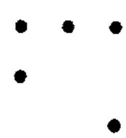
THE PERCEPTION OF STRUCTURE



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CHAPTER 20

THE PERCEPTION OF FACIAL STRUCTURE IN INFANCY

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It has recently been claimed that the reaction of newborn infants to face-like stimuli is mediated by stimulus energy. We examine and reject this proposal and describe an alternative view whereby it is the structure of the face that attracts the infant's gaze through the operation of a detection device that we call CONSPEC. *We show, in addition, that the infant is still learning the structural description of the face between 3 and 5 months of age, at which age dynamics are integrated into face perception.*

How do young infants extract the invariant structure of a face from their total perceptual input? Empirically, this general question has focused on two issues. First, does the newborn infant preferentially attend to faces because faces merely happen to be optimal stimuli for the infant's sensory system, or is there some reason to suppose that facial patterns are special in some way? Second, what types of invariance related to the face are extracted by the infant over the first few months of life? We shall begin by considering the first of the two issues.

STRUCTURE OR ENERGY?

Young infants seem to be interested in stimulus energy. The techniques used to establish this fact simply involve measuring the amount of time an infant will

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The influence of Wendell Garner on me has been profound. He gave me an extra way of looking at the world. He also set me standards of behavior as a scientist that I have not always been able to live up to but which form a good basis for the advice I give others. He has my admiration and affection.—*John Morton*

look at a pattern, either when it is presented by itself or when two patterns are presented at the same time. With a variety of patterns, the best account of the amount of interest an infant will have in a pattern is given by the linear systems model (LSM; Banks & Salapatek, 1981; Banks & Stephens, 1982).

To make predictions on the basis of the LSM, the amplitude spectrum of any stimulus pattern, collapsed over orientation, is filtered through a function representing the sensitivity of the infant's visual system to different spatial frequencies. For a newborn, this filtering effectively removes all information at frequencies greater than about 2 cycles per degree. Newborns are most sensitive to frequencies between 0.2 and 0.5 cycles per degree (Atkinson, Braddick, & French, 1979), so energy in that range, according to the model, will be most effective in attracting and holding the infant's attention. How that energy is arranged—its phase spectrum—does not contribute to determining newborn preferences in this model.

Can an energy model of this kind account for infants' responses to faces or face-like stimuli? A number of studies have shown that newborn infants will track a schematic face further than certain control stimuli (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991, Experiments 1 and 2; Maurer & Young, 1983). Our own studies used infants with a mean age of 37 min, and the data and stimuli for one of these experiments can be seen in Figure 1. However, these studies do not allow a direct evaluation of the LSM because the appropriate control stimuli were not used. Instead, control stimuli were constructed by scrambling the features of a schematic face. Such stimuli test the importance of the way in which the elements of the face are configured, and control for a number of variables that have been thought to be important, such as the number of elements, the average illumination, the amount of contour, and so on. However, when the features are rearranged, the amplitude spectrum changes, however slightly. It remains possible that the scrambled faces that newborns tracked less far than a schematic face had amplitude spectra containing less energy in the optimal range.

The experiment involving faces that has manipulated amplitude and phase spectra most appropriately is one performed by Kleiner (1987). Kleiner's primary stimuli were a schematic face and a lattice pattern, labeled A and B in Figure 2. These stimuli underwent a Fourier analysis to determine an amplitude spectrum and a phase spectrum for each. The spectra were crossed to provide two further stimuli. Stimulus C, with the phase spectrum of the face, looks face-like to an adult viewer, although its resemblance to a face is somewhat concealed by the lattice pattern. Stimulus D, with the amplitude spectrum of the face, does not look face-like at all to the adult viewer. The prediction of the LSM is that newborns' preferences would depend entirely on amplitude spectrum and not at all on the phase spectrum of the pattern.

Kleiner (1987) used a two-choice preference paradigm with infants of an average age of 1.7 days. When presented with the basic face (A) and lattice pattern

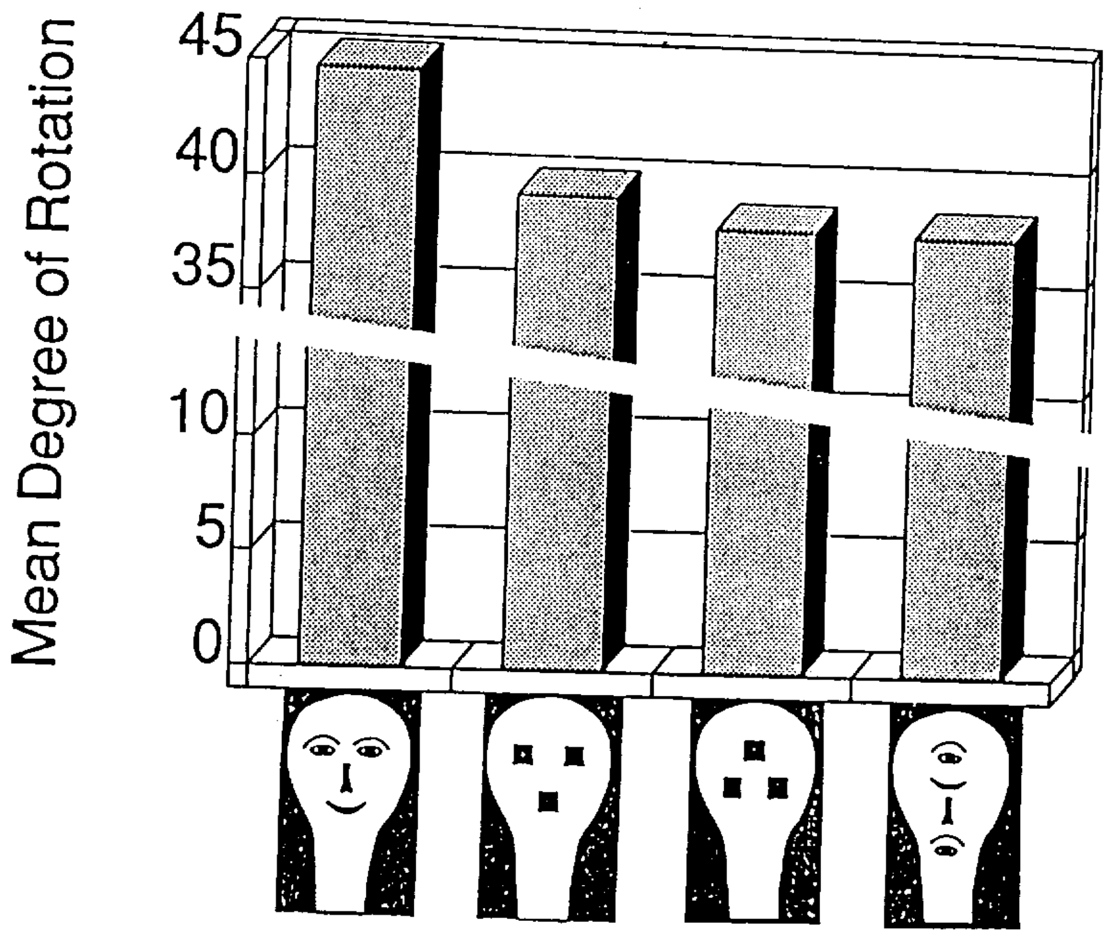

Figure 1. Data from Johnson, Dziurawiec, Ellis, and Morton's (1991) Experiment 2. The experiment involves testing the extent to which newborn infants (mean age 37 min) will track stimuli. The response to the "face" stimulus was significantly greater than to the "scrambled" or the "inverse" stimuli.

(B) together, the infants looked at the face 67% of the time. When Stimuli C and D were compared, the infants looked 63% of the time at stimulus D, which had the amplitude spectrum of the face, in accordance with the LSM.[1]

However, Kleiner's (1987) data produced one result that is not predicted by the LSM. As we have already stated, this model explicitly claims that the phase relationships will be irrelevant for newborns, and thus predicts that the original schematic face, A, will be no more attractive to the infant than Stimulus D, because they possess the same amplitude spectrum. But in the condition using these two stimuli, the newborns overwhelmingly preferred the face pattern, looking at it 69% of the time. This cannot be because the phase spectrum of the face is preferred to that of the lattice, because the infants showed no preference for Stimulus C over B.

[1] Because a face is preferred to a lattice, the advantage of C over D cannot be due to C having the lattice phase spectrum.

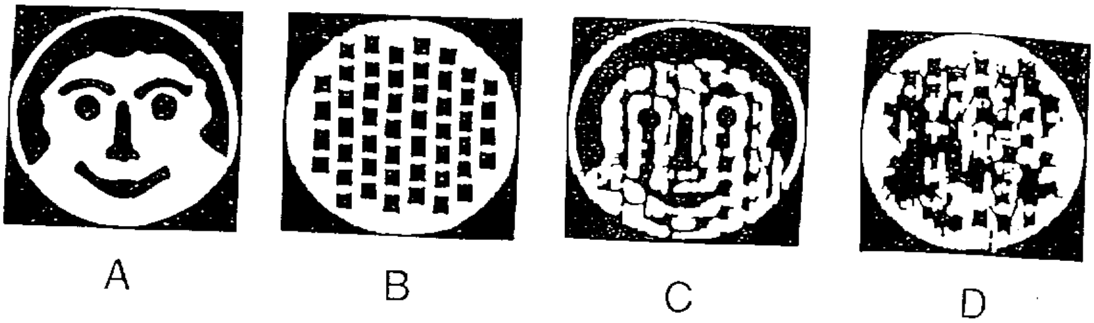

Figure 2. The stimuli used by Kleiner (1987). Stimulus A has the amplitude spectrum of the face and the phase spectrum of the face. Stimulus B has the amplitude spectrum of the lattice and the phase spectrum of the lattice. Stimulus C has the amplitude spectrum of the lattice and the phase spectrum of the face. Stimulus D has the amplitude spectrum of the face and the phase spectrum of the lattice. Kleiner showed that infants (mean age 1.7 days) preferred D to C and preferred A to D. In addition, they preferred A to B, preferred A to C, preferred D to B, and showed equal preference for B and C. Reprinted with the permission of Abelex Publishing Corporation.

Kleiner (1987) acknowledged this result as a problem for the LSM and erected a three-stage model including phase to rescue the position. Subsequent interpretations of Kleiner's results have not been as careful. As an example, Kleiner and Banks (1987) write that "the results showed rather clearly that neonates' preferences were predicted from the amplitude spectrum and not from the phase spectrum" and that. therefore, "neonates' preferences were based on stimulus energy" (p. 595). Furthermore, Dannemiller and Stephens (1988), Aslin and Smith (1988), and Nelson and Ludemann (1989) all reported that neonates' preferences conform to predictions based on the LSM. A myth is in danger of being created. (Further discussion of this issue can be found in Morton, Johnson, & Maurer, 1990.)

The alternative is that the newborn infant possesses a mechanism that has structural information about the human face. This information could be something as simple as three high-contrast blobs in a formation corresponding to the eyes and mouth; elsewhere, we have termed this mechanism CONSPEC (Johnson & Morton, 1991; Morton & Johnson, 1991). Stimuli in peripheral vision that satisfy the specification would attract the infant's interest.[2] In postulating CONSPEC, we acknowledge the possible influence of evolutionary pressures in a way parallel to that believed to be the case with the domestic chick (Johnson, 1990).

We suggest that some mechanism whose function is predicted by the LSM effectively operates in parallel with a mechanism sensitive to face structure. The face in Stimulus C. masked as it is by elements of the lattice pattern, fails to

[2] Note that the similarity metric for such detection devices cannot be understood in terms of amplitude and phase spectra. Stimulus C in Figure 1 has the same phase spectrum as A. but would not be recognized by CONSPEC because it does not fit the structural description.

match the information in CONSPEC. Stimulus C does not, then, qualify as a face and is evaluated solely on the basis of its energy. Stimuli with the amplitude spectrum of the face will then be preferred over stimuli with the amplitude spectrum of the lattice, in accordance with the predictions of the LSM. For this reason, Stimulus D is preferred to Stimulus C. Stimulus A is preferred to Stimulus D, on the other hand, by virtue of its structural characteristics, through the operation of CONSPEC. Kleiner's (1987) data is thus accounted for by the two mechanisms acting in parallel.

THE EXTRACTION OF APPROPRIATE INVARIANTS

A face-like stimulus does not have a meaning for a newborn infant in the same sense that it does for an older infant. We do not wish to argue that it is a "social" stimulus to the newborn, to use the term used by Kleiner and Banks (1987). Rather, we propose that CONSPEC is a mechanism that merely causes newborn infants to orientate toward faces, thereby providing a separate, more general learning mechanism with ample experience in this important class of stimulus (Johnson, 1988; Johnson & Morton, 1991; Morton & Johnson, 1988, 1991). We have been exploring how this learning mechanism develops the perceptual specification of "faceness" with respect to one dimension.

