

Genetic influences on the development of spatial skills during early adolescence*

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Abstract

The course of development of skill at face encoding is disrupted in early adolescence. Evidence is provided that the timing of this disruption is under genetic control. Regardless of their age, girls in the midst of pubertal change encode faces less efficiently than prepubescent or postpubescent controls. This maturational influence on face encoding is contrasted with a different effect of pubertal development on another visuo-spatial ability, performance on the Embedded Figures Test (EFT). Regardless of their pubertal status at time of testing, girls who mature earlier are disadvantaged on EFT compared to those who mature later. The results for EFT replicate earlier findings on the relation between individual differences in the age at which adolescence begins and certain spatial skills. Several possible explanations for each of these effects—that of maturational status on face encoding and that of maturation rate on EFT—are discussed. Consideration of the relation between physical and mental growth is advocated as a source of constraints on explanations of cognitive development.

A deep issue in psychology is the manner in which genetically timed physiological and neural events influence development. Although few would doubt that there is a maturational component to the development of perception and cognition, empirical support for this proposition is sparse and

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indirect. Because during infancy marked changes in the central nervous system occur, efforts to demonstrate a genetic component to the development of specific cognitive and perceptual capacities have concentrated on this period (cf., Aslin *et al.*, 1981). Adolescence, another time of dramatic physical change, is also likely to bear fruit when scrutinized from this perspective.

Our inquiry into a possible maturational influence on the development of face perception was prompted by the observation that this important skill is disrupted during adolescence. When children are presented photographs of unfamiliar people to remember, the rate of accurate recognition increases steadily and greatly from age 2 to age 10 (Blaney and Winograd, 1978; Carey, 1981; Carey *et al.*, 1980; Diamond and Carey, 1977; Flin, 1980; Goldstein and Chance, 1964; Kagan and Klein, 1973). Subsequently, there is a plateau during ages 10–14, and usually an actual decline in performance maximal at age 12, followed by attainment of the adult level of proficiency by age 16 (Carey *et al.*, 1980; Flin, 1980).

As yet, the disruption of development at about age 12 is not understood. We would want an information-processing account of the changes in these years; none is now available. We would also want an account of the timing of this change—why just then? The experiments in the present paper evaluate the hypothesis that the timing of the disruption of face encoding skills is related to the onset of pubertal development. That is, we test the prediction that face encoding is sensitive to maturational status at time of testing. Our hypothesis is that children in the midst of pubertal change will be worse at face encoding than others matched for age, sex, and IQ who are either prepubescent or postpubescent.

It is certainly plausible that pubertal development is irrelevant to the timing of the decline in face encoding skills. For example, Bever (1980) suggested that the decline might be related to the move from small elementary schools to large junior high schools: the presence in memory of many partially encoded new faces could interfere with the encoding of faces presented in the experimental situation. Alternatively, the decline may reflect a reorganization of the child's knowledge of faces occurring when a certain level of proficiency has been attained (see Strauss, 1982, for many examples of developmental dips in whose timing no maturational component is implicated).

The hypothesized influence of maturational status on face encoding skills gains interest from studies suggesting a quite different relation between pubertal development and the acquisition of spatial skills. In a study of children between ages 10 and 15 Waber (1977) found that irrespective of maturational status at time of testing, individuals of both sexes who began

pubertal development at a later age were better at a certain class of spatial skills than those who began earlier. The spatial skills associated with individual differences in the timing of adolescence are tapped by the Embedded Figures Test (EFT), Block Design, and other tests on which males consistently perform better than females.

By now there have been several attempts to replicate Waber's findings. Successful replications have been reported by Herbst and Petersen (1980a), Newcombe and Bandura (1981), and Waber *et al.* (1981, for upper middle-class boys). Unsuccessful attempts at replication have been reported by Herbst and Petersen (1979, 1980b), Petersen (1976), and by Waber *et al.* (1981, for boys from lower middle-class and working class backgrounds). In view of the successful replications, a conservative conclusion is that the timing of puberty (referred to as 'maturation rate' in this literature) has a real effect on this class of spatial skills but that the effect is quite small. A secondary goal of the present experiments is to make another attempt to replicate Waber's findings by including in our study one task supposedly sensitive to maturation rate, the EFT.

