From Piecemeal to Configurational Representation of Faces

Abstract. *Unlike older children and adults, children of less than about 10 years of age remember photographs of faces presented upside down almost as well as those shown upright and are easily fooled by simple disguises. The development at age 10 of the ability to encode orientation-specific configurational aspects of a face may reflect completion of certain maturational changes in the right cerebral hemisphere.*

Most adults can recognize a vast number of individual faces, despite the high degree of physical similarity among them and regardless of changes in angle of view, hairstyle, accessories, or even many years of age. The process of recognition requires a match between the current input and a stored mental representation. Apparently, two different kinds of information are contained in facial representations—piecemeal and configurational—and children under 10 seem able to encode new faces only in terms of the former. We present evidence of two kinds to support these generalizations: the effects of inversion on face recognition and the confusions among unfamiliar faces when superficial disguises are manipulated.

When a face (such as one in Fig. 1) is viewed upside down, much of its facelike quality seems to have been lost. Even familiar people are difficult to recognize in inverted photographs (*1*). Moreover, it is difficult to remember unfamiliar faces if they have been presented upside down. Yin (*2*) showed normal adults a series of faces and later asked them to select from pairs of faces which of the two he or she had seen before. When the original and test faces were upright, 90 percent of selections were correct; when all faces were inverted, 62 percent were correct. A much smaller difference, 10 percent, was obtained between upright and inverted photographs of houses, another class of stimuli customarily seen in a single orientation. Not all perceivers gave this pattern of results. Patients with lesions in the right posterior cortex were affected equally by inversion of both faces and houses (around 10 percent more error for inverted than for upright images). Thus, Yin's patients may have been processing faces as they did houses, while normal adults treated faces and houses differently.

Yin's results suggest that faces might be represented mentally in two different ways, one of which is also used for other visual stimuli. One way could be in terms of isolated features—for instance, a mole, bushy eyebrows—derived almost as well from inverted as from upright photographs. Individual faces, however, also present distinctive, spatial relations among their features, representation of which might be accomplished much more readily when the face is viewed in its normal orientation. Apparently, Yin's patient population had selectively lost the ability to utilize the configurational properties of faces, since there was no difference between normal controls and patients with regard to memory for inverted faces. We first determined whether the two kinds of mental representation of faces might have separate developmental courses, just as they are separately affected by lesions.

In experiment 1, 36 children, 12 each at ages 6, 8, and 10, viewed two mixed sets of 24 photographs of faces and houses, one upright and the other inverted. The sets were counterbalanced across orientation and order of viewing. After each set had been presented, recognition was tested with pairs containing an item that had appeared in the set and a new item of the same type. The test pairs were shown in the same orientation as the inspection items. We computed the extent to which the difference between the number of faces recognized upright and inverted exceeded the difference between the number of houses recognized upright and inverted. For 6- and 8-year-olds this difference was small and nonsignificant (−8 and 4 percent, respectively). For 10-year-olds the difference rose to 25 percent; recognition of faces was affected significantly more by orientation than was recognition of houses ($P < .01$, one-tailed t-test for correlated means). This is the normal adult pattern (*3*).

While accuracy on upright faces improved sharply between ages 6 and 10, performance on inverted faces remained constant (Table 1). Indeed, 6- and 8-year-olds did as well on inverted faces as did adults; the young children we tested differed from adults only in performance on upright faces. Thus, the substantial effect of inversion which emerges by age 10 (Table 1) is due to the development of an efficient means of representing upright faces, presumably by utilizing configurational information.

The developmental course of house recognition differs from that of face recognition. Performance on upright houses remains constant; performance on inverted houses is at chance level at age 6, improving sharply by age 10 (Table 1). The decreasing effect of inversion on house recognition probably reflects an improvement in encoding the piecemeal features of this relatively unfamiliar stimulus domain from an inverted exemplar (*4*).

A second experiment provided direct evidence that 6- and 8-year-olds do use isolated features in their attempts at recognizing people while 10-year-olds do not. We constructed four types of recognition problems (Fig. 1) by manipulating facial expression and paraphernalia such as clothing, hairstyle, or eyeglasses.

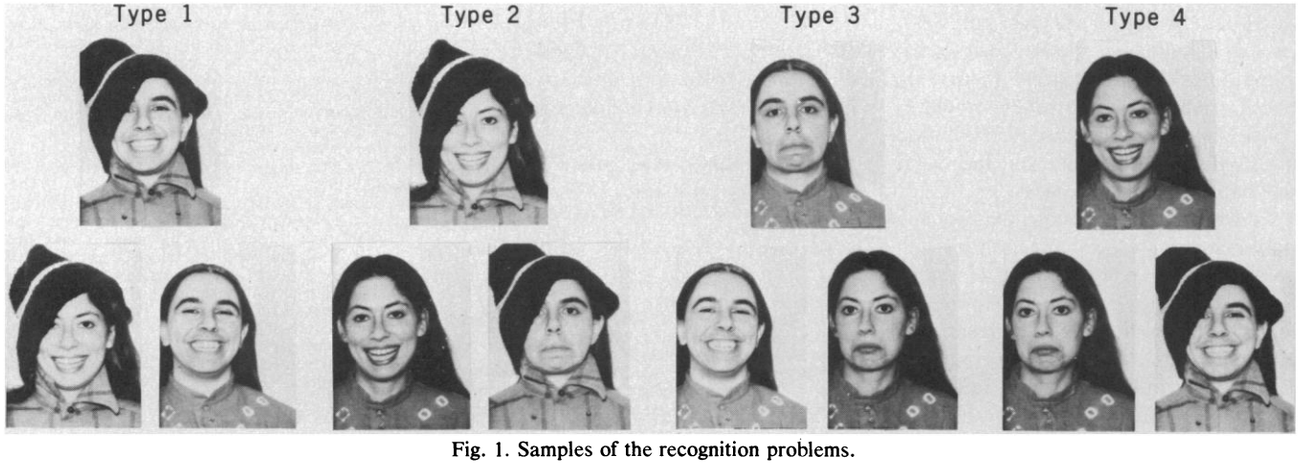

Fig. 1. Samples of the recognition problems.

Thirty-six children, 12 each at ages 6, 8, and 10, saw sets of 12 problems, one contributed by each of 12 pairs of models; there were three examples of each problem type per set. Within each age group each pair of models contributed equal numbers of examples of each problem type. An inspection photograph was presented and then covered while a pair of photographs was shown (Fig. 1). The child was asked, "Which is the same person?" The subject was told to be very careful to look at the face, because the clothes, eyeglasses, or even the hair might change, and that facial expression might also change.

Our hypothesis was that young children cannot abstract the permanent facial configuration from single photographs of unfamiliar people, and instead must encode isolated features, such as facial expression or paraphernalia in our photographs. Reliance on either of these sources would yield a distinctive pattern of errors. Several considerations suggested that identification errors would be based on paraphernalia but not expression. First, paraphernalia are more veridical cues to identity than are facial expressions: we expect hair, eyeglasses, or even clothing to remain constant for a period of time, whereas facial expressions change from moment to moment. Second, in another study subjects were shown four photographs of a single person, two with the same paraphernalia and two with the same expression. When asked which two pictures looked most alike, children below age 10 chose the two matched in paraphernalia (*5*). The predicted pattern of results for 6- and 8-year-olds is summarized in Fig. 2, inset; problems of types 1 and 2 (paraphernalia to fool) (*6*) should be harder than those of type 3 (paraphernalia equal), which in turn should be harder than those of type 4 (paraphernalia to help).

In the study requiring a choice of similarity among four photographs of the same person, children 10 and older chose those matched on expression. There is no right answer to this question, and systematic responding demands the use of one cue or the other. In contrast, there are correct answers to the question of identity (Which is the same person?) posed in the present experiment. If 10-year-olds are able to encode the facial configurations, expression will not merely substitute for paraphernalia as the basis for choice; rather, the older children should be capable of correct judgments.

As shown in Fig. 2, 6- and 8-year-olds are highly susceptible to confounding paraphernalia cues; this susceptibility has decreased markedly by age 10. The problem types were compared by a Wilcoxon signed ranks analysis of differences of within-model pairs, with the null hypothesis rejected at $P < .05$. At age 6 all the predicted differences are significant. At age 8 all are significant except that type 3 problems are no longer more difficult than those of type 4. By age 10, only type 1 problems are significantly harder than those of types 3 and 4. As predicted, expression is not used as a cue to identity at any of the three ages (*7*).

Table 1. Percentage of correct responses in recognition problems on upright and inverted faces and houses.

Age	Correct responses (%)			
	Faces		Houses	
	Upright	Inverted	Upright	Inverted
6	69	64	71	58*†
8	81	67	74	64
10	89	68‡	73	77

*Chance performance. All other entries better than chance ($P < .01$, t-test). †Correct responses on upright houses greater than on inverted houses ($P < .05$). ‡Correct responses on upright faces greater than on inverted faces ($P < .001$). No other significant effect of inversion (t-test for correlated means, one-tailed).

We conclude that 10-year-olds base their judgments on some properties of faces that lead to correct identification. These could be isolated features not confounding in our materials (a mole, eyebrow shape). Older children might simply have a better theory than younger children of which features best serve recognition. But the results of the first experiment (Table 1) cannot be explained on this basis; such features can be seen on inverted faces. Instead, we suggest, these two experiments taken together imply that the properties that replace paraphernalia by age 10 are configurational aspects of faces, aspects that can be encoded best from upright faces.

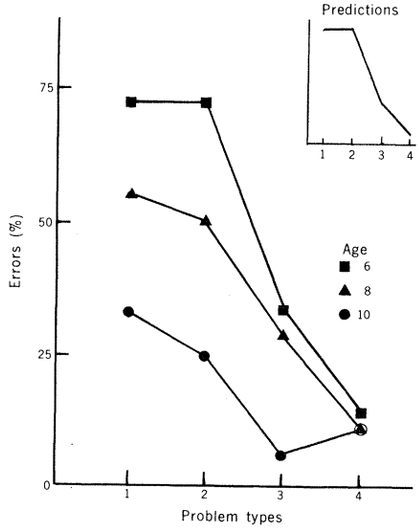

Fig. 2. Recognition errors.

These experiments provide no information about the representation of familiar faces. We have found that children as young as 5 solve paraphernalia-to-fool problems easily if the persons photographed are well known to them (*8*). This suggests that familiar faces are represented configurationally by young children and that it is the adult efficiency in forming configurational representations of new faces that is approached by age 10.

What might account for this long period of development? Perhaps experience with a wide range of real faces, including opportunity to make many of them familiar through repeated exposure, is required. Additionally, perhaps efficient configurational representation of new faces depends upon maturational changes in the right cerebral hemisphere, the part of the brain implicated in many complex visuospatial tasks. Several lines of argument support a maturational hypothesis. (i) The right cerebral hemisphere plays an essential role in perception of unfamiliar faces (*9*), and the pattern of results given by 6- and 8-year-olds in experiment 1 is the same as that given by patients with lesions of the right posterior cortex (*2*). (ii) Recovery from aphasias associated with left hemisphere stroke is much more rapid and complete if the injury takes place before ages 10 to 13 than afterward (*10*). If parts of the right hemisphere are not yet serving their adult functions, they might be more readily available for the representation of language. Loss of plasticity with respect to language and attainment of the adult ability to represent new faces might both reflect commitment of the right hemisphere to some of its visuospatial specializations by age 10. (iii) There is evidence that the right and left hemispheres are not differentiated with respect to certain right hemisphere functions until age 10 (*11*). (iv) A more direct test of the contribution of right hemisphere specialization to the development of face recognition capacities can be made. A left hemisphere advantage for speech perception emerges at least by age 5 or 6 (*12*); perhaps the right hemisphere advantage shown by adults for recognition of unfamiliar faces does not emerge until age 10. This possibility has recently been confirmed (*13*).

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References and Notes

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2. R. K. Yin, *Neuropsychologia* **8**, 395 (1970).
3. A. G. Goldstein [*Psychonom. Sci.* **3**, 447 (1965)] reported that 8-year-olds, unlike adults, learned to pair letters with inverted faces almost as easily as with upright faces. He did not specify the age at which the adult susceptibility to inversion appears. The full reports of experiments 1 and 2 (*4*, *8*) indicate subtle changes in face perception at least until age 16. See also A. G. Goldstein [*J. Genet. Psychol.* **127**, 109 (1975)].
4. S. Carey, R. Diamond, B. Woods, in preparation.
5. A. Lévy-Schoen, *Image d'Autrui Chez l'Enfant* (Presses Universitaires de France, Paris, 1964).
6. On paraphernalia-to-fool items, if the child bases his judgment of identity on paraphernalia, he will make the wrong choice. On paraphernalia-equal items, reliance on paraphernalia cannot lead to a choice since all three photographs show the same paraphernalia. On paraphernalia-to-help items, reliance on paraphernalia leads to a correct choice. There are also expression-to-fool (types 3 and 4), expression-equal (type 1) and expression-to-help (type 2) items (Fig. 1).
7. That is, the 6- and 8-year-olds gave the pattern of errors expected if paraphernalia alone were the source of confounding while the 10-year-olds have moved toward equal difficulty of all four problem types. At age 10 expression does not replace paraphernalia as the sole source of confounding; expression-to-fool problems are not harder than expression-to-help problems.
8. R. Diamond and S. Carey, *J. Exp. Child Psych.*, in press.
9. Face recognition deficits are associated with right hemisphere injury [for example, E. De Renzi and H. Spinnler, *Neurology* **16**, 145 (1966), E. Warrington and M. James, *Cortex* **3**, 317 (1967), B. Milner, *Neuropsychologia* **6**, 191 (1968), A. L. Benton and M. W. Van Allen, *Cortex* **4**, 344 (1968)]. A privileged role for input to the right hemisphere in nonverbal face recognition tasks has been demonstrated for patients in whom the two hemispheres have been surgically disconnected [J. Levy, C. Trevarthen, R. W. Sperry, *Brain* **95**, 61 (1972)] and for normal adults [for instance, G. Rizzolatti, C. Umiltà, G. Berlucchi, *Brain* **94**, 431 (1971); R. D. Hilliard, *Cortex* **9**, 246 (1973)].
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11. B. Kohn and M. Dennis [*Neuropsychologia* **12**, 505 (1974)] found that young adults with early right hemidecortication were unimpaired on a number of visual and spatial tasks in which patients with right hemisphere lesions incurred during adulthood are severely deficient. Sparing was limited to tasks on which normal children become proficient before age 10. This suggests that the early-maturing skills can be mediated by either hemisphere but that functions for which the right hemisphere is specialized by age 10 cannot be assumed by the left.
12. For example, D. Kumura, *J. Comp. Physiol. Psychol.* **56**, 899 (1963); D. S. Geffner and I. Hochberg, *Cortex* **7**, 193 (1971); but see also D. Ingram, *Neuropsychologia* **13**, 103 (1975); P. Satz, D. Bukker, J. Tenunissen, R. Goebel, H. Van der Vlugt, *Brain Lang.* **2**, 171 (1975).
13. S. Leehey, thesis, Massachusetts Institute of Technology (1976). With tachistoscopic presentation of words and faces, 8-and 10-year-olds both show a right visual field advantage for words, but only at age 10 is the left visual field advantage for faces present. Leehey used unfamiliar faces, each presented only once. In young children the right hemisphere might be differentially involved in the processing of familiar faces, especially if represented configurationally. Leehey found a left visual field advantage in the recognition of familiar faces as young as age 8. Thus it seems that maturation of the right hemisphere may be directly implicated in efficient configurational encoding of new faces, the ability tapped in experiments 1 and 2.

14. Supported by Spencer and Grant Foundation grants to H.-L. Teuber. We thank H.-L. Teuber for engaging our interest in face perception, R. K. Yin for the use of his materials, B. Woods for collaborating on Experiment 1 and R. M. Held, M. C. Potter and V. V. Valian for comments.

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Huntington's Disease: Delayed Hypersensitivity in vitro to Human Central Nervous System Antigens

Abstract. *Huntington's disease is a hereditary, chronic, degenerative disease of the brain which is transmitted by an autosomal dominant gene. We have discovered that lymphocytes from patients with Huntington's disease respond to the presence of brain tissue from patients with the disease by producing migration inhibition factor, a correlate of the cellular immune response. Lymphocytes from donors without the disease do not respond to the diseased brain tissue, and lymphocytes from patients with Huntington's disease respond only rarely to brain tissue from donors without the disease.*

Huntington's disease (HD) is a chronic, degenerative disease of the brain most often characterized by progressively increasing choreiform movements and dementia. It is hereditary and is transmitted by an autosomal dominant gene. Pathologically it is marked by neuronal dropout principally in the striatum and cerebral cortex, but with diffuse and variable involvement of other brain regions as well. Other characteristic features include an intense gliosis in regions of neuronal loss, and accumulations of lipofuscin in both neurons and glia (*1*, *2*). Although brain macrophages are often found in devastated regions, no infiltration of lymphocytes or other signs of inflammation have been seen (*2*). Nothing is known about the manner in which the HD gene causes cell death, and management of the disease is largely confined to the use of tranquilizers and dopamine antagonists which reduce choreiform movements (*1*).

We have discovered that lymphocytes from patients with HD respond to the presence of HD brain tissue with the production of migration inhibition factor (MIF), a correlate in vitro of delayed hypersensitivity. Lymphocytes from donors without HD do not respond to HD brain, and HD lymphocytes respond only rarely to brain tissue from donors without the disease.

Brain antigen was prepared by homogenizing frontal lobe gray matter in Ca- and Mg-free Hanks balanced salt solution (CMF Hanks) in a Teflon tissue grinder at 4°C. The homogenate was centrifuged at 1000*g* for 20 minutes at 4°C, and sterilized by passage through a 0.45-μm filter. The brains used are identified in Table 1 with the catalog number of the Human Specimen Bank (*3*). Specimens 201 (from a female, age 69), 203 (from a female, age 55), and 204 (from a male, age 60) were all removed postmortem from patients with HD. Pneumonia was the immediate cause of death in all cases. Specimens 208 (from a female, age 61) and 154 (from a female, age 63) did not have HD and died of pulmonary tuberculosis and a myocardial infarction, respectively. Specimens 209 (from a male, age 62) and 193 (from a male, age 65) both had Alzheimer's disease and died of renal failure and pneumonitis, respectively. Specimen 180 (from a male, age 60) had Parkinson's disease and died of a pulmonary embolism with infarction.

Lymphocytes were obtained from patients with HD and from individuals without degenerative disease of the central nervous system or other serious medical problems. One donor of control lymphocytes (C4) had tardive dyskinesia. Venous blood (30 ml) was drawn in heparin or ethylenediaminetetraacetate (EDTA) and lymphocytes were purified by centrifugation in a discontinuous Ficoll-Hypaque gradient (*4*). The cells were washed twice in CMF Hanks and suspended in Medium 199 (GIBCO) supplemented with 15 percent horse serum and 25 m*M* Hepes buffer (complete medium) (*5*) at a final concentration of 10^6 cells per milliliter.

Lymphocyte cultures were prepared by placing 2 ml of cell suspension in 15-ml plastic culture tubes (loosely capped) with and without antigen (100 to 300 μg of protein). All cultures were made in duplicate and incubated for 24 hours at 36°C in 5 percent CO_2 and 95 percent air. Better responses were obtained in a CO_2 incubator despite the presence of Hepes buffer. The conditioned medium was centrifuged at 1000*g* for 10 minutes, and the supernatants were stored at −70°C prior to assay for MIF activity.

Migration inhibition factor was assayed with guinea pig peritoneal exudate elicited with an intraperitoneal injection of 25 ml of light mineral oil. Four days after the injection the peritoneal cavity was washed with CMF Hanks and the exudate separated from oil. The cells were washed twice in CMF Hanks and suspended in complete medium (approximately 2×10^6 cells per milliliter). Microcaps (50 μl) containing the cell suspension were heat-sealed and centrifuged at 400*g* for 5 minutes. The