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Development of Face Recognition—A Maturational Component?

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In these studies we assessed development between ages 6 and 16 of the ability to encode unfamiliar faces. Performance improved markedly between ages 6 and 10 and then remained at a fixed level or actually declined for several years, finally improving again by age 16. Evidence is provided that this distinctive developmental course reflects, in part, acquisition of processes specific to the encoding of faces rather than general pattern encoding or metamemorial skills. The possibility that maturational factors contribute to the developmental course of face recognition is raised, and two sources of data relevant to assessing this possibility are discussed.

Normal adults have a prodigious capacity for making new faces familiar. Whether one's high school class contained 90 or 800 people, approximately 90% of those classmates are recognized 35 years after graduation (Bahrick, Bahrick, & Wittlinger, 1975). Less dramatically, laboratory studies have shown that very brief exposure to previously unfamiliar faces permits subjects to distinguish those faces from new ones at a later time. The level of performance remains high across inspection sets that range in size from 20 to 72 (Bower & Karlin, 1974; Galper, 1970; Hochberg & Galper, 1967; Yarmey, 1971; Yin, 1969; but also see Diamond & Carey, 1977, and Patterson & Baddeley, 1977, for conditions under which performance is poor).

We will use the phrase *encoding an unfamiliar face* to refer to the dual process of forming a representation of a new face and storing that representation in memory. Thus, "encoding" means roughly the same as "making familiar." *Recognition* will refer to matching a representation of a new instance with a representation already stored in memory.

Undoubtedly, there are processes involved in encoding all visual patterns that contribute to face encoding. In addition, for any class of stimuli with which one is familiar, knowledge of features that discriminate among members of that class in particular is recruited during encoding of new members of that class. Whenever previous experience with a stimulus class affects subsequent encoding of new members, it can be inferred that knowledge particular to that class has been applied during encoding. Two such effects of familiarity have been demonstrated for faces. First, faces from racial groups with which one is well acquainted are better encoded than faces from groups with which one is not so familiar (e.g., Malpass & Kravitz, 1950; Shepherd, Deregowski, & Ellis, 1974). Second, performance on faces presented upright for inspection and recognition is more accurate than on faces presented upside down. The cost of inversion

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is typically about 30% (Hochberg & Galper, 1967; Scapinello & Yarmey, 1970; Yarmey, 1971; Yin, 1969). Since all of the information in a face is present when it is inverted, this robust effect implies that subjects fail, to some extent, to bring to bear their knowledge of faces when encoding an inverted instance. Both the familiar race effect and the inversion effect indicate that knowledge specific to faces is applied during face encoding. This implies that there is a component of the encoding process that functions to deploy that knowledge.

Inversion effects have been demonstrated for many classes of stimuli other than human faces (e.g., houses, buildings, dog faces, bridges, airplanes, costumes, stick figures of men in motion, landscapes; cf. Carey & Diamond, 1980, for a review). In each case, a processing component specific to the class must play a role in the encoding of new members of that class. From the fact that inversion affects face encoding to a much greater extent than it does encoding of any other class of stimuli yet studied, Yin (1969) and others have argued that there are kinds of processes involved in face encoding that play no role in the encoding of members of any other familiar class. Whether or not face encoding involves special processes in this strong sense is still an open question. In this study we are interested simply in the demonstration of a component of processing specific to the encoding of faces. We wish to study the development of the encoding processes, specific and general, that are engaged when a new face is made familiar.

Several studies have found marked improvement between ages 5 and 10 on tasks requiring encoding of upright faces (Blaney & Winograd, 1978; Carey & Diamond, 1977; Diamond & Carey, 1977; Goldstein & Chance, 1964, 1965; Saltz & Sigel, 1967). The question arises to what extent this improvement reflects the development of general encoding and memory processes and to what extent it reflects the development of processes specific to faces. The period from 5 to 10 years is clearly one in which general memorial and metamemorial abilities develop (e.g., Brown, 1975; Flavell, 1977) and appears also to be a time when the efficiency of pattern recognition is increasing (e.g., Vurpillot, 1976). A comparison of developmental histories for the encoding of upright and inverted faces would provide relevant information; development of general pattern encoding skills would be reflected in improved encoding of inverted as well as upright faces. Goldstein (1965) compared the effect of stimulus inversion on face encoding by 7- and 8-year-olds and by adults. In his study, face–letter paired associates were less readily learned by the children than by adults overall, but the children's performance was relatively less affected by inversion of the faces. Using a simple forced-choice recognition paradigm, Carey and Diamond (1977) found that 6- and 8-year-olds encoded upright faces as poorly as inverted faces. By age 10 a significant effect of orientation emerged, reflecting an improvement between ages 6 and 10 in the ability to encode upright faces, but the ability to encode inverted faces did not change. The relative absence of improvement on inverted faces suggests that the dramatic gain in ability to encode upright faces during these ages reflects development of the component of processing specific to faces.