Like the EFT, face encoding clearly involves subtle spatial analysis (see, for example, Carey and Diamond, 1980, for a review). However, performance patterns on the two tasks contrast in three salient respects. First, the robust male advantage on EFT is absent for face encoding. The small sex difference on face encoding which emerges in some adult studies favors females (Shepherd, 1981). Second, face encoding is affected markedly more by right hemisphere lesions than by left hemisphere lesions (e.g., Hécaen, 1981),¹ while the EFT is impaired by both left hemisphere and right hemisphere lesions (Corkin, 1979). Finally, the development of face encoding is disrupted around age 12 while that of the EFT is not (Witkin *et al.*, 1967).

Experiment 1

In Experiment 1 a single group of subjects is used to examine whether face encoding and the EFT have different courses of development during

¹ The claim that face encoding is disrupted markedly more by lesions of the right hemisphere than of the left appears to some to be contradicted by the finding that prosopagnosia, a severe deficit in recognition of highly familiar faces is associated with bilateral lesions (Damasio *et al.*, 1982; Meadows, 1974). The two findings are reconciled by explicitly distinguishing the encoding of unfamiliar faces (i.e., forming a mental representation of a previously unfamiliar face) from the process of recognizing a face already represented. There is by now considerable evidence that encoding and recognizing of faces are psychologically distinct: neurologically Benton, 1980; Damasio *et al.*, 1982; Warrington and James, 1967); developmentally (Diamond and Carey, 1977) and in information-processing terms (Ellis *et al.*, 1979). The claim for differential right hemisphere involvement is restricted to encoding of unfamiliar faces.

adolescence and whether the two tasks differ with regard to sex differences. We expect face encoding but not EFT to show a decline during the junior high school years. This result would rule out the possibility that the decline is due either to decreases in motivation or to shifting biases in children's self-selection to participate in the study at different ages.

Method

Subjects

Fifteen children of each sex at each of ages 8, 10, 11, 12, 13, 14, and 16 drawn from an upper middle-class community served as subjects. The mean WISC-R IQ for the sample was 122.2 with s.d. 8.2. There were no significant differences among age groups or between sexes in IQ and no interaction of sex and age with IQ.

Materials and procedures

The face encoding task consisted of 36 college yearbook photographs, half of members of each sex, presented for 5 seconds each, followed by a memory test in which the subject had to select those faces when each was paired with a face of the same sex not seen before. The EFT was the short form of this task used by Waber (1977). It consists of 5 timed items in which a simple shape must be found when hidden in a complex design. Subjects were administered the face encoding task first and the EFT second, on separate days within a three week period.

Results and discussion

An ANOVA carried out on these data revealed a main effect of age ($F(6, 196) = 15.34$; $p < 0.001$) and an interaction of age with task ($F(6, 196) = 3.79$; $p < 0.002$). This interaction indicates that no general factor such as motivation or sampling bias can account for the effects of age. There was also a significant interaction of sex with task ($F(1, 196) = 6.41$; $p < 0.02$). No other main effects or interactions were significant.

Separate analyses of each task showed that the sex by task interaction was due to the advantage for boys on EFT ($t(196) = 1.73$; $p_{\text{(one-tailed)}} < 0.05$) as contrasted with no difference between the sexes on face encoding. There was no significant interaction between age and sex on EFT, indicating that the male advantage was present at all ages.

Figure 1. *Performance on face encoding and EFT at ages 8, 10, 11, 12, 13, 14, and 16. Raw scores were converted to z-scores by computing the deviation of each score from the overall mean for that task and expressing the deviation as a proportion of the standard deviation of the mean.*

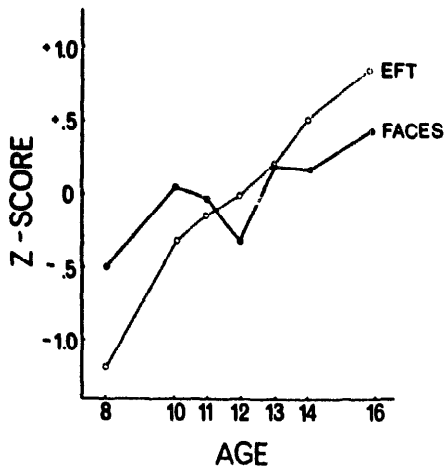


Figure 1 shows the age by task interaction. A Newman-Keuls analysis of differences among age means (Winer, 1971) confirmed that the two tasks had different courses of development. For EFT the following clusters emerged:

8 10 11 12 13 14 16.
 —————

The 8-year-olds performed worse than all others; performance increased monotonically with age with older children forming overlapping groups with breaks between ages 10 and 11, 12 and 13, 13 and 14, and 14 and 16. For face encoding the following clusters emerged:

8 12 11 10 14 13 16.
 —————

The 12-year-olds did not differ from the 8-year-olds; there was a break between these two groups and all other ages and another break between 16-year-olds and all of the younger groups.