Johnson, Dziurawiec, Bartrip, and Morton (in press) carried out a set of experiments designed to confirm earlier work using the "infant control procedure." This technique involves simply presenting the stimulus to the infants until they look away. With this method, Maurer and Barrera (1981) found that 2-month-olds looked longer at a schematic face than at control stimuli. Infants 1 month old, however, did not show any difference in preference among the stimuli. We have replicated this finding (Johnson et al., in press, Experiment 1).[3]

Johnson et al. (in press) also found that 5-month-olds actually looked less at the face than at any of the control stimuli. We surmised that this might be because these infants found the schematic face relatively impoverished. Once infants reach a certain level of perceptual sophistication, they may no longer find the schematic face stimuli interesting. If this is the case, then adding some of the appropriate cues of real faces ought to result in the return of the preference for the face. Among the most prominent characteristics of real faces is movement of the internal features.

[3] The alert reader may be puzzled as to why 1-month-old infants are reported here as not preferring faces when in the previous section it was claimed that newborn infants were already doing so. The answer lies in the difference between the two preference testing techniques that have been used, which we suppose to tap two different mechanisms. Briefly, the tracking task taps a subcortical mechanism that operates from birth but declines at about 30 days, whereas the other preference tests tap a cortically mediated system. See Johnson (1988), Johnson and Morton (1991), and Morton and Johnson (1991) for further details.

Johnson et al. (in press) used three different computer-generated configurations of facial features: normal, scrambled, and linear (see Figure 3). The linear stimulus was chosen because it preserved the features of the face stimulus without the configuration. In the scrambled stimulus, the eyes were broken up into their component parts. 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 (a maximum of 3 mm) by making transitions from one static presentation to another. The effect was one of animation of an otherwise constant stimulus, with a slight change in the smile accompanied by partial hooding of the eyes and slight movements of the eyebrows and nose. In the other condition, a static frame was used. Each 5-month-old child was exposed to six stimuli, three static and three moving.

In the top panel of Figure 3 we show the geometrical mean values of looking time for the three configurations and two conditions. For the static presentations, there were no significant differences between the times spent looking at the three different configurations on the Friedman test ($\chi^2 = 1.00$, $df = 2$, ns). In contrast, for the moving stimuli there was an effect of configuration on looking time ($\chi^2 = 7.44$, $df = 2$, $p = .024$). The face stimulus was significantly preferred over the other two ($p < .05$ in both cases, Wilcoxon test, planned comparisons). There was no difference in the overall length of time the infants spent looking at moving versus static stimuli ($p = 0.48$, sign test). This surprising result could be because these small movements were meaningless except in the context of the face, and because the static stimuli were interesting enough to hold the infants' attention. We may conclude that movement alone is not important for the 5-month-old infants' preference. However, the movement of the internal features restores preference for a face-like configuration.

By the time a child is 5 months of age, it seems that such schematic faces are treated the way adults would treat them: as face-like but not real. Scrambled faces may sometimes, then, be more interesting to these children than schematic faces (as we found in the Johnson et al., in press, experiment mentioned above) by virtue of being novel patterns. However, if face-like internal movement is added to the schematic face, it becomes much more interesting, perhaps as interesting as a real face in motion.

Of particular interest is the fact that movement affected the looking time only in the context of a normal, schematic face. With the other two patterns, movement made no difference at all. Before interpreting this result, we can contrast it with the results of another experiment in which the same procedure was carried out on 3-month-old and 1-month-old infants (Johnson et al., in press). These data can be seen in the middle and bottom panels, respectively, of Figure 3. The geometrical mean looking times are plotted in both cases. Because we had no prior expectations as to outcome, we simply performed a two-way analysis of variance on the log-transformed looking times. For the 3-month-old infants, this

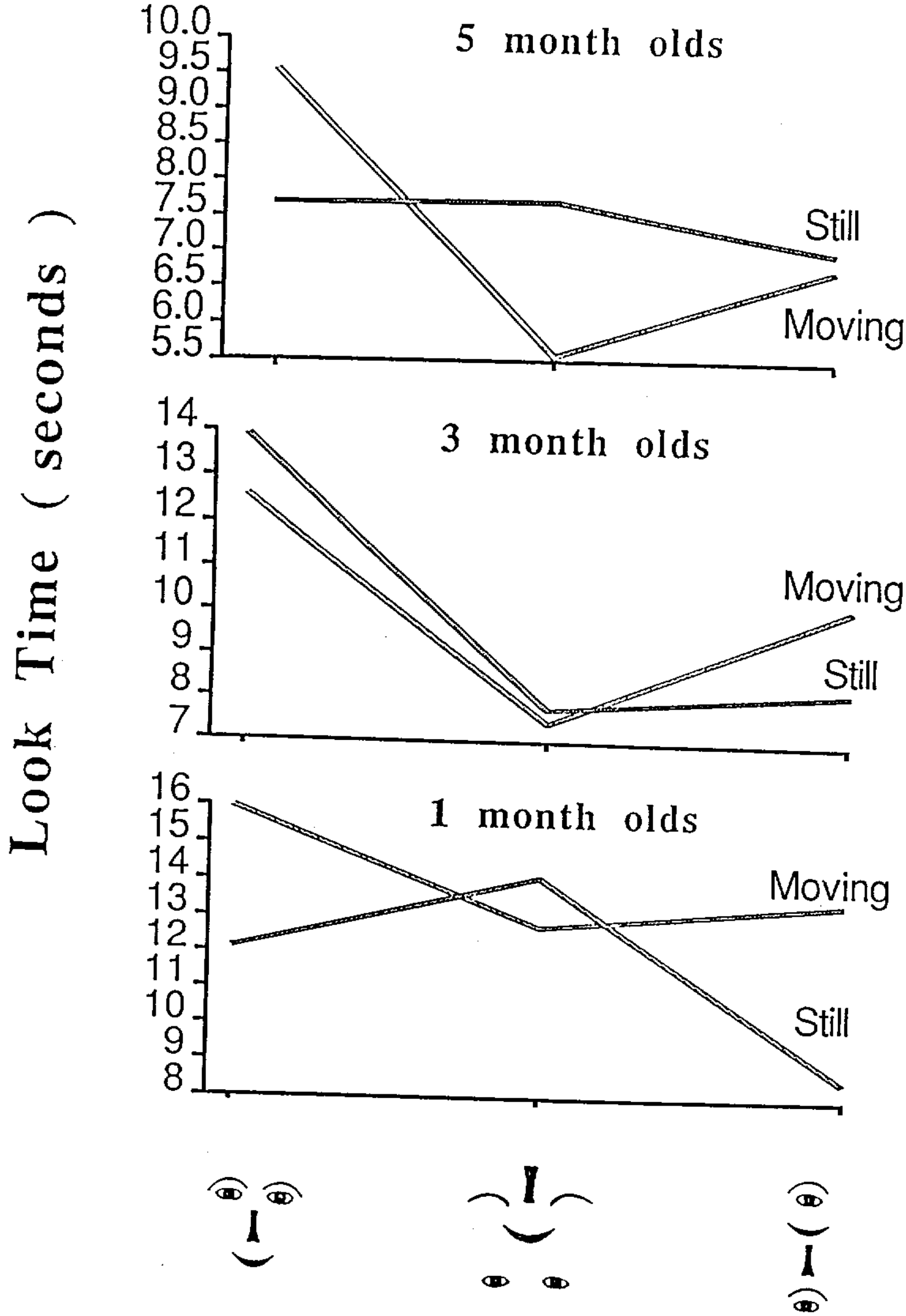

Figure 3. Mean length of time for which 5-, 3-, and 1-month-old infants look at stimuli with static versus moving internal features. The stimuli are called *normal*, *scrambled*, and *linear*, respectively. Data from Johnson, Dziurawiec, Bartrip, and Morton (in press).

showed a highly significant effect of stimulus ($F = 3.46$, $df = 2$, $p = .041$) and an insignificant effect of movement ($F = 0.17$). The interaction term was virtually zero, indicating that inasmuch as movement affected how interesting the stimuli were for these infants, it did so independently of the nature of the stimulus. For the 1-month-old infants, the effect of movement was significant ($F = 4.55$, $df = 1$, $p = .043$). There was no significant effect of the nature of the stimulus.

The first thing about these data is that the results with static faces replicate the findings previously mentioned in that, in contrast with the 3-month-olds, 1-month-old and 5-month-old infants do not look longer at schematic faces (Johnson et al., in press). Second, it seems that the way in which movement has its effects changes with age. With the youngest group of infants, internal feature movement was the only factor to have an effect. With the 3-month-old infants, internal feature movement had no effect on preference, although the arrangement of the pattern did have an effect. By 5 months, however, movement becomes integrated into the infant's characterization of a face.

CONCLUSIONS

Our work has confirmed that newborn infants have a special interest in face-like patterns. Our analysis of Kleiner (1987) leads us to conclude that this interest is not simply attributable to the spatial frequency components of the stimuli used. Rather, we have shown that there exists some innate specification of certain structural characteristics of faces. This results in newborn infants' preferentially orienting toward faces around them. Subsequently, developing cortical circuits configure themselves according to the faces' input. That this process is gradual can be seen from the fact that between 3 and 5 months of age there is a change in the way movement is integrated into the structural description of the face.

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