Our previous study had only 12 subjects in each age group, and the Age × Orientation interaction for faces was not significant. Also, because our interest in that study was the comparison of face encoding with house encoding, faces were mixed with houses in the inspection and recognition sets. The influence of this aspect of the procedure on the developmental results for faces is unknown. In Experiment 1 we use a simple procedure to discover whether there is an Age × Orientation interaction in face encoding between ages 6 and 10 such that improvement on upright faces is greater than improvement on inverted faces.

Experiment 1

Method

Subjects. Subjects were 22 6-year-olds and 22 10-year-olds drawn from public schools in Lexington, Massachusetts, a middle-class community. There were 12 girls and 10 boys at each age.

Materials. The materials were a subset of the faces used by Yin (1969, 1970) and in our previous study. They were studio photographs of male adults without glasses, mustaches, beards, or other obvious distinguishing marks, chosen to be alike with respect to expression. The portraits were cropped beneath the chin and were taken against a uniform background. There were 20 target faces and 20 distractors. The target items were grouped into two inspection sets of 10 each. Copies of the target items were paired with distractors for the two recognition sets. A practice series of three targets and three distractors was also prepared. Analogous sets of houses were also prepared. Faces and houses were each blocked during presentation and recognition; only the faces results are presented here.

Procedure. Each subject was shown the three practice target items in the upright orientation for 5 sec each and was instructed to remember them. The three forced-recognition pairs were then shown, and the subject was asked to indicate the face seen before. The test items were presented using the same procedure. Subjects viewed one set of test items in the upright orientation for both inspection and recognition and the other set in the inverted orientation for both. Before the child was presented an inverted inspection set, he or she was instructed that the pictures would also be inverted when they were presented later for recognition. Which subset of items was viewed upright and whether the upright or inverted set was presented first were independently counterbalanced across subjects within each age group. A fixed random order was used for presenting each inspection item and each recognition pair. No time limit was placed on viewing recognition pairs. Target and distractor items were positioned randomly to the left and right during recognition trials.

Results and Discussion

Figure 1 presents the performance of each age group on recognition of upright and inverted faces. The data were subjected to an analysis of variance (ANOVA) with age (6 and 10), sex of subject, and orientation (up and down) as dimensions. There was no main effect for sex of subject and no interaction of sex with any other variable. Significant main effects were found for age, $F(1, 42) = 22.6$, $p < .0001$ and for orientation, $F(1, 42) = 9.6$, $p < .004$. Most pertinent, the interaction between age and orientation was also significant, $F(1, 42) = 6.1$, $p < .02$. A Newman-Keuls range test for differences among means revealed two clusters, significant at the .01 level: 6 down, 6 up, 10 down, 10 up. Thus, as in our previous study, at age 6 there was no significant difference in accuracy on upright and inverted faces, but by age 10 the significantly better performance on upright faces characteristic of normal adults had emerged. The improvement in face encoding between ages 6 and 10 that has frequently been reported was once again observed, but only for upright faces. Ten-year-olds were not significantly better than 6-year-olds on inverted faces.

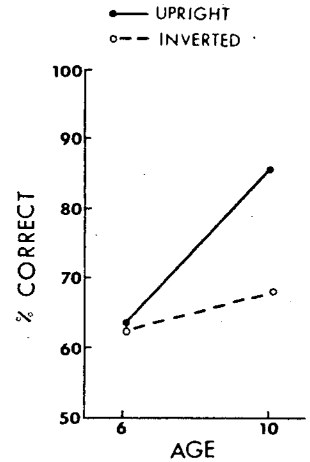

Figure 1. Performance on faces inspected and recognized upright and inverted, at ages 6 and 10.

Improvement in general pattern recognition ability, as well as in general memorial skills, should be reflected in improved performance on inverted as well as on upright faces. Thus, it appears that the rapid development of face-encoding skills during these years reflects increasing knowledge of faces per se rather than development of general encoding skills.

Experiment 2

No study of simple recognition memory for unfamiliar faces has traced its developmental course throughout childhood. In a preliminary exploration of the course of development after age 10, the procedure of Carey and Diamond (1977) was administered to 12 children each from the same population as the subjects of that study at ages 12, 14, and 16. The skill in face encoding that had been gained between age 8 and 10 appeared to decline at ages 12 and 14 and to recover at age 16. Performance levels were 69%, 81%, 89%, 83%, 80% and 89% at ages 6, 8, 10, 12, 14, and 16, respectively. Even though in the data pooled over all ages there was a main effect for age, the decline in performance after age 10 did not reach significance. The sample sizes in this pilot study were very small, so the apparent decline in performance may have been due to sampling error. The first goal of Experiment 2 was to trace the development of face encoding throughout childhood, with special interest in the possibility of a decline after age 10.