The distinct psychological profiles of face encoding and EFT predicted on the basis of previous findings were confirmed here in a single sample of subjects. EFT is characterized by steady improvement throughout the adolescent years while face encoding shows a stasis during ages 10–14 with an actual decline at age 12 and a rise at age 16. Males are advantaged on EFT at all these ages while there is no sex difference on face encoding.

These differences between the two tasks suggested that each would be influenced differently by maturational events at puberty. Two hypotheses were evaluated:

Maturational status hypothesis

Face encoding is sensitive to maturational status at time of testing, that is, the stage of pubertal development centered around age 12 is detrimental to performance. Since EFT does not show any disruption during these years it is predicted to be immune to the influences of maturational status at time of testing.

Maturation rate hypothesis

EFT is predicted to be sensitive to maturation rate; early maturers are predicted to be worse at EFT than late maturers regardless of maturational status at time of testing. Since the tasks (including the EFT) that have previously been related to maturation rate have all been those on which males consistently perform better than females, and since there is no sex difference on face encoding, face encoding is predicted to be immune to the influences of maturation rate.

Experiment 2

While there was empirical support for the hypothesis that EFT is sensitive to maturation rate (see above), there was as yet no support for the hypothesis that the decline in face encoding skills around age 12 is influenced by pubertal development. Experiment 2 was a pilot study designed to evaluate the influence of maturational status on face encoding. It also adds to efforts to replicate the finding of a relation between maturation rate and the EFT.

A commonly used index of pubertal status is derived from Tanner's description of stages of pubic hair development in both boys and girls, breast development in girls and genital development in boys. Assigning children to these stages requires an invasive physical examination. However, for young girls, another less invasive method is available, requiring only height and weight measurements. We felt that if pilot results using the latter method with 10- and 11-year-old girls supported our hypothesis, a larger study requiring physical examinations would be justified.

Method

Subjects

A sample of 100 10- and 11-year-old upper middle-class girls had height and weight measurements taken while they were dressed for swimming. At the onset of adolescent development in girls the proportion of body weight that is lean (Total Water, TW) drops appreciably (Frisch *et al.*, 1973). This proportion can be calculated from height and weight measurements, using the equations of Mellits and Cheek (1970). Frisch (1974) showed that age at menarche can be predicted accurately from TW at these ages. Extrapolating from mean TW at mean age of initiation of the growth spurt and mean age of menarche (Frisch, *et al.*, 1973), it was possible to identify 23 girls at least 1 s.d. below the TW norm in leanness (relatively early maturers) and 18 girls at least 1 s.d. above the norm in leanness (relatively late maturers). The former group will menstruate about a year earlier than the latter group. At these ages the early maturers have begun undergoing the changes for which Marshall and Tanner give age norms; they are pubescent. The late maturers are still prepubescent.

Materials

The face encoding task and the EFT as used in Experiment 1 were given to the 41 girls. In addition, the Stroop color naming task was administered. This is a test of articulation speed in which the color names of a long series of red, blue and green patches must be spoken aloud as quickly as possible. It is typically performed faster by females than by males at all ages and performance is not associated with maturation rate (Waber, 1977). The color naming task was included as a control for possible differences between the two groups that might have confounded any differences found for face encoding or EFT.

Predictions

The maturational status hypothesis for face encoding predicts that in two groups of children matched for age and sex, one of which is prepubescent and the other in the midst of puberty at time of testing, the prepubescent children will be more proficient at face encoding. The maturation rate hypothesis for EFT predicts that late maturing children will perform better on EFT than early maturing children.

Table 1. *Performance in Experiment 2 on Faces (% error), EFT (mean solution time per item, in seconds) and Stroop (mean time to complete task, in seconds).*

	Pubescents ¹ (early maturers) n = 23	Prepubescents ² (late maturers) n = 18	t	p
Faces	23.6	17.0	2.06	<0.025*
EFT	75.8	45.5	3.12	<0.002*
Stroop	74.7	68.9	1.22	n.s.

