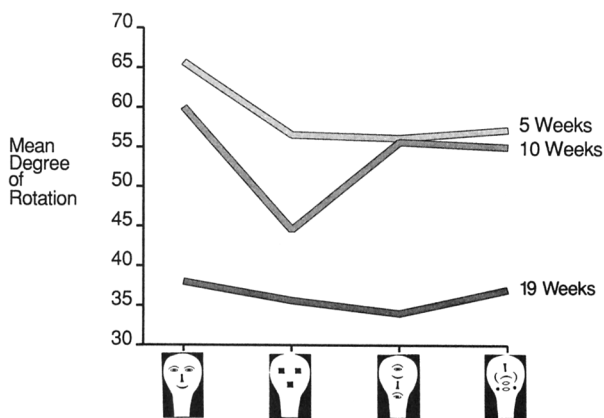

Figure 6. Data from Experiment 3, showing the extent to which infants will turn their head to maintain fixation. (Only for the youngest age group was the face followed farther than the other stimuli. From Johnson, Dziurawiec, Ellis, & Morton, 1991, Experiment 3.)

The data indicate that infants around 5 weeks will track a schematic face farther than they track other stimuli. This, then, is the first stage in bridging the gap between the newborn results and the previous findings with infants around 1 month. In Goren et al. (1975) and in Experiment 1 of this article, it has been established that, with a tracking task, newborns turn farther to look at faces than they do to look at severely scrambled faces. In the earlier studies (see Maurer, 1985), it had been found that faces are not preferentially attended to until the infants are at least 2 months old. Experiment 3 established that the discrepancy relates to the testing method used. Although infants around 1 month show no preference for faces in the infant control procedure, a straightforward looking task, they show a face preference in a tracking task.

Because the older infants failed to show a preference for the *face* stimulus, we looked to see whether we could detect an age trend in the youngest age group. Accordingly, we divided this group into two, with the younger group having an age range of 23–30 days and the older one a range of 34–43 days. Using t tests, we found that with the younger group ($n = 21$), *face* was preferred to *linear* ($p = .018$) and *scram* ($p = .029$) but not *config*. There were no significant differences with the older group ($n = 17$). This indicates that the preferential tracking of faces may decline between 4 and 6 weeks.

The first of our three alternative accounts was that there is a single process used in both tasks. For this process a U-shaped function is found over the first 2 months of life. The data from the 4-week-old infants rules this out as a possibility. In addition, with 6- and 10-week-olds, we could find no differential response with the tracking task. With the first account, we would have expected the 10-week-olds to continue to preferentially track the face.

The second of our alternative accounts was that the tracking task is absolutely more sensitive than the infant control procedure. The fact that infants about 2 months old show no preference with the tracking task but show a preference with the infant control procedure demonstrates there are no overall differ-

ences in sensitivity between the procedures. Therefore, the second account is also ruled out.[8]

To account for the paradox, then, we are left with the third option—that the two tasks tap different mechanisms, one of which is active by 2 months and the other of which is functional at birth but has declined or been inhibited by the time the infant has reached 2 months of age. Furthermore, our data suggest that this latter mechanism may still be active at 4 weeks but is not demonstrable at 6 weeks.

TRACKING VERSUS ORIENTING

Although we have confirmed that newborn infants and 1-month-olds will, under certain circumstances, preferentially attend to a schematic face rather than other stimuli, we have not established the conditions for this preference. The task we have focused on is a tracking task, and this has been contrasted with a looking task. It is tempting to suppose the appropriate contrast is between moving and stationary stimuli. Such a supposition might be supported by considering other experimenters who have failed to obtain preferences for faces. Maurer (1985) summarized the available research. Of the studies mentioned in that chapter, Hershenson, Kessen, and Munsinger (1967) and Fantz (1966) failed to demonstrate an advantage with newborns for schematic faces over control stimuli comprising the features of the faces rearranged. Fantz (1966), Fantz and Nevis (1967), Wilcox (1969), Sherrod (1979), and Maurer and Barrera (1981) failed to find any preference for faces with 1-month-olds. All of these studies used stationary stimuli. However, more recently, Kleiner (1987) has shown an advantage with newborns for a schematic face over control stimuli. The experiment involved presenting a pair of stimuli simultaneously for 10 s and measuring the relative amount of time spent looking at each. In this case, the stimuli were stationary. How can this apparent conflict be resolved? We believe that success or failure in obtaining a face preference with newborns depends crucially on the task demands. If the details of the experimental set-up are changed, the infant may effectively be performing a different task.

First of all, let us consider what the infant is doing in the tracking task. It turns out that newborns are not capable of tracking a moving stimulus smoothly. What they do, in order to follow it, is to make a saccadic movement when the stimulus has moved about 10° into the periphery (Aslin, 1981). One could typify this behavior, then, as repeated orienting rather than tracking. If we look at the Kleiner (1987) study, we discover that the stimuli were about 50° apart, from the infant's point of view.[9] Thus, given that the infant is fixating one stimulus, the other will be well into the periphery. This resembles the situation in the tracking experiment, where the infant keeps one steady direction of regard until the stimulus has moved into the periphery. The infant control procedure, and other procedures involving only one stimulus, would fail to find significant differences among stimuli because peripheral vision is not involved. However, there are some other studies that have used paired stimuli. Of these, the Hershenson et al. (1967) experiment, which found no face preference with newborns, used stimuli that were 30° apart,[10] that is, closer than the Kleiner (1987) stimuli. Although the issues are far from settled, we provisionally conclude that the process involved in face preference

in newborns is that of orienting to a peripheral stimulus rather than smooth tracking.

MODELS OF FACE PREFERENCE

Of the three possible general accounts of the data we have described, we have eliminated all except one, by which two separate mechanisms are required. Before exploring the possible nature of these mechanisms, we need to discuss three factors: the nature of the ability of the newborn, the nature of the learning process over the first few months, and the interaction between the two.

We first discuss the question of the abilities of newborns. The extreme positions that can be taken here can be characterized as sensory versus structural. The sensory hypothesis would hold that preference for facelike stimuli results from general characteristics of the infant sensory system. The opposing view is that specific structural information about the characteristics of faces is present without prior exposure to these objects. For example, Kleiner and Banks (1987) contrast the *social hypothesis* and the *sensory hypothesis* as accounts of face preference in early infancy. The social hypothesis is characterized as "young infants are predisposed to attend to social stimuli" (Kleiner & Banks, 1987, p. 594). The sensory hypothesis is that "infants are predisposed to attend to stimuli that are readily visible. . . . facelike patterns are fixated preferentially because they contain large [low spatial frequency], high-contrast features that are arranged symmetrically" (Kleiner & Banks, 1987, p. 594).

Newborn Abilities

Sensory Hypotheses

The fundamental assumption of sensory hypotheses is that certain classes of stimuli are preferred by young infants as a result of the general properties of the early stages of visual processing. This class of theories can be thought of as having two stages of processing. The first stage is a set of sensory mechanisms, the output of which is affected by particular stimulus properties. Information from these mechanisms is passed on to the second stage, a decision-making process that determines where the infant will look and whether it will continue to look at a particular stimulus. Any preference for facelike patterns would be the result of the general characteristics of these patterns, which happened to match the perceptual mechanisms. Particular nonfacelike stimuli would also be preferred as a result of the operation of the same mechanism.

In most cases, theories of infant visual preference have been

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[8] It is logically possible that newborn infants are more sensitive to the tracking task, whereas 2-month-old infants are more sensitive to the looking task. To argue such a case, however, one would have to make a distinction between the preference mechanism on the one hand and two independent means whereby the preference was expressed in behavior. This option, then, is equivalent to the third possible account.

[9] This figure is not given in Kleiner (1987) but was calculated from another description of the same apparatus given in Fagan (1976).

[10] This figure was taken from Hershenson, Munsinger, and Kessen (1964) on the assumption that the same apparatus was used in the two experiments.

tested with stimuli other than faces. Such experiments involved estimating the infant's interest in a stimulus by measuring the amount of time he or she looked at it when it was first presented. Alternatively, pairs of stimuli are presented to the infant, and the amount of time spent looking at each is compared. By such methods, certain stimulus properties have been identified as influencing the infant's gaze. If faces are not special, then any preference for facelike patterns will arise simply because the pattern possesses certain general stimulus properties.

A large number of stimulus variables have been proposed as influencing the way in which infants look at figures. These include contour density, size, kind of motion, distance, brightness, complexity, contrast, color, size and number of elements, and spatial frequency characteristics. For example, Karmel (1969; Karmel, Hoffmann, & Fegy, 1974) suggested that the amount of contour in a stimulus—"the sum of all the lengths of black-white transition" (Karmel et al., 1974, p. 39)—is a "major influence" on preference. Karmel's theory at least made predictions about preferences "rather than merely offering post hoc interpretations of them" (Slater, Earle, Morison, & Rose, 1985, p. 38), which had been the prevailing habit. Karmel did not actually propose that his theory could account for preferences for faces. More recent theories and, particularly the linear systems model, have made this explicit claim.

For the first few months of life, infants' preferences for patterns other than faces are well predicted by the linear systems model (Banks & Ginsberg, 1985; Banks & Salapatek, 1981; Gayl, Roberts, & Werner, 1983; Slater et al., 1985). This model, a form of the sensory hypothesis, predicts infants' preferences on the basis of a particular kind of analysis of the stimuli, the Fourier transform. For any pattern, two functions may be derived: the *amplitude spectrum,* comprising the amplitude and orientation of the component spatial frequencies, and the *phase spectrum,* comprising the phases and orientation of the components. The phase information is not used further within the linear systems model, which holds that pattern preferences for young infants are influenced only by the amplitude spectrum.

In the linear systems model, the amplitude spectrum of any stimulus pattern, collapsed over orientation, is filtered through the contrast sensitivity function (CSF) of the appropriate age group. For a newborn, this effectively removes all information at frequencies greater than about two cycles per degree. For each remaining spatial frequency, what is crucial is the extent to which the contrast in the pattern at that frequency exceeds the infant's contrast threshold. Newborns are most sensitive to frequencies between 0.2 and 0.5 cycles per degree (Atkinson, Braddick, & French, 1979). Energy in that range, according to the model, will be most effective in attracting and holding the infant's attention.

Whereas the linear systems model predicts infants' preferences very well with high-contrast patterns such as regular checks (Banks & Ginsberg, 1985; Gayl et al., 1983), rectangular gratings (Banks & Salapatek, 1981; Banks & Stephens, 1982), bull's-eyes (Banks & Ginsberg, 1985), and patterns of stripes (Slater et al., 1985), and variations on the model predict infant preference with irregular checks of different sizes (Gayl et al., 1983), it does not follow necessarily that the model will predict infant preferences for stimuli of other kinds, for example, those without sharp contours or with low contrast or irregular curves.

Whether preferences with such stimuli can be predicted by the linear systems model is an empirical issue. For the moment we can see that, on this theory, young infants might prefer faces over other stimuli by virtue of the *incidental* characteristics of the amplitude spectra of faces. This could be an odd quirk of fate. Otherwise it would seem to be necessary to propose either that the shape of the newborn CSF was molded by natural selection to favor faces or that the human (or mammalian) face was partially designed to fit the infant CSF.

Structural Hypothesis

This contrasting view holds that the neonate brain contains innate information concerning the structure of faces. In order to explore this position more seriously, we wish to propose the general term *CONSPEC* to refer to a unit of mental architecture in any species that has the following properties.

1. The device contains structural information concerning the visual characteristics of conspecifics. By *structural,* we mean that the information is concerned with relative spatial location of elements within a pattern. For a face, such a specification might be as broad as three high-contrast blobs in the correct relative locations for two eyes and a mouth on a stimulus of about the right size (i.e., *config* in Figure 3). This information need not be species or genus specific. It need only be sufficient to select the parent's face from the set of common stimuli in its environment. Indeed, even two circles, bilaterally located, might be sufficient for the purpose.

2. CONSPEC information is available without the organism requiring exposure to specific stimuli. The device may, however, require nonspecific stimulation to "trigger" or "validate" (Bolhuis, Johnson, & Horn, 1985; Horn, 1985) its functioning.

There are several options with regard to the means by which a CONSPEC may become apparent in behavior. A CONSPEC might regulate approach behavior, or it could control the allocation of attention or influence looking preferences. There do not appear to be any reasons for restricting the options here.

A word is, perhaps, in order here concerning the extensive use of schematic faces rather than photographs, three-dimensional models, or real faces both in our experiments and in those of most other experimenters. If an infant did not make a discrimination at a particular age, then this could be because the schematic stimuli were too impoverished relative to real faces. However, because we have put forward evidence for sensitivity from birth, it is not obvious what the use of more realistic stimuli could accomplish apart from amplifying these effects.[11]

Do Infants Have a CONSPEC?

Structural information. In principle, it is possible that the apparent preference shown by newborn infants for facelike stim-

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[11] Suppose, instead, that real faces gave weaker effects than the schematic faces. Given that we have the appropriate controls for the schematic faces against any appropriate primitive stimulus property, we would have the options of either supposing that the irrelevant aspects of the real faces impede the infants' performance (i.e., that the schematic face is a "supernormal" stimulus) or concluding that the results with schematic faces are an amusing coincidence—that infants just happen to prefer stimuli that just happen to look like faces.

uli over thoroughly scrambled faces (Goren et al., 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991; Maurer & Young, 1983) may be accounted for entirely by the amplitude spectrum of the stimuli. None of these three experiments controlled for this possibility. One experiment on face preferences that has manipulated amplitude and phase spectra appropriately was carried out by Kleiner (1987) and is briefly mentioned earlier in this article. Kleiner used a simultaneous choice paradigm with 48 infants of an average age of 1.7 days (SD = 1.0). In her experiment, the basic stimuli were a schematic face and a lattice pattern. These stimuli were analyzed into the component amplitude and phase spectra with a fast Fourier transform. These spectra were then recombined to create two new stimuli, one created from the amplitude spectrum of the face together with the phase spectrum of a lattice pattern (A_f/P_l) and the other created from the amplitude spectrum of the lattice together with the phase spectrum of the face (A_l/P_f). These stimuli are shown in Figure 7.

The prediction of the linear systems model, described earlier, is that newborns' preferences would depend entirely on amplitude spectrum and not at all on the phase spectrum because phase relationships will be irrelevant for newborns. In support of this latter claim, we note that Atkinson, Braddick, and Wattam-Bell (1986) have reported that even 1-month-old infants show no evidence of discriminating among complex gratings on the basis of phase relationships alone. In Kleiner's (1987) experiment, the role of phase information was tested by the comparison of the lattice, A_l/P_l, with the crossed stimulus with the phase of the face (A_l/P_f). The newborn infants showed no preference between these stimuli. Therefore, the phase spectrum of the face had no independent influence on preference.

Kleiner (1987) also presented good evidence that the amplitude spectrum of the face was preferred to that of the lattice (A_f/P_l > A_l/P_l and A_f/P_l > A_l/P_f). However, Kleiner's data produced one result not predicted by the linear systems model. As we stated earlier, this model explicitly claims that phase information would be irrelevant to newborns' preferences. To the newborn, then, the A_f/P_l stimuli should be equally preferable to the schematic face, A_f/P_f. However, with these two critical stimuli, differing only in phase information, the newborns over-

whelmingly preferred the face, looking at it 69% of the time. We therefore conclude from Kleiner's data that the human CONSPEC contains structural information, that is, some specification of the features of a face together with their relative location in space.[12]

The reader should note at this point that we are not rejecting the notion of the linear systems model nor would we expect facelike stimuli to be preferred over all other stimuli. Indeed, we have found that a checkerboard pattern, designed to be optimal with regard to the linear systems model, provoked a far greater orientation response than our standard schematic face (Morton, Bartrip, & Johnson, 1990).

Is exposure required? The infants in Goren et al.'s (1975) experiment were, on average, 9 min old. In our replication of this study, the mean age was 40 min. Although we cannot entirely rule out the possibility of very rapid learning, there are several reasons for preferring the alternative of CONSPEC:

1. In the study of newborns by Goren et al. (1975), the delivery staff and experimenters wore partial face masks.

2. With learning, we would expect a positive correlation between age and some measure of face preference. We estimated performance on nonface stimuli in Experiment 4 (see next section) by taking the mean of the scores on *inverse* and *linear*. The correlation of the difference of face to nonface mean with infant age (range 20–126 min) was in fact negative ($r = -.20, n = 41, p = .215$). In a later experiment (Morton, Johnson, & Maurer, 1990) using infants tested on their second day of life, up to 2,500 min old, the correlation between age and the difference between face and a nonface stimulus was also negative ($r = -.50, n = 20, p = .025$). These figures are not suggestive of learning about faces.

3. The phenomenon of neonatal imitation has recently been demonstrated under conditions where the experimenter is the first face seen after birth (Reissland, 1988). Although the relationship between imitation and face preference is unclear, it would seem plausible that their emergence should be subject to equivalent constraints.

4. Sackett (1966) provided evidence from monkeys reared in social isolation that some aspects of processing facial expressions in rhesus macaques do not have to be learned.

5. Slater, Rose, and Morison (1984) failed to find any transfer between experience of a three-dimensional figure and subsequent response to a two-dimensional projection of that object. If this data were generalizable, then we would not expect the experience of mother's face to transfer to the two-dimensional schematic stimuli used with newborns.
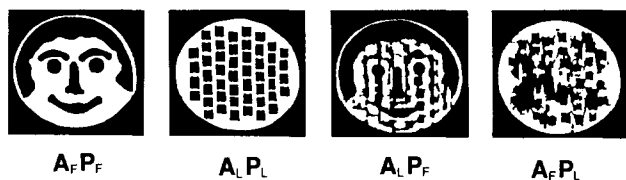
Further Experiments on Human CONSPEC—Experiment 4

We have determined that the human infant qualifies for the existence of a CONSPEC. Our next experimental step was to

$A_F P_F$ $A_L P_L$ $A_L P_F$ $A_F P_L$

Figure 7. Approximate reproductions of the stimuli used by Kleiner (1987) and Kleiner and Banks (1987). (Stimulus A_F/P_F has the amplitude spectrum of the face and the phase spectrum of the face. Stimulus A_L/P_L has the amplitude spectrum of the lattice and the phase spectrum of the lattice. Stimulus A_L/P_F has the amplitude spectrum of the lattice and the phase spectrum of the face. Stimulus A_F/P_L has the amplitude spectrum of the face and the phase spectrum of the lattice. *Note:* We were unable to obtain copies of the original stimuli. From "Amplitude and Phase Spectra as Indices of Infant's Pattern Preferences" by K. A. Kleiner, 1987, *Infant Behavior and Development, 10,* pp. 54–55. Copyright 1987 by Ablex. Adapted by permission.)

explore its properties further. We knew that a CONSPEC provided sufficient information to allow an infant to prefer a normal from a scrambled schematic face. However, there is a good deal of leeway in the specification that would allow this discrimination. For example, the infants could have been simply responding to the three high-contrast areas, blobs that constitute the configuration or arrangement of features that constitute a face. In the next experiment (Johnson, Dziurawiec, Ellis, & Morton, 1991, Experiment 2), we investigated what aspects of the face stimulus used in the earlier study were responsible for attracting the newborns' attention. Accordingly, we included *config,* the stimulus composed of three dark squares in the appropriate locations for the eyes and mouth region. If newborns use the configuration of high-contrast elements to track faces, then the realistic face should not be preferred over this stimulus. We used as a control stimulus an identical but inverted pattern, *inverse,* as well as the scrambled face called *linear.* The stimuli are shown in Figure 8.

The sample consisted of 41 newborns from the delivery ward of the Obstetrics Department of University College Hospital, London. They were tested at between 15 and 69 min after birth. The procedure used was identical to that in Experiment 1, except that four rather than three stimuli were used. In addition, the infant lay in a purpose-designed holder with a headrest that fitted on the experimenter's lap.

The mean head- and eye-turning responses to the four stimuli are shown in Figure 9. For eye turning, the response to the schematic face was significantly greater than the response to *inverse* or *linear. Face* was marginally different from *config* ($p = .064$, two-tailed).[13] There were no differences among the other stimuli. Head turning did not discriminate the stimuli. Although the eye movement data have been replicated in three different infant samples, whether newborns will reliably track a moving face farther by head turns must still remain an open question. However, in Experiment 4, the mean amount of head turning was lower than that in Experiment 1 and corresponded more closely to that in the study by Maurer and Young (1983) than with the figures reported by Goren et al. (1975). Thus, it is likely that a certain minimal amount of mean head turning is required before a differential head-turning response can be obtained.

Because there have been three replications of the eye movement data reported in the Goren et al. (1975) study, we conclude that infants in the first hour of life are sensitive to the structure of the human face to some degree of detail. Our experiments
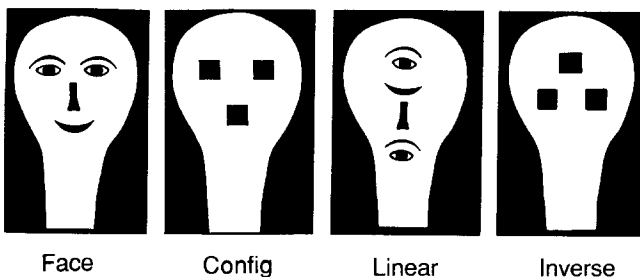
have not been able to distinguish between the *face* stimulus and the *config* stimulus, so the simplest hypothesis is that the specification of CONSPEC resembles the second panel in Figure 7. We should also consider the slightly scrambled stimulus used by Maurer and Young (1983), which was not looked at significantly less than the *face* stimulus. Our conclusion is that this stimulus, in which the eyebrows remain in place and the mouth remains central and below the eyebrows, sufficiently resembles a face to trigger the sensitive mechanism.

The data obtained from Experiments 1 and 4 support the result of Goren et al. (1975), and strengthen the argument for a fairly complex perceptual organization being present at birth. Moreover, the argument that faces are special objects in the newborn's visual world gets qualified support. It can now be accepted with some degree of confidence that neonates find slowly moving faces with high-contrast definition particularly attractive stimuli. That is not to say, however, that neonates have any conception of the meaning of a face. All that can be said is that they will track farther a pattern that has facelike properties.

Learning About Faces

In the previous section, we defined a type of innate mechanism, CONSPEC, which effectively provides the newborn with information concerning the visual characteristics of biologically relevant objects. At the moment, we do not have enough data to say whether the human CONSPEC provides sufficient information to allow unique identification of the human face compared with, say, a primate face. However, for the human infant, as for the chick and many other species, it will be necessary to learn the visual characteristics of several individuals. Although the first function with most social vertebrates may be to discriminate "mother" from all others, differences among other individuals will eventually have to be acquired.

We now consider some of the properties of the system by which the young of any species learn[14] about particular faces of members of their species. We propose the term *CONLERN*[15] to describe the variety of systems that might serve this function. CONLERN is simply a system that acquires and retains specific information about the visual characteristics of conspecifics. There are several questions concerning a CONLERN. Beyond specifying the time course of what it learns, we can, for example, examine the relationship between the mechanisms and representations underlying CONLERN and those underlying other learning systems or underlying CONSPEC. A further set of questions concerns the underlying neural structures.

Face   Config   Linear   Inverse

Figure 8. Stimuli used in Experiment 4 using newborn infants with a tracking technique.
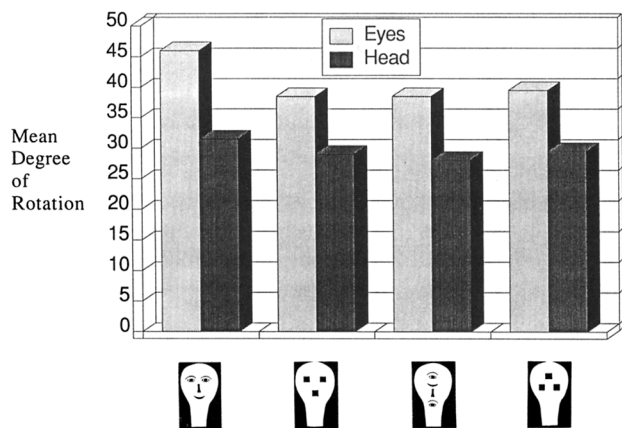
Figure 9. Data from Experiment 4, again showing that newborn infants aged 15–69 min follow a face farther than other stimuli. (This applied only with eye movements. From Johnson, Dziurawiec, Ellis, & Morton, 1991, Experiment 2.)

What Does CONLERN Learn?

At 2 Months

We have seen that one of the mechanisms influencing the tracking behavior of infants from birth to 4 weeks has the properties of CONSPEC. What of the behavior of 2-month-old infants in the infant control task? It is clear that infants learn something about the properties of faces in the first 2 months. This was demonstrated most clearly by Kleiner and Banks (1987), who tested 8-week-old infants with the stimuli shown in Figure 7. There were three differences between the results for these infants and those for newborns reported by Kleiner (1987). As we noted earlier, the newborns preferred the crossed stimulus with the amplitude spectrum of the face, A_f/P_1, to the one with the phase spectrum of the face, A_1/P_f. By 2 months of age, this preference had reversed. In addition, there was no preference between A_f/P_1 and A_1/P_1, where the former had been preferred by newborns. Finally, whereas the newborns had treated A_1/P_f and A_1/P_1 as being equivalent, the 2-month-olds preferred A_1/P_f.

Kleiner and Banks (1987) summarized the differences between newborns and 2-month-olds in the following way: "Neonates' preferences appear to be based on stimulus energy, as indexed by the amplitude spectrum, whereas some 2-month-olds' preferences seem to be based on stimulus structure as indexed by the phase spectrum" (p. 599). We discussed the interpretation of the neonate data in the Models of Face Preference section, concluding that although stimulus energy, as indexed by the amplitude spectrum, might be the correct account of neonate preferences for stimuli other than faces, Kleiner's (1987) own data suggest most strongly that the neonate possesses some structural knowledge concerning faces. In the quotation just given, Kleiner and Banks were attempting to maintain a form of the sensory hypothesis with the 2-month-olds in this experiment.[16] This phase-spectrum theory would predict that there would be no preference expressed at 2 months between the stimuli A_f/P_f (the face) and A_1/P_f because they share the phase spectrum of the face. In fact, as might be expected,

the infants overwhelmingly preferred the face. Now it cannot be argued that such a preference is the consequence of the summing of preferences driven by phase and by amplitude spectra, because amplitude spectra do not seem to play any role in the preferences of the 2-month-old infants. This follows from the fact (that we have already noted) that in the Kleiner and Banks experiment, there was no preference expressed between A_f/P_1 and A_1/P_1. The only option for a nonstructural theory would be to say that the amplitude spectrum only influenced preferences if the stimulus had the phase spectrum of a face. It seems much simpler to say that by 2 months, CONLERN has learned something about the structure of the face.[17] What has been learned is separate from the information in CONSPEC that was clearly available to the newborn. The major difference, we postulate, is that the CONLERN information enables the 2-month-old to pick out the face in stimulus A_1/P_f (see Figure 7), whereas the neonate, with a simpler mechanism, cannot. This causes the 2-month-old to prefer A_1/P_f to either A_1/P_1 or A_f/P_1 (Kleiner & Banks, 1987). The data for the 2-month-old, then, can be completely accounted for simply on the basis of CONLERN's responding strongly to the face stimulus and less strongly to the A_1/P_f stimulus.[18]

At 5 Months—Experiment 5

We have already noted that in many studies, including Experiment 2 in this article, 5-month-old infants show no preference for schematic faces over scrambled faces.[19] A complete account of this would require a theory of preference such that the most strongly attractive stimuli so far as CONLERN is concerned would be a compromise between novel and familiar. We might assume, then, that when infants reach 5 months of age, CONLERN has a representation of faces sufficiently complete for infants to find a static monochrome schematic face uninteresting to look at. In that case, adding some of the appropriate cues of real faces ought to result in the return of the preference for

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[16] Kleiner and Banks (1987) used the term *structural hypothesis* throughout their article to refer to predictions from the phase spectrum. They never referred to faces as having features in a spatial relationship, which is the sense in which we use the term *structural*.

[17] Note that, in any case, the phase spectrum of the face is arguably more complex computationally than the face itself. That is, to learn the phase spectrum would be the more complex task unless there were extensive innate structures available to perform the task.

[18] In contrast to these conclusions concerning the state of CONLERN with 2-month-olds, the data on newborns published by Kleiner (1987) led us to conclude that CONSPEC did not respond at all to the A_1/P_f stimulus, which is why the purely energy-based linear systems model dominated all comparisons with newborns other than those involving the schematic face.

[19] There are two studies that have shown a preference for faces over asymmetrical scrambled faces at 6 months of age. Fantz and Nevis (1967) used a paired comparison. With their stimuli and method, they failed to show a difference with 4-month-old infants. Lewis (1969) used the first fixation time to a single stimulus. He failed to obtain any effects with 3-month-old infants. We suggest, then, that there is something about the method used by these experimenters that serves to delay performance relative to the procedures or stimuli we used or those used by Maurer and Barrera (1981).

the face. Among the most prominent characteristics of real faces is movement of the internal features. In a further experiment (Johnson, Dziurawiec, Bartrip, & Morton, 1991), we used the infant control procedure to establish whether such movement would make a facelike configuration the most attractive for the 5-month-olds.

Three different configurations of facial features were used: normal, scrambled, and linear scrambled (similar to those shown in Figure 3). For each of the three stimuli, there were two conditions, moving and static. In the moving condition, the internal features of the face were made to move slightly by making transitions from one static presentation to another. The two frames alternated every second. The effect was one of animation of an otherwise constant, stationary stimulus. Each child was exposed to six stimuli, three static and three moving, presented in a random order. The procedure was similar to that used in Experiment 1.

In Figure 10 we show the geometric mean values for the three configurations and two conditions. There was no difference in the overall length of time the infants spent in looking at moving versus static stimuli. For the static presentations, there were no significant differences between the times spent looking at the three stimuli, whereas for the moving stimuli the face stimulus was significantly preferred over the other two ($p < .05$ for both cases by Wilcoxon test for planned comparisons). This finding is consistent with other recent reports indicating the importance of internal feature movement for infants' recognition of facial expressions (Biringen, 1987) and infants' ability to discriminate between facial and nonfacial movement of abstract patterns (Stucki, Kaufmann-Hayoz, & Kaufmann, 1987).

The total time spent looking at the moving stimuli was the same as the total time spent looking at the static stimuli. From this we may conclude that movement alone is not critical for the infants' preference. However, the movement of the internal features restored preference for a facelike configuration. We can therefore conclude that movement is part of the specification in CONLERN by the time the infant is 5 months old. This finding
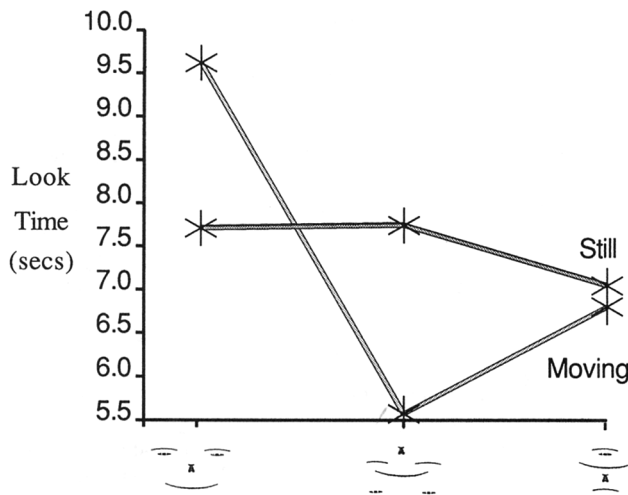

Figure 10. The mean look times by 5-month-old infants in Experiment 5 for each of three stimuli when static and when the internal features were in natural motion. (A significant effect of stimulus was found only when the features were moving.)

helps us to understand why Fantz (1966) and Sherrod (1979) failed to find a preference for faces in 5-month-old infants.

How Do Mechanisms and Representations Underlying CONLERN Relate to Those Underlying Other Kinds of Learning?

To our knowledge, there are no relevant data available from infant work. The data that do exist suggest that face learning is not special in the sense of being based on a special mechanism. Data from the neuropsychology of adults indicate that patients suffering from prosopagnosia also have problems in identifying other types of visual stimuli, although the precise nature of the problem differs from individual to individual (see de Renzi, 1989; Ellis & Young, 1989). One phenomenon that has been cited to support the notion that face recognition is linked to a purpose-built mechanism is that processing of faces suffers a particularly large penalty when the faces are presented upside down. However, Diamond and Carey (1986) recently established that similar orientation effects can be achieved with other objects, as long as there is sufficient experience of the stimulus class. An example is the identification of individual champion dogs by experts who have been judging that particular breed at shows for a minimum of 10 years. The inversion effects are found only for the breeds for which the judge is expert. Thus, some of CONLERN's special properties may arise only by virtue of the degree of exposure to faces. That is, our expertise with faces could just be a matter of practice. Carey and Diamond (1980) proposed that this stage is not normally reached in children until about the 14th year.

The Interactions Between CONLERN and CONSPEC

There are several options which, in some cases, could coexist. Some of these options have been discussed by de Schonen and Mathivet (1989) in the context of hemispheric specialization for face recognition.

1. There is no direct internal interaction between CONLERN and CONSPEC. This option may seem paradoxical, but it could apply if the function of CONSPEC was to direct attention to the faces around it and CONLERN learned simply by exposure. Therefore, CONLERN need not be distinct from any other perceptual learning system. The specialness of faces would arise from the fact that in the natural situation, CONLERN will be exposed mainly to faces, and only in this sense will the information it acquires be constrained by the information within CONSPEC. Such an interaction is mediated through the environment of the infant.

2. CONSPEC has a directive function over CONLERN within central processing. The simplest situation would be one where CONSPEC issues a functional ⟨learn now⟩ signal to CONLERN whenever a stimulus that matches CONSPEC is present.

3. CONSPEC could act as a specific filter for information entering CONLERN. This interaction and the one described in Item 2 fall into the category of *templates* as defined by Marler (1976) and others.

4. It is possible that the CONSPEC mechanism is also the CONLERN mechanism. In this case, the process of learning

about faces would result in changes primarily to the structures that originally underlay CONSPEC.

Although the evidence is not clear, the developmental anatomy and time courses we mention in the next section suggest that the two systems may not share the same neural substrates. This would rule out Item 4. There is other evidence against this option. If it were the case that the process of learning simply involved the steady refinement of the information in CONSPEC, then there would be no reason to expect a dip in performance after a month. Any of the other three options must still be considered possible.

We have accounted for the apparent contradictions in the literature on infant response to faces and in our own experiments by postulating two independent mechanisms. We assume that the neonate abilities are due to CONSPEC and that by 2 months, infant preference is controlled by CONLERN. In the next section we discuss evidence in favor of the hypothesis that CONSPEC is located subcortically, whereas CONLERN is primarily mediated by cortical functioning. We show that this suggestion makes sense of the psychological facts in light of postnatal developmental neuroanatomy (see also Johnson, 1990).

THE COMBINED THEORY

Let us summarize. The literature indicates that 2-month-old infants make differential responses to schematic faces with the infant control procedure but 1-month-old infants do not. We have replicated these findings. Goren et al. (1975) reported that newborn infants would track schematic faces farther than control stimuli. We have partially replicated these findings and extended them to 1-month-old infants. The issue, then, is how to reconcile these apparently conflicting bodies of data. We have argued that the difference in testing technique is crucial and reflects the operation of two separate mechanisms, which we refer to as CONSPEC and CONLERN. First, we have demonstrated that infants are born with some knowledge concerning the visual structure of the human face. This is CONSPEC. The effect of the CONSPEC mechanism is to cause the infant to orient toward any stimuli fitting its specification. Separate from CONSPEC is the CONLERN function. We discussed three possible options for the interaction between CONSPEC and CONLERN. Perhaps the simplest of these is that there is no direct internal interaction between the two systems. Furthermore, in the absence of evidence to the contrary, we postulate that for the human infant, CONLERN is a nonspecialized learning mechanism. Effectively, it learns about the characteristics of faces because the infant pays a lot of attention to them. The role of CONSPEC is to direct this attention.

The theory we have just sketched accounts for the data very simply. From birth there is an influence of CONSPEC such that an infant will orient toward faces. There are other influences on the infant's attention—an attraction toward any contrasting, peripheral stimulus, for example—some of which we discuss later. Such influences mean that the infant will attend to the control stimuli to some extent. However, up to about 1 month of age, CONSPEC ensures that faces get a greater response as long as the task involves presentation in the peripheral visual field. With tasks that involve the child just looking directly at a single

stimulus, as opposed to orienting toward it, CONSPEC will not exert any influence. Hence, the lack of discriminative response with the 1-month-old when using the infant control technique and the resulting apparent U-shaped developmental performance.

Over the first 2 months, we suppose that CONLERN acquires knowledge of the human face. By the end of the first month, CONSPEC has only a weakened influence. Why should this be? We hypothesize that some time in the second or third month, cortical structures begin to control the infant's response and inhibit the largely subcortical pathways underlying CONSPEC. Consequently, the tracking technique ceases to show advantages for faces. As CONLERN develops, it begins to create an advantage for faces in the infant control procedure. By 5 months, CONLERN has acquired sufficient knowledge about faces such that static schematic faces are no longer more interesting than control stimuli. Indeed, the control stimuli have the advantage of being novel. Having the internal features of the faces move is sufficient to reactivate the 5-month-old infants' attention.[20]

We can now inquire into the anatomical correlates of CONSPEC and CONLERN in the human infant. First, we note that evidence has been accumulating that suggests that newborn perceptuomotor activity is mainly controlled by subcortical mechanisms (Atkinson, 1984; Bronson, 1974, 1982; Maurer & Lewis, 1979). Some subcortical structures such as the superior colliculus appear to be critically involved in attention and orienting toward stimuli and are also capable of handling complex visual and acoustic information (for review, see Stein & Gordon, 1981). We propose that the preferential tracking ability of the newborn, the CONSPEC function, is controlled by such a primitive, subcortical attentional mechanism. Furthermore, there is strong evidence that the retinocollicular visual pathway is developmentally in advance of the retinocortical pathway, which may not be functioning until about 2 months after birth (e.g., Atkinson, 1984; Braddick, Wattam-Bell, & Atkinson, 1986). This fits in with the age at which the infant control procedure starts to reveal preferences for faces. CONLERN, then, we suppose to be dependent on the full functioning of the primary cortical visual pathway (see also de Schonen & Mathivet, 1989).[21]

During the first 2 months of an infant's life, we propose that information about faces is entering cortical circuits, even

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[20] It might be suggested that the moving stimulus reawakens CONSPEC rather than reviving attention. If this were the case, then we might expect an advantage for the moving face in the 3-month-old infants, which we did not find.

[21] We do not wish to exclude the possible involvement of deeper layers of the visual cortex (Layers 5 and 6, see Johnson, 1990). Certain parts of the cortex may be functioning and controlling preference from birth. Slater, Morison, and Somers (1988) reported that 1-day-old infants can detect the orientation of bars; Slater, Mattock, and Brown (in press) reported size constancy in newborns; and A. Slater (personal communication, February 19, 1987) found that newborns can form conjunctions of features (e.g., red + vertical vs. blue + diagonal). These functions are all supposed to be cortical. However, we do wish to claim that the functioning of CONSPEC does not require the *full* maturation of primary visual cortex.

though the structure may not be influencing decisions concerning visual stimuli (see Johnson, 1990). One hypothesis is that, following maturation of various cortical pathways at around 2 months of age, the control of visual attention passes to mechanisms accessed via the retinocortical pathway (Bronson, 1974; Johnson, 1990; Maurer & Lewis, in press). These mechanisms would be responsible for the emergence of a preference for face-like configurations in standard infant preference tests found at 2 to 3 months (Maurer, 1985; Maurer & Barrera, 1981). Such tests, with their reliance on static nasal visual field presentations, would not generate a discriminatory response from the subcortical attentional mechanism that controls responses in infants over the first month of life.

Our position is summarized in Figure 11. The ordinate corresponds roughly to the relative activity of the two sets of structures, S and C. At birth, the S structures, which contain CONSPEC, are relatively highly active, and so the CONSPEC functions dominate. By 30 days or so, the activity of the C structures has risen sufficiently to cut off some of the S functions. However, the C structures have not learned enough about faces to enable them to reveal face preference in particular experimental conditions.

These proposals are only novel in the context of infants' reactions to faces. Dodwell (1983) put forward similar arguments in relation to auditory attention. He drew on data from Muir, Abraham, Forbes, and Harris (1979), who followed the orienting of infants to auditory stimulation over the first 4 months of age. Orienting to either a voice or a rattle dropped from virtually 100% at birth to 40% at 80–100 days and rose to near 100% again at 120 days. Dodwell did not believe that the reappearance of the auditory orienting in the fourth month is simply the return of the earlier behavior. He commented:

> It has a different character at this stage. Rather than being "drawn to" the sound, the older infant appears to search with a rapid glance for the source of stimulation. On the average, the latency of these later turns is only about one-half that of the earlier movements. (Dodwell, 1983, p. 205)

Dodwell, then, supposed that two mechanisms are at work here, one primarily mediated by subcortical structures and the
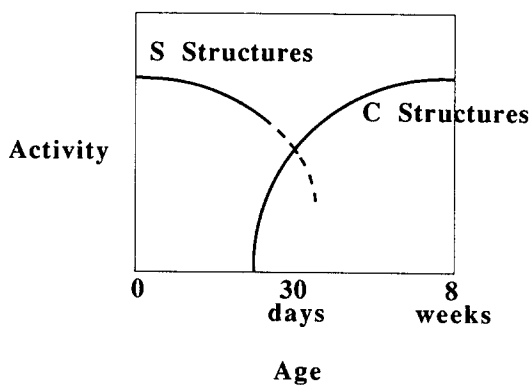
other by cortical structures, with the former being inhibited by the latter during the third month of life.

CONSPEC AND CONLERN IN THE CHICK

In this article, we have discussed CONSPEC and CONLERN in relation to the human infant. However, the definitions of these constructs have been couched in terms quite general. It makes sense to ask of any species whether it has a CONSPEC and what, if any, its relation might be with any CONLERN mechanism for that species.[22] Whereas a putative anatomical basis for face recognition has been established in the rhesus macaque (Perrett, Rolls, & Caan, 1982), this evidence does not directly relate to the argument being developed in this article. Specifically, there is no evidence relevant to the distinction between CONSPEC and CONLERN (but see Johnson & Morton, in press, for an extensive discussion of this point). In contrast to this, however, the distinction between CONSPEC and CONLERN proposed in this article is partially prompted by the earlier interacting systems model in the chick (Horn, 1985; Johnson, Bolhuis, & Horn, 1985). In this section, we review evidence from the chick within the framework outlined earlier for the human infant.

The Properties of CONSPEC in the Chick

Recently, it has been proposed that there are two distinct but interacting neural systems underlying filial preference behavior in the domestic chick. The first underlies a predisposition to attend to objects resembling conspecifics, and the second is a learning device engaged by those objects to which a young chick attends. It has been argued further that in the chick's normal environment the first system ensures that the second learns about the characteristics of an individual hen (Horn, 1985; Johnson et al., 1985; Johnson & Horn, 1986). The evidence for these two interacting systems comes largely from the analysis of the neural basis of visual preference behavior in the chick. Newly hatched chicks rapidly develop preferences for particular conspicuous objects to which they are exposed (Bateson, 1966; Horn, 1985; Johnson, 1991). From this we may infer a learning system that is engaged by those objects to which the young chick attends. In addition, there is strong evidence for a specific predisposition for the newly hatched chick to attend to objects resembling adult conspecifics. This predisposition was originally discovered in chicks reared in the dark; they showed a spontaneous preference to approach a stuffed hen rather than less naturalistic objects (Johnson et al., 1985). The neural system underlying this predisposition is located separately in the chick's brain from the learning system. For reviews of the evidence leading to these conclusions, see Horn (1985), Horn and Johnson (1989), and Johnson (1991). Does the system underlying the predisposition meet any or all of the requirements mentioned earlier for a CONSPEC?

The first requirement for our definition of CONSPEC con-

Figure 11. Proposals concerning the relative activity of subcortical (S) and cortical (C) structures with respect to control of infant visual attention.

cerns the presence within the device of structural information. A series of experiments with the chick have demonstrated that the preference is not exclusively due to any simple parameters of the stimulus such as color, outline complexity, or textural richness. Instead, features of the head and neck of the adult hen in their correct arrangement appear to be critical for expression of the preference. However, the features of the head and neck do not have to be specific to the chick's own species because the head and neck region of other species of a similar size are just as effective (Johnson & Horn, 1988).

The second requirement for our definition of CONSPEC is that the preference device should operate in a specific manner without prior specific experience. A chick does not require any visual experience for expression of the predisposition but does require a period of motor activity (Bolhuis et al., 1985; Johnson et al., 1985). This period of motor activity must occur between 12 and 36 hr after hatching (Johnson, Davies, & Horn, 1989). It is possible that this activity leads to an increase in the level of the hormone testosterone, which in turn leads to the facilitation of neural circuits underlying CONSPEC.

It is evident that the chick, as well as the human infant, possesses such a mechanism. In the case of the chick, it is clear that the information provided by CONSPEC is insufficient to distinguish a hen from other species (Johnson & Horn, 1988). For this degree of specificity, CONSPEC information needs to be supplemented by learning.

The Properties of CONLERN in the Chick

How Do Mechanisms and Representations Underlying CONLERN Relate to Those Underlying Other Kinds of Learning?

Let us take two examples of a particular line of evidence concerning the relationship between CONLERN and other structures. The evidence concerns the fact that information acquired through one form of learning cannot be used by a different learning system. The first example comes from Bateson and Reese (1968), who used two groups of chicks. The members of one of the groups were first imprinted onto a rotating, illuminated box (a CONLERN function), whereas the members of the other group were not. All the animals were then put into an operant conditioning apparatus, where the response required was to press a particular pedal and the rewarding stimulus was the imprinting object. The group that had been imprinted were no quicker to learn the operant component of the task. If the information acquired by CONLERN were accessible to those systems involved in operant learning, then one would have expected facilitation from the imprinting training.

The second example comes from Bolhuis and Johnson (1988), who carried out the reverse of the experiment by Bateson and Reese (1968) described in the previous paragraph. Bolhuis and Johnson took two groups of chicks, one of which was trained to press a pedal in order to be exposed to an illuminated red box. These chicks imprinted on the red box at the same time as it acted as a reinforcer for operant learning. In the other group, the presentation of the red box was not contingent on the responses of the bird itself but on those of a paired-response–contingent bird. The groups subsequently showed equal prefer-

ences for the red box. This shows that the contingent learning condition of the experimental group had no effect on the CONLERN function. Taken together, these experiments suggest that the structures underlying CONLERN in the chick are not involved in other forms of learning.

A second line of evidence is of a different kind. In the chick's brain, the particular localized forebrain region IMHV[23] has been demonstrated to be critical for the function we have referred to as CONLERN. If bilateral lesions are placed in IMHV before the chick has had any specific visual experience, then it will not learn to prefer any object to which it is exposed (Horn, 1985; McCabe, Horn, & Bateson, 1981). If the lesion occurs shortly after the chick has been exposed to some object, then it will no longer display a particular preference for that object (Horn, 1985; McCabe, Cipolla-Neto, Horn, & Bateson, 1982). However, IMHV-lesioned birds are able to acquire an operant skill—for example, learning to tread on one particular pedal of two in order to obtain the reward of exposure to an attractive object (Johnson & Horn, 1986). These three experiments indicate at least that IMHV, although not implicated in some associative learning tasks, is involved at least in the retrieval of CONLERN information and possibly in the acquisition and storage of this information (for reviews, see Horn, 1985; Horn & Johnson, 1989; Johnson, 1991).

It does not appear to be the case that IMHV is exclusively dedicated to individual recognition, because Davies, Taylor, and Johnson (1988) showed that chicks with a lesion in IMHV can no longer learn the characteristics of a food type they dislike. As with humans, then, it seems as though one cannot argue that the chick CONLERN is anatomically special (see Morton & Johnson, 1989).

The Interactions Between CONSPEC and CONLERN in the Chick

Earlier, we listed four possible kinds of interaction between CONSPEC and CONLERN. These are, briefly,

1. No direct interaction,
2. CONSPEC issues a functional ⟨learn now⟩ command to CONLERN,
3. CONSPEC acts as a perceptual filter, and
4. CONSPEC and CONLERN are the same mechanism.

For the human infant, we were unable to decide among the first three options. What can we conclude in the case of the chick? We have already reported the experiment by Johnson and Horn (1986) in which damage to the area IMHV impaired acquired (CONLERN) preferences but not the developing (CONSPEC) predisposition to approach the hen. This experiment implies that Interaction Type 4 is not valid for the chick. If Interaction 3 is correct, then birds should not be able to learn about an artificial stimulus *after* the predisposition has appeared, because the specificity of the filter would mean that visual stimuli that did not meet the characteristics defined in the experiments by Johnson and Horn (1988) would not be allowed through to CONLERN. In a recent series of experi-

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[23] IMHV stands for the intermediate and medial portion of the hyperstriatum ventrale.

ments, Bolhuis, Johnson, and Horn (1989) tested this predic-
tion. The results clearly indicated that chicks are capable of
learning about the characteristics of artificial stimuli after the
predisposition is expressed. The properties of CONSPEC, there-
fore, do not restrict the information arriving at CONLERN,
and Interaction Type 3 can be ruled out for the chick.

There is no clear evidence to lead to the rejection of either
Interaction Type 1 or 2. However, it has been found that chicks'
preferences are much more easily reversible after exposure to an
artificial object than after exposure to a stuffed or living hen
(Boakes & Panter, 1985; Bolhuis & Trooster, 1988). This is to say
that the degree to which CONLERN can be changed can be
affected by the contents of CONSPEC. Under Option 1, this
would be accounted for in the following way. We suppose that
the chicks' direction of approach is influenced by both CON-
SPEC and CONLERN. Irrespective of the early training, CON-
SPEC would always favor the hen. If the chick was then trained
on an artificial object, the influence of both processes would
have to be overcome to effect reversal of preference. Thus, to
show a preference for the box after learning about the hen
would be more difficult.

Although it would be possible to create a scenario using Op-
tion 2, this option would require that CONLERN learned the
features of a hen (under instructions from CONSPEC) more
efficiently than those of an artificial object. There is no conclu-
sive evidence on this issue.

The Recognition of Species and Individual
Members of a Species

Originally, for Lorenz (1937), the function of imprinting was
"to establish a sort of consciousness of species in the young
bird" (p. 265). However, recent evidence supports the conten-
tion that, at least in some precocial avian species, the primary
function of imprinting is to establish preferences for individual
adult birds. Species recognition may follow as a consequence of
this.

Two predictions of the interacting systems model of imprint-
ing alluded to earlier are (a) 2-day-old chicks should be capable
of discriminating between two individually different adults of
the same species, and (b) bilateral ablation of the IMHV should
impair the acquisition of such an ability. Johnson and Horn
(1987) tested these predictions and established that whereas
intact control chicks and chicks with lesions placed elsewhere in
the forebrain showed a significant preference for an individual
stuffed hen to which they were exposed, chicks with lesions to
the IMHV did not.

The question remains whether imprinting in early life in the
chick is related to the recognition of individuals in later life.
Females of many species prefer to mate with males that differ
slightly from those with which they were reared, a phenomenon
often referred to as "optimal outbreeding" (Bateson, 1980). In a
recent experiment, Bolhuis, Johnson, Horn, and Bateson (1989)
reared small social groups of female chicks with individual
males. When 3 months old, the females were allowed to ap-
proach either the male with which they were reared, a novel
male of the same strain, or a male of a novel strain. The intact
females preferred the novel male of the same strain over the
other 2. Although appearing normal in other respects, females

that received bilateral IMHV lesions on the first day of life had
no preferences among the 3 males. That is, the IMHV damage
appeared to specifically impair the ability to recognize individ-
ual members of their own species. This raises the possibility
that the same structures are responsible for learning about indi-
viduals in later life as are responsible for filial imprinting.

Are the Neural Structures and Pathways Supporting
CONLERN the Same as Those Supporting CONSPEC?

We have seen that the region IMHV in the chick forebrain
has been implicated in the acquisition and retention of infor-
mation following imprinting. Bilateral ablation of this area im-
pairs both the acquisition and retention of preferences resulting
from exposure to an object, a CONLERN function. However, it
does not impair the specific predisposition to approach objects
resembling an adult hen, a CONSPEC property (Johnson &
Horn, 1986).

We conclude, then, that for the domestic chick, the neural
structures critical for CONLERN are not crucial for CON-
SPEC.

CODA

If we believe that the functioning of CONLERN in the hu-
man infant can be detected by fixation times in the infant con-
trol task, then it is not until 8 weeks or so that CONLERN
influences behavior. On the basis of the evidence we have sum-
marized, we surmise that CONLERN builds a representation
that enables the infant to discriminate the human face from
other stimuli and especially from the faces of other species.
Such a view is presented with possible problems by some recent
experiments on newborn responses to individual faces. The
best controlled of these experiments is one by Bushnell, Sai,
and Mullin (1989), who used infants of an average age of 1.7
days. These infants were presented with two faces, about 30 cm
away and about 30 cm apart. One of the faces was the baby's
mother, and the other was that of another woman who had just
given birth who was "judged to be broadly comparable in terms
of hair color and facial complexion" (Bushnell et al., 1989, p. 6).
Careful controls were carried out to check that the infant re-
sponse could not be influenced by smell, and the women were
instructed to keep their faces immobile and to refrain from
vocalization of any kind. In spite of these precautions, the in-
fants fixated on the face of their mother for an average of 60% of
the time.

It is not known what the properties are of the learning system
mediating this result of Bushnell et al. (1989). However, given
Bushnell's earlier evidence on the *externality* effect in early in-
fancy, that the outline of stimuli are scanned rather than the
internal detail (Bushnell, Gerry, & Burt, 1983), it appears likely
that the discrimination is based on some external characteris-
tics of a mother's face such as hairstyle or face outline. In this
case, the types of representation upon which the early discrimi-
nations are made will differ from those upon which individual
face identification proceeds in later life. One indication that
this might be the case is a finding by Sai and Bushnell (1988),
who presented 1-month-old infants with their mother and a
stranger in three different poses. In this experiment, the faces

were matched subjectively by the experimenters as closely as possible for hair color, hair length, and facial complexion. It was found that the infants looked longer at their mothers when the faces were in full face or in half profile. When they were in profile, however, there was no preference. Older infants, of course, eventually recognize mother equally well in profile. Further, Legerstee, Pomerleau, Malcuit, and Feider (1987) did not find differences in the amount of looking at mother and stranger until their infants were 17 weeks old. We anticipate that if the Bushnell effect proves replicable, we will need to specify in more detail subtypes of the CONLERN mechanism, some involved in extracting the common features of inputs (invariance extraction) and some their differences (exemplar extraction). This issue is discussed in more detail in Johnson and Morton (in press).

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