We have interpreted the studies in the literature, as well as the results in Experiment 1, as showing that in young children the capacity for encoding unfamiliar faces is as yet poorly developed. However, evidence that in verbal memory tasks children in that same age range frequently fail to demonstrate cognitive skills that they in fact possess (cf. Brown, 1975; Flavell, 1977) suggests caution in accepting this interpretation. The second goal of Experiment 2 was to explore the possibility that our previous studies had underestimated the face-encoding skills of young childen. We adapted Bower and Karlin's (1974) depth-of-encoding procedure in an effort to move the young children toward better performance. Bower and Karlin showed with adult subjects that faces judged for likability or honesty during inspection were better remembered than faces judged for sex (Bower & Karlin, 1974; see also Patterson & Baddeley, 1977; Warrington & Ackroyd, 1975). We reasoned that if young children possess face encoding capacities that our earlier experiments had failed to reveal, likability instructions might engage those capacities, improving their performance disproportionately (compared to that of 10-year-olds) and resulting in a flatter developmental curve. This result would imply that at least part of the performance problem of young children in encoding faces is due not to a lack of capacity but rather to a lack of appropriate strategies for utilizing that capacity. In a similar experiment, Blaney and Winograd (1978) found no Age × Instructions interaction in 6- and 10-year-olds, arguing against such an interpretation. Experiment 2, then, was an attempt to confirm the findings of Blaney and Winograd and to extend the ages studied to adulthood.

Method

Subjects. Subjects were 30 adults and 30 children each at ages 7, 9, 10, 11, 12, and 14. Half of the subjects in each age group were male, and half were female. The children were from public schools in Lexington, Massachusetts, and had IQs ranging from 95 to 135 on the Wechsler Intelligence Scale for Children (WISC). The adults were Massachusetts Institute of Technology undergraduates.

Materials. Photographs of 48 faces (24 men and 24 women) were chosen from a college yearbook, class of 1958. The people wore no glasses and had no beards or mustaches. The photographs were assembled into four inspection blocks, each of which contained 6 women and 6 men. Items in each block were in a fixed random order.

A recognition series for forced choice was constructed by pairing a copy of each inspection photograph with a photograph of a new person from the same yearbook. The recognition series of 48 pairs was arranged in a fixed random order.

Procedure. Subjects were told that they would have 5 sec to view each photograph and that after all had been presented they would be shown pairs of faces and asked which member of each pair had been seen before. They were told to look at the photograph for the full 5 sec. Following the procedure of Bower and Karlin (1974), the subjects were asked to indicate either the sex of the person in the photograph or whether the person seemed likable. A set of six photographs was provided for practice in making these judgments prior to presentation of the inspection items. During inspection, half of the subjects judged the sex of models in the first and third blocks and the likability of models in the second and fourth blocks. For the remaining subjects the order of likability and sex judgments was reversed. After all four inspection blocks had been viewed, the recognition series was shown. Subjects proceeded at their own rate during recognition trials and gave confidence ratings for their judgments (sure, pretty sure, just guessing).

Results and Discussion

Performance was above chance for both judgment conditions at every age. The data were subjected to an ANOVA with age (seven levels) and sex of subject as between-subjects variables and with judgment condition (likability vs. sex of model photographed) as a within-subjects variable. There were main effects for age, $F(6, 203) = 8.00$, $p < .001$, and for judgment condition, $F(1, 203) = 48.04$, $p < .001$, and no interaction between these two variables. There was no main effect for sex of subject, nor was there any interaction between sex of subject and age or between sex of subject and judgment condition.

Figure 2 shows the effects of age and

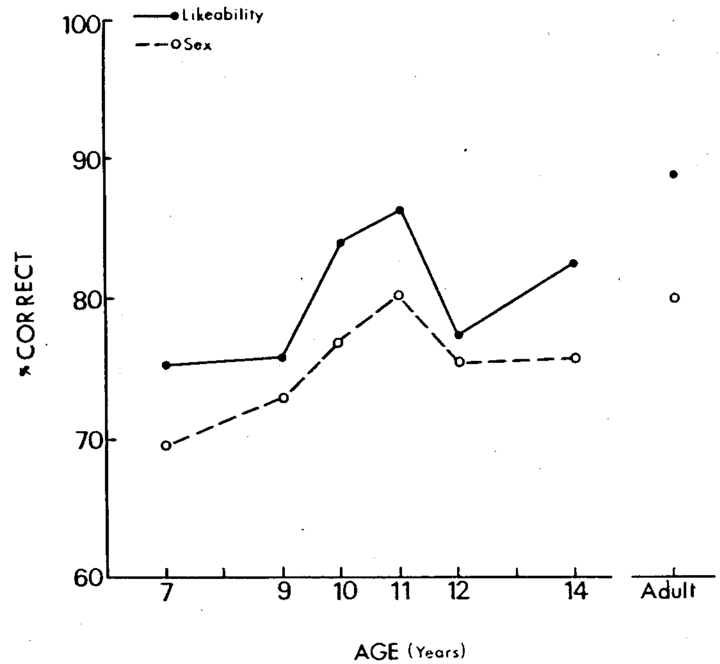

Figure 2. Recognition of faces judged during inspection for likeability or sex, at ages 7, 9, 10, 11, 12, 14 and in young adults.

judgment condition. At every age, photographs judged for likability during inspection were better recognized than those that had been judged for sex. This agrees with Blaney and Winograd's (1978) finding that 6- and 10-year-olds did not differ in the size of the depth of encoding effect and extends that comparability through adolescence. As there was no interaction between age and judgment condition, further analyses on the effects of age were performed on the data collapsed over all 48 items seen by each subject. These data were subjected to a Newman-Keuls range test for differences among means. The following clusters emerged: 7 9 12 14 10 11 Adult. Adults performed better than all other groups. A cluster whose performance was worse than all other groups consisted of 7- and 9-year-olds. Of relevance to the possibility of a dip, the 9-, 12-, and 14-year-olds formed a cluster that differed from both the 10- and 11-year-olds. Planned t tests showed that the performance of both 7- and 9-year-olds was worse than that of 10-year-olds, that the performance of both 12- and 14-year-olds was worse than that of 11-year-olds, and that the performance of 14-year-olds was worse than that of adults (all effects significant at the .05 level or better, t tests, two-tailed). Thus, the developmental course of encoding upright faces that had been observed in our pilot study was replicated in Experiment 2. Performance improved until age 10 and declined at ages 12 and 14. Since the oldest children studied were age 14, we do not know when recovery from the decline is complete or when the adult level of performance, which is higher than that of 10-year-olds, is attained.

The existence of a decline in face-encoding skills in the years after age 10 has recently been confirmed by Bain (Note 1). In three separate studies, using successive "hit" or "miss" recognition items rather than forced-choice recognition pairs, Bain found that the mean d' scores of 11- and 12-year-olds was inferior to that of 10-year-olds. In one study, the performance of 12-

year-olds did not differ from that of 7-year-olds.

In the present experiment the developmental pattern of improvement until age 10, subsequent decline, and then recovery was shown at two different performance levels associated with different instructions during inspection trials. This outcome supports the interpretation that relatively poor performance among children younger than age 10 (and among 12- and 14-year-olds) reflects genuinely less capacity to encode faces. If the poor performance of young children in our previous work had been the result of a failure to respond to the instruction "look at this face so you will remember it later" by bringing to bear encoding skills that they in fact possessed, instructions to judge the face for likability might have been expected to engage those skills. To the extent that those latent skills are equal at different ages, the developmental pattern should have been obliterated. It is possible, of course, that some other instruction would have this effect; the burden of proof is on those who would attribute the course of development of face encoding to metamemorial factors.

Experiment 3

The Age × Materials interaction obtained in Experiment 1 replicated that reported in Carey and Diamond (1977). In that study a parallel was drawn between the performance of children younger than 10 and that of adult patients with injury to the right posterior sector of the brain. Both young children and such patients encode upright faces much more poorly than do normal adults. The parallel extends beyond merely the poor level of face encoding in both groups, since in both cases the deficiency is not found with regard to inverted faces (Carey & Diamond, 1977; Yin, 1970).

One goal of Experiment 3 was to assess the generality of two findings: that children under 10 resemble patients with right-hemisphere lesions as regards efficiency at face encoding and that the normal adult level of performance is reached by age 10. We chose Benton and van Allen's (1968) face-encoding task because it was developed as a neuropsychological diagnostic instrument and because it differs markedly from Yin's forced-choice recognition procedure. In Benton and van Allen's task, a target photograph and an array of six other photographs are presented to the subject. In most items, the array contains three photographs of the model in the target, these three photos having been taken under different conditions of lighting or from different angles of view than the target. To succeed with these items, the subject must represent the target person in terms sufficiently abstract to accommodate the transformations. Although target and array are simultaneously present and there is no time limit, it is a difficult task; normal adult accuracy is only 84%. Further, the task reliably diagnoses right-hemisphere damage (Benton & van Allen, 1968, 1973). In the manual for the test, the authors compared the performance levels of children aged 6 to 11 directly with that of brain-injured patients. The 6-year-olds performed at the level of patients judged to be severely impaired, 7-year-olds at the level of those judged impaired, and 8- and 9-year-olds at the level of those judged possibly impaired. At ages 10 and 11 the mean was below that for normal young adults but the scores fell within the normal range. Benton and van Allen found steady improvement between ages 6 and 10 with no subsequent change between ages 10 and 11. Because they did not include children between ages 11 and 16, no information was available concerning a possible decline in performance during that period. Our second goal in Experiment 3 was to assess the generality of the decline in face encoding at ages 12 and 14 found in Experiment 2.

Method

Subjects. Subjects were drawn from public schools in Lexington, Massachusetts. The IQ range on the WISC was from 95 to 135. There were 19 to 23 children each at age 8, 9, 10, 11, 12, 13, 14 and 16. The difference between the number of boys and girls at any age did not exceed two.

Materials. The stimuli are described in Benton and van Allen (1968). The faces are photographed against black backgrounds; the models' hair is not visible nor are their clothes, eyeglasses, facial hair, or other superficial distinguishing properties. The target photograph is displayed above six comparison photographs. There are three types of problems. In the first type, one comparison photograph is a physical match to the target photograph, and the other five are photographs of other people. In the second type, the comparison photographs include three pictures of the person in the target photograph, each taken from a different angle of view. In the third type, the comparison photographs include three photographs of the target model, each taken under different conditions of lighting.

Procedure. The procedure of Benton and van Allen (1973) was followed. For each item the subject was told how many matches were to be found among the comparison photographs. Subjects were given unlimited time to make their choices.

Table 1
Performance on Benton and van Allen Matching Task

	From Benton and van Allen		From Experiment 3	
Age	n	% accurate	n	% accurate
6	22	61[a]		
7	24	66[b]		
8	25	69[c]	19	68[c]
9	27	70[c]	23	73
10	27	74	29	74
11	24	74	22	73
12			23	75
13			22	74
14			21	77
15				
16			21	84
17–55	107	84		

[a] At level of severly impaired patients with right hemispheric damage. [b] At level of impaired patients with right hemispheric damage. [c] At level of possibly impaired patients with right hemispheric damage.

Results and Discussion

These data were subjected to an ANOVA with age (seven levels) and sex as between-subjects variables and problem type (three levels) as a within-subjects variable. There was a main effect for age, $F(7, 154) = 5.71$, $p < .001$, and for problem type, $F(2, 308) = 548.7$, $p < .001$. Physical match problems were easier (mean correct 95%) than were the angle of view problems (mean correct 80%), which in turn were easier than the different lighting condition problems (mean correct 65%). The interaction between problem type and age was also significant, $F(14, 308) = 2.46, p < .002$. This interaction reflected a ceiling on the six physical match problems; performance on these did not change with age. Since Benton and van Allen did not report their data for the different problem types separately, the three types were combined for further analysis. There was no main effect for sex of subjects and no interaction between sex and any other variable.

As can be seen in Table 1, the results of Experiment 3 replicate in considerable detail those of Benton and van Allen (1973), despite the slightly higher IQ of our sample. (Benton and van Allen's sample ranged in IQ from 87 to 116.) There is one point of discrepancy: Performance of the 9-year-old subjects in their experiment was at the level of "slightly impaired" patients, whereas that of 9-year-olds in Experiment 3 was in the normal adult range.

A Newman-Keuls range test for differences among means was performed on the data from Experiment 3. This analysis yielded three clusters: 8 9 11 10 13 12 14 16. That is, the 16-year-olds differed from all other groups and the 9- to 14-year-olds did not differ from each other. In addition, the 8-, 9-, and 11-year-olds formed a cluster within which there were no differences. Planned t tests showed that performance of the 8-year-olds was worse than that of both the 9-year-olds and the 10-year-olds ($p < .05$ or better, two-tailed). Thus although no actual dip in performance was observed around ages 12–14, significant improvement until age 9 or 10 was followed by several years with no further gain. The leveling of performance Benton and van Allen observed after age 10 was seen to persist through age 14. Between ages 14 and 16, however, performance again improved, reaching the adult level. Figure 3 shows the pooled data from both studies, giving a rough picutre of the entire developmental course of performance on this task.

Experiment 3 confirmed the improvement in performance on face encoding in the years before age 10. It also confirmed the finding that children under 9 perform much like adult patients with lesions of the right hemisphere. The results from Experiments 2 and 3 apparently differ, however, with regard

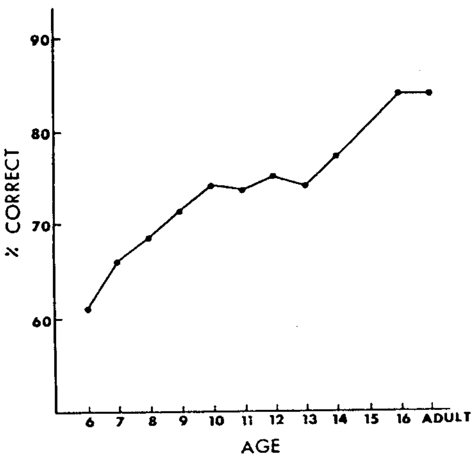

Figure 3. Performance on Benton and van Allen's task of facial recognition. Data for ages 6 and 7 and for adults from Benton and van Allen (1973); data for ages 8–11 pooled from that source and from Experiment 3; data for ages 12–16 from Experiment 3.

to the course of development in the years following age 10. In Experiment 2, there was a decline at ages 12 and 14 relative to the level at age 11. In Experiment 3, the level of performance at age 10 did not reach that of 16-year-olds, and there was merely a plateau between ages 10 and 14.

Flattening of the developmental curve between ages 10 and 14 in the Benton and van Allen paradigm may have resulted from two opposing developmental trends. First, the ability to encode unfamiliar faces from still photographs might decline during these ages, as performance in simple recognition tasks using identical photographs suggests (pilot study; Experiment 2; Bain, Note 1). Second, certain general information-processing skills may continue to improve during these years. One such skill might be that required to scan systematically a complex array, an ability tapped by the Benton and van Allen matching task but not by the memory task of Experiment 2 (see Vurpillot, 1976). The effects of declining efficiency in encoding faces could be cancelled by improvement in such a skill. One outcome would be less change in overall performance between ages 10 and 14 than during the years before age 10. Another would be a higher level of performance at age 16 than at age 10. Both results were obtained in Experiment 3. Thus, although the results in Experiment 3 do not directly support the claim that there is a temporary decline in face-encoding skills in the years following age 10, they are not incompatible with that claim.

The course of development of face encoding emerging from Experiments 2 and 3 can be described as continuous improvement until age 10 followed by a decline or by a period of no improvement, with another improvement sometime after age 14. The ages at which the developmental discontinuities are observed are the same in the two studies, whether the period of no improvement actually involves a decline or not. One assessment of the development of face encoding, Diamond and Carey's (1977) confounding paraphernalia task, yielded no developmental discontinuities. Rather, a performance level of 90% correct was reached by age 12 and maintained through age 16. This confounding paraphernalia task differs in its problem-solving demands from Benton and van Allen's matching task. Face-encoding tasks can be placed on a continuum from simple recognition memory paradigms to tasks with more scope for metamemorial strategies. Perhaps the degree of decline at ages 12–14 is a function of the task's place on this continuum. At any rate, just what conditions yield the developmental functions of Experiments 2 and 3 is a question for further research.

General Discussion

These results raise two major questions. First, in terms of information processing, what is developing in the years before age 10 and what accounts for the temporary decline or leveling after that age? Second, what is the significance, if any, of the resemblance between children and adult patients with right-hemisphere damage? These two questions will be taken up in turn.

Improvement in any skill between ages 6 and 10 is hardly surprising. Indeed, lack of improvement would be more worthy of note. In this study two results support the proposition that improvement in general

cognitive abilities alone does not account for the rapid gain in face-encoding skills during those years. General cognitive gains would be reflected in improved encoding of upside-down faces. However, in Experiment 1 the improvement on inverted faces between ages 6 and 10 did not even reach a statistically significant level. In Experiment 2, instructions designed to engage possibly latent encoding skills improved performance but failed to affect the developmental pattern. Both results suggest that what develops relates mainly to that component of processing specific to faces. Indeed, the present results are consistent with the proposal that general information-processing capacities do not develop during these years and that apparent improvements in memory span, encoding efficiency, and so on actually reflect the acquisition of domain-specific knowledge (cf. Chi, 1976).

How might we conceptualize the knowledge about faces that the child acquires in these years? When presented with a new face, a representation must be formed adequate to distinguish that face not only from all others represented in memory but from other faces one might encounter as well. If the input is a still photograph, the encoding problem is compounded by the ambiguity of the stimulus. For example, those aspects of the stimulus contributed by permanent facial characteristics must be differentiated from those contributed by momentary expression—is that a wide mouth or a grin? Several lines of evidence suggest that young children differ from older children and adults in terms of what kind of information from an unfamiliar face is represented in memory. Properties that distinguish one face from another vary in the degree to which they involve the entire face. Relatively piecemeal distinguishing properties such as "bushy eyebrows" or "mustache" contrast with relatively configurational properties such as "large, wide-set eyes for such a long, narrow face." There is reason to believe that the encoding of configurational properties is more likely to be adversely affected by stimulus inversion than is the encoding of relatively isolated properties (see Carey, 1978). If the young child relies more on relatively piecemeal information, his/her performance should be affected less by inversion than is the older child's, as was the case in Experiment 1 and in Carey and Diamond (1977). Further, Diamond and Carey provided direct evidence that 6- and 8-year-olds encode unfamiliar faces in terms of such relatively isolated features as hats and eyeglasses.

Diamond and Carey (1977) also found that young children were not fooled by simple disguises if the photographs showed persons already highly familiar to them. This finding (see also Leehey, 1976) implies that it is not a difficulty in processing photographs of faces per se, nor an absolute inability to form the adult type of representation, that accounts for the poor performance of children before age 9. Instead, we suggest that their problem is in representing the configurational properties of a previously unfamiliar face when presented a degraded stimulus. To put our hypothesis concretely: a 6-year-old may require many minutes of experience with a face, presented with variations in angle of view and expression, to form as adequate a representation of that face as a 10-year-old or adult can form in 5 sec from a still photograph.

What, then, of the decline after age 10? Developmental decrements have by now been documented in many different conceptual domains, at all ages from infancy to adulthood (cf. Bower, 1976; Strauss, 1978). It is likely that these dips have many different causes, but at least some seem to be "growth errors." Systematization of knowledge of a domain can produce temporary oversimplifications (e.g., Karmiloff-Smith & Inhelder, 1974/1975). Carey (1978) argued that the data of Goldstein (1975) are consistent with such an explanation of the decline in face-encoding skills displayed at ages 12 and 14.

To recapitulate, our tentative answer to the question of what develops by age 10 is the capacity to represent the configurational properties of an unfamiliar face from minimal input. Knowledge particular to faces is exploited in such efficient encoding. Further, this capacity requires an intact right hemisphere in adults. Yin (1970) showed that adult patients with right posterior lesions were impaired (relative to normals and to patients with lesions in other cerebral areas) on the encoding of upright faces but not on the encoding of inverted faces. And in normal adults, Leehey, Carey, Diamond, and Cahn (1978) showed that the left visual field advantage for encoding upright faces was significantly greater than the left visual field advantage for inverted faces. Both results indicate that in addition to the general role of the right hemisphere in encoding complex visual patterns, the right hemisphere is specifically involved in the component of processing in which knowledge of faces as such is deployed.

What, then, might be the significance of the resemblance between the performance of young children and that of adults with right-hemisphere damage? It is by no means obvious that there will be any significance to this similarity. For any task differentially impaired by lesions in a particular cerebral area, there will be some age at which children do badly. In most cases this fact will be of no neurophysiological import. However, in the case of face encoding, the same childhood ages have been targeted as yielding accuracy levels similar to those of right posterior patients on two quite different paradigms. Moreover, both in Experiment 1 and in Carey and Diamond (1977), the similarity was not merely in performance level for upright faces but extended to the effects of stimulus inversion on the pattern of performance as well. The parallel gains interest precisely because this resemblance in pattern was found despite evident differences between young children and adults in general cognitive skills. Perhaps changes in the functioning of the right hemisphere are associated with the development of the capacity to encode faces.

Some direct evidence is available on the relation between right-hemisphere functioning and the development of face-encoding ability. In two separate studies with different face stimuli and different subjects, Leehey (1976) found that 8-year-olds, although displaying the usual right visual field advantage for verbal materials, lacked a left visual field advantage for faces.[1] Nine- and 10-year-olds displayed the robust left visual field advantage in encoding faces that characterizes normal adults. Between ages 8 and 9–10, performance on faces presented in the left visual field improved, whereas performance on faces presented in the right visual field remained constant. Thus, the developmental advance during the years before age 10 in encoding of unfamiliar upright faces is associated with better performance on faces presented to the right hemisphere but not the left. Leehey also found that the magnitude of the left visual field advantage for encoding faces decreased at ages 12 and 14. Thus, the temporary decline in performance on face-encoding tasks in the years after age 10 is matched by a smaller right-hemisphere advantage in encoding faces at those ages.

These observations raise the question of whether maturational factors may be implicated in the development of the capacity to encode upright faces. By "maturational" we mean a genetically programmed component to developmental change. For example, perhaps one limiting factor in the performance of children younger than age 9 is immaturity of the right posterior cortex. And perhaps hormonal upheavals at puberty might in some way affect right hemisphere involvement in the processing of unfamiliar faces. (For further discussion of what is meant by "maturational factor" and for attempts to constrain the maturational hypotheses further, see Carey, 1980; and Carey & Diamond, 1980.) Our hypothesis does not require that young children and adults with right-hemisphere damage will perform alike on every face-encoding task. Indeed, Dricker, Butters, Berman, Samuels, and Carey (1978) found that patients with right-hemisphere damage, although impaired relative to normals on the confounding paraphernalia task, did not resemble 6- and 8-year-old children in their pattern of errors. Some aspects of adult knowledge of faces and some general cognitive abilities not yet acquired by young children would be expected to be spared by the lesions. A task tapping this knowledge or those abilities will be performed differently by children and right-hemisphere patients. What is predicted is that, compared with normal adults, both groups will be deficient on any face encoding task.

[1] Leehey's (1976) results conflict with a number of reports of a left visual field advantage for faces as early as age 5 (Young & Ellis, 1976) or 7 (Broman, 1978; Marcel & Rajan, 1975). With regard to the study of Young and Ellis, we have elsewhere (Leehey et al., 1978) questioned whether their paradigm actually involves face encoding, since the durations of stimulus presentation were below those for recognition of an already familiar face (Chi, 1977). In Broman's study, the task was not encoding unfamiliar faces but discriminating four faces that had previously been familiarized. In Leehey's paradigm, faces already represented in memory (classmates) are recognized better in the left visual field than in the right by age 8 (Leehey, 1976). In the case of Marcel and Rajan, the face presented had to be chosen from an array of only two, an easier encoding task than that used by Leehey. The conclusion from Leehey's study that is of importance here is that there is an increase in left visual field advantage in the age range from 6 to 10. At every age task variables will influence the presence or absence of a right hemisphere advantage for faces as well as its absolute magnitude.

It is possible, of course, that maturation plays no role in the development of face encoding. Increasing ability to encode unfamiliar faces certainly reflects knowledge gained from experience with the range of faces one encounters. The limitations that account for the poor performance of children before age 9 might arise simply from insufficient experience in making faces familiar. Such social experience might support construction of a schema for face encoding that enables more and more efficient processing of information, including what is provided in relatively degraded stimuli. Similarly, the dip in performance at ages 12 and 14 need not implicate any maturational factor. As discussed earlier, the decline could result from a temporary shift in the type of distinguishing properties relied on in encoding faces from still photographs. The available data do not permit a conclusion about the role of maturational factors in the development of face encoding. Carey and Diamond (1980) discuss two different methods for bringing empirical considerations to bear on the issue.

The first method concerns the possibility of a maturational contribution to the decline after age 10, and involves relating efficiency at face encoding to individual differences in maturational status in the adolescent period. If the decline is associated with onset of the adolescent period, prepubescent children should encode faces better than children of the same age who are already adolescent. A pilot study comparing seven prepubescent and six pubescent girls yielded a significant difference in the expected direction (Carey & Diamond, 1980). A full-scale study comparing face encoding in children of both sexes matched for age (within sex) but differing in stage of adolescent development is in progress in our laboratory (Carey & Diamond, Note 2). Since girls reach puberty 2 years earlier than boys, on the average, one would expect the decline earlier in girls than boys. In our studies and in Bain's (Note 1), this expected sex difference was not found, suggesting that the decline is not related to maturational status. However, sample sizes in these studies ranged from 12 to 30 per age group. Leehey (1976) has provided some evidence for the expected sex difference. In her study, the left visual field advantage shown at age 10 by both sexes was absent by age 12 for girls and not absent until age 14 for boys. Leehey's study had 40 children at each age. Thus, preliminary results from the first method are equivocal with regard to a maturational influence on the decline or leveling of face-encoding efficiency in the years after age 10.

The second source of evidence concerning the maturational hypothesis assumes that whatever maturational factors affect the developmental course of face encoding might influence other capacities so as to produce a similar developmental history. Of course, if the same developmental course were found for some other capacity, common maturational influences would not necessarily be implicated. Indirect evidence for common maturational influences would be provided if the two capacities shared a relevant aspect of neural substrate, if in both cases children under 10 resembled patients with lesions of that neural substrate, and if no experiential factors were common to the two capacities.

We have been collecting developmental norms for tasks that are impaired by focal lesions in adults (see Carey & Diamond, 1980, for a discussion of all of the norms collected so far). Among the 40 cases examined to date, only one appears to show a developmental history similar to that of face encoding. This is the Seashore tonal memory task, which shows the same developmental course as the Benton and van Allen face encoding task (1973, Experiment 3). Performance on the Seashore is selectively impaired by right hemisphere damage, and adult patients with such damage perform at the same level as 9-year-olds (Milner, 1962). Since it seems unlikely that a common experiential factor would account for the similarities in developmental history of tonal memory and face encoding, this pattern of results supports the maturational hypothesis.

In conclusion, the meager evidence now available is consistent with a maturational component to the development of face encoding. Of course, even if further studies sustain this interpretation, an account of exactly what is developing, in terms of information processing, remains to be given. We are actively pursuing that goal as well. The present discussion has emphasized the maturational issue in part because there has been relatively little work on maturational influences on human cognitive development past infancy. Whatever the final outcome for face encoding, consideration of the theoretical and methodological problems involved in formulating and testing maturational hypotheses appears to be worthwhile.

Reference Notes

1. Bain, R. University of Aberdeen, personal communication, August 9, 1979.
2. Carey, S., & Diamond, R. *The relation between maturational status and spatial skills during adolescence*. Manuscript in preparation.

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