¹ ranges and s.d.'s: Faces 8-45%, s.d. = 3.27; EFT 26-138, s.d. = 32.25; Stroop 47-118, s.d. = 18.63.

² ranges and s.d.'s: Faces 3-33%, s.d. = 4.09; EFT 5-98, s.d. = 28.48; Stroop 55-92, s.d. = 9.52.

*one-tailed

Results and discussion

The results are given in Table 1. Support was found for the hypothesis that the timing of the dip in face encoding is influenced by pubertal development: the girls estimated to be in the midst of pubertal development performed worse (23.6% errors) than those estimated to be prepubescent (17.0% errors). In addition, the relation between EFT and maturation rate was replicated; late maturers solved the problems much faster (46 seconds per problem) than did early maturers (76 seconds per problem). As predicted, the groups did not differ on the Stroop test.

Thus, the pilot study confirmed both predictions. However, at these young ages the effects of maturational status and maturation rate cannot be evaluated independently because those who are pubescent are necessarily earlier maturers than those who are prepubescent. Thus, evaluation of the hypotheses that face encoding is insensitive to maturation rate and that EFT is insensitive to maturational status requires data from older children. This is provided in Experiment 3 in which actively pubescent and postpubescent girls are compared, as well as actively pubescent and prepubescent girls.

Experiment 3

In Experiment 3 girls in the age range from 10; 0 to 14; 8 were given full physical examinations. Thus, precise information about pubertal status was available and the sample included girls at all stages of pubertal development, including postpubescents (adult body types).

Method

Subjects

The population of girls screened consisted of paid volunteers. The purpose of the study was explained to them as an attempt to understand the relation between rate of physical growth and development of memory abilities. One hundred and forty-five girls were given brief physical examinations by a female physician at their school or summer day camp or by their regular pediatrician in the course of a scheduled checkup. The first 94 girls screened were retained for full-scale study. From the remainder, an additional 23 girls were added so as to balance, as nearly as possible, the distribution of pubertal stages across age. IQ scores for girls included in the sample were obtained from school records. The changes in female secondary sexual characteristics associated with attainment of puberty have been classified into 5 discrete stages for pubic hair growth (PH) and breast development (B). Published norms for large samples of children studied longitudinally show a pattern of overlap of stages at each age and a range of ages for each stage; s.d.'s approximate 1 year (Marshall and Tanner, 1969). Our sample displayed these characteristics and was in close agreement with those norms. The summed score for B and PH development can range from 2 to 10. For the purpose of constituting groups we partitioned the subjects on the basis of these sums: prepubescent (2-4), actively pubescent (5-7), and postpubescent (8-10). Menarche occurs relatively late in pubertal development; the mean age at menarche is later than the mean age of onset of both PH-4 and B-4 (Marshall and Tanner, 1969). Our sample accords with these norms; none of the prepubescents had menstruated, 5% of the actively pubescent girls had menstruated, and 71% of the postpubescent girls had menstruated. The arbitrary nature of our partitioning of the Tanner stages should be noted; in particular, the designation 'postpubescent' does not mean fully mature, as many of these girls had not reached the adult stage of PH and B development, nor had they menstruated.

Procedure

The face encoding and EFT tasks as used in Experiments 1 and 2 were administered within 3 weeks of the time of physical examination.

Treatment of data

Two different methods were used to evaluate the hypotheses. The first used 35 pairs of girls matched closely in age (within 3 months) and IQ (within 9

points) in which one member was actively pubescent and the other prepubescent (17 pairs) or in which one member was actively pubescent and the other postpubescent (18 pairs). This will be referred to as the pairs analysis. The other method used all the data, comparing the group of 40 actively pubescent girls with the group of 77 girls who were either prepubescent ($n = 39$) or postpubescent ($n = 38$). This will be referred to as the all data analysis.

Predictions

The maturational status hypothesis for face encoding predicts that actively pubescent girls will perform worse than their prepubescent and postpubescent controls. Pubescent girls should not differ on EFT from their prepubescent and postpubescent controls taken as a single group. While actively pubescent girls are early maturers relative to prepubescent girls of the same age, they are late maturers relative to postpubescent girls of the same age.

Results and discussion

The results of both the pairs analysis and the all data analysis are given in Table 2. Both analyses reveal a small but significant decrement on face encoding associated with being in the active stages of pubertal development. No such association is found for EFT.

It appears, then, that proficiency at face encoding is affected by maturational status at time of testing. Experiment 2 showed that actively pubescent girls were worse at face encoding than prepubescent controls, and Experiment 3 showed that actively pubescent girls were worse at face encoding than prepubescent and postpubescent controls. Further, Experiment 3 shows EFT to be immune to maturational status at time of testing.

The two types of pairs used in the pairs analysis were also analyzed separately. Comparison of pairs in which an actively pubescent girl is matched with a prepubescent girl is comparable to the analysis of data from Experiment 2; comparison of pairs in which an actively pubescent girl is matched with a postpubescent girl is new and is needed to show that the differences on face encoding revealed in Table 2 are not due solely to differences between pubescent and prepubescent girls.

Since the girls in each pair are matched for age, actively pubescent girls are earlier maturers than their prepubescent controls. Therefore, the maturation rate hypothesis for EFT predicts that in this type of pair pubescent girls will be worse at EFT. Conversely, since actively pubescent girls are later maturers than their postpubescent controls, in this type of pair the pubescent girls should be better at EFT.

We will discuss the results for face encoding first. As can be seen from Table 3b, pubescent girls made more errors on face encoding than did their postpubescent controls ($p < 0.01$) or their prepubescent controls (Table 3a, $p < 0.11$), although the latter comparison failed to reach a conventional level of statistical significance. Thus, the overall difference between the groups seen in Table 2 is certainly not attributable to the pubescent-prepubescent pairs alone. Indeed, the question arises why the comparison between pubescent and prepubescent girls in Experiment 2 yielded a larger difference between the groups (6.6%, $p < 0.025$) than did the comparable comparison in Experiment 3 (3.8%, $p < 0.11$). We think the answer lies in the different methods used to estimate maturational status in the two studies. Prepubescents in Experiment 2 were probably less far along in pubertal development than those in Experiment 3 (who included girls who were stage 2 on both breast and pubic hair development). Substantiating this, in Experiment 2 prepubescents had a TW index of 64 while pubescents were at 52, in Experiment 3 both prepubescents and pubescents were at 58. Further research is clearly needed to determine precisely what maturationally timed pubertal events are associated with the decline in face encoding skills.

Table 2. *Performance in Experiment 3 on Faces (% error) and EFT (mean solution time per item, in seconds). The pairs analysis uses girls matched in age and IQ. For the all data analysis age is in months and IQ is WISC-R equivalent.*

	Pubescents	Prepubescents and Postpubescents	t	p
Pairs analysis	n = 35 ¹	n = 35 ²		
Faces	20.0	15.7	2.61	<0.007*
EFT	46.2	54.7	1.26	n.s.
All data analysis	n = 40 ³	n = 77 ⁴		
Age	143.8	145.8	0.59	n.s.
IQ	121.8	120.7	0.44	n.s.
Faces	20.0	15.8	2.45	<0.01*
EFT	46.0	54.3	1.51	n.s.

¹ ranges and s.d.'s: Faces 0-36%, s.d. = 3.61; EFT 6-99, S.d. = 26.98.

² ranges and s.d.'s: Faces 3-36%, s.d. = 3.09; EFT 5-120, s.d. = 28.34.

³ ranges and s.d.'s: Age 120-174, s.d. = 13.35; IQ 85-151, s.d. = 14.58;
Faces 0-36%, s.d. = 3.6; EFT 6-99, s.d. = 25.38.

⁴ ranges and s.d.'s: Age 121-176, s.d. = 16.71; IQ 94-151, s.d. = 11.69;
Faces 3-36%, s.d. = 2.96; EFT 5-120, s.d. = 29.59.

*one-tailed

Table 3. *Performance in Experiment 3 on Faces (% error) and EFT (mean solution time per item, in seconds). Separate analysis of pubescent-prepubescent pairs (a) and pubescent-postpubescent pairs (b).*

(a) n = 17	Pubescents ¹	Prepubescents ²	t	p
Faces	20.6	16.8	1.31	<0.11*
EFT	56.5	59.4	0.31	n.s.
(b) n = 18	Pubescents ³	Postpubescents ⁴	t	p
Faces	19.4	14.7	2.71	<0.008*
EFT	36.5	50.2	1.40	<0.09*

¹ ranges and s.d.'s: Faces 0-36%, s.d. = 3.86; EFT 6-98, s.d. = 26.58.

² ranges and s.d.'s: Faces 3-31%, s.d. = 3.21; EFT 5-100, s.d. = 28.21.

³ ranges and s.d.'s: Faces 6-36%, s.d. = 3.46; EFT 13-99, s.d. = 24.17.

⁴ ranges and s.d.'s: Faces 6-36%, s.d. = 3.01; EFT 10-120, s.d. = 28.54.

*one-tailed

The maturation rate hypothesis predicts that earlier maturing girls (pubescents in Table 3a and postpubescents in Table 3b) will be worse on EFT than later maturing girls (prepubescents in Table 3a and pubescents in Table 3b). The hypothesis is not supported for the group as a whole nor for the pubescent-prepubescent pairs alone but the results for pubescent-postpubescent pairs are in the right direction and approach significance. The differences between pubescent and postpubescent girls are in the opposite direction for face encoding and EFT, consistent with the hypothesis that the two tasks are affected differently by maturational status and maturation rate.

In Experiment 3 pubescent girls were not disadvantaged on EFT compared with their prepubescent controls (Table 3a). This conflicts with our finding in Experiment 2 (Table 1). Experiment 2 used an extreme groups design in that of 100 girls screened only 41 at least 1 s.d. above or below age norms for leanness were included in the study. Moreover, the early maturers in Experiment 2 were absolutely early, that is early relative to age norms, not merely earlier than their controls. In all previous examinations of the maturation rate hypothesis, both those supporting the relationship ($n = 5$) and those failing to support it ($n = 4$), groups were constituted in terms of earliness or lateness relative to age norms. In making the early-late comparison, four of the five successful studies used an extreme groups design (as did two of the four unsuccessful studies). In Experiment 3, on the other hand, the pairs used in the analysis shown in Table 3 had been constituted so as to evaluate the effect of maturational status on face encoding. Depending upon

their age, a prepubescent-pubescent pair could consist of two girls both maturing later or earlier than average or both maturing at an average age. So too for a postpubescent-pubescent pair. Thus, earliness and lateness were not defined by age norms nor was this analysis restricted to extreme groups.

It was possible to use the data from Experiment 3 in an analysis in which earliness and lateness were defined relative to published age norms for Tanner stages. Because the entire sample was relatively young, it was easier to identify early maturers than late maturers. Eighteen children were found who were more than 1.5 s.d. younger than the mean age for their stage on either breast or pubic hair development (early maturers). Thirteen were found who were at least 1 s.d. older than the mean age for their stage (late maturers).

The use of age norms for stage in classifying children as early or late is, in practice, not as straightforward as it might appear. Typically, as in our study, the children are given physical examinations only once. The stage at the time of this examination is known but it cannot be known how long the child has been at that stage nor when she will enter the next. Therefore, at some ages, it is not possible to find girls who are clearly late (e.g., a 10-year-old who is PH-1 and B-1, prepubescent, is either average or late, depending upon when she moves into the next stages.² And in our age range (since we had few children who were 14 and none older than 14; 8), there were few children who were more than 1.5 s.d. older than the norms for their stage. Therefore, we are less confident of our categorization of the 13 late maturers than of the 18 early maturers.

Since EFT improves with age in this age range (see Figure 1) and since the mean age of the early maturers was considerably less than that of the late maturers, the two groups could not be compared directly. Therefore, we attempted to pair each early and each late maturer with a girl of the same age and IQ who was average on both pubic hair and breast development. The difference between the early or late maturer and her average control could thus be used to evaluate the effect of maturation rate.

Pairs could be formed for 15 of the early maturers and 9 of the late maturers. This method of analysis is an extreme groups design; girls who are merely slightly early (less than 1.5 s.d. younger than age norms) or slightly late (less than 1.0 s.d. older than age norms) were omitted. The use of groups of average maturers to control for the effects of age and IQ does not bear on

²As Waber (personal communication) agrees, while it is possible to find among 10-year-old girls those who are 1 s.d. younger than age norms for stage, that is, genuinely early by her criterion, it is not possible to use this criterion to identify late developers. At this age, girls who are PH-1-B-1 include some individuals who will begin pubertal development within 1 s.d. of the mean, as well as some individuals who are genuinely late.

this; the two groups of average maturers are assumed to be equal with respect to effects of maturation rate. As a check on our assignment, we compared TW for the members of all pairs younger than age 14. The earlier maturers had a TW (55.2) that was significantly lower than the later maturers (58.0; $p < 0.04$, Wilcoxon signed ranks test, 1-tailed). Early maturers were disadvantaged on EFT compared to average (9 seconds per item); late maturers were advantaged on EFT compared to average (17 seconds per item). For the entire group ($n = 24$), earlier maturers perform significantly worse (12 seconds, $t_{\text{corr}} = 2.03$; $p < 0.05$, 1-tailed). The two groups do not differ at face encoding.

We conclude that there is a relation between maturation rate and performance on EFT. The effect is small, accounting for 20% of the variance in Experiment 2 and 16% of the variance in the analysis of data from Experiment 3 in which groups were defined relative to age norms. The relation appears to emerge more reliably in extreme groups designs. Five of the six analyses supporting the hypothesis (including Experiment 2 and the analysis of Experiment 3 based on age norms) used such a design, while three of the five studies failing to find such a relation (including the analysis of Experiment 3 given in Table 3) did not.

There are two possible reasons that the relation between maturation rate and EFT might be sensitive to use of extreme groups designs. One is merely statistical: if skill at the EFT is normally distributed with respect to maturation rate and if the effect accounts for only a relatively small proportion of the total variance, extremely large samples would be needed to pick up a difference if many of the subjects are from the middle of the distribution. Alternatively, maturation rate may not be continuously related to spatial abilities; the association may hold only for very early and very late maturers.

Conclusions

Support was found for both maturational hypotheses. The two skills—encoding unfamiliar faces and finding line drawings embedded in more complex figures—are each related to physical development at puberty, albeit in quite different ways.

The most noteworthy upshot of these studies is that pubertal status is implicated in the timing of the decline in face encoding skills that occurs around age 12, at least for girls. Boys mature later than girls, especially in regard to the timing of the adolescent growth spurt. If maturational status determines the timing of the dip in boys as well as girls, it would be reasonable to expect the dip to occur later in boys. However, none of the

studies that have traced face encoding skills through the early adolescent years has found an age by sex interaction, including Experiment 1 in the present study. The dip is maximal at age 12 for boys as well as for girls.

Pubertal development is marked by three major physical changes: pubic hair growth, breast and genital development, the growth spurt (plus onset of menstruation for girls). The major changes occur during a much more compressed time span for girls than for boys. Moreover, the relative timing of events differs for the two sexes; the growth spurt occurs relatively late in boys, especially as contrasted with genital development (G). While the sexes differ by 1.9 years in the age of peak height velocity, and 1.4 years in the age at which PH-3 is reached, there is only a 0.7 year difference in the age at which girls reach B-3 (12.15) and boys reach G-3 (12.85). In both sexes these latter pubertal milestones are attained at age 12 (Marshall and Tanner, 1969; 1970). Therefore, the lack of an age $\times$ sex interaction, especially in small samples, is not as damaging to the maturational status hypothesis as it might seem. We are currently extending our study to boys. If the data confirm the hypothesis, they may also permit us to identify one aspect of physical growth as most implicated in the timing of the decline in face encoding skills.

The association of maturation status at time of testing and relatively poor performance on face encoding rules out some explanations for the developmental course exemplified in Figure 1. The dip at age 12 is not due to the change from elementary to junior high school since our pairs consisted almost entirely of girls in the same school grade. Nor does the dip reflect a reorganization of knowledge about faces that occurs merely as a function of age. While ruling out whole classes of explanations for the dip, the relation of pubertal status to the decline remains consistent with either of two quite different types of underlying mechanisms. One possibility is that hormonal events that are part of the physical changes of early adolescence (see Peterson, 1979) directly affect the neural substrate for face encoding in a way that produces less efficient functioning. Another possibility is that physical changes at puberty influence face encoding indirectly. Suppose that, as children grow up, they begin to attend to different aspects of faces, concomitant with changing interests in people. This could result in a period in which encoding is less efficient, until the use of the new features is worked out. If the child's awareness of her own pubertal development were the impetus for the change in interest, we would have an understanding both of the decline in face encoding and its timing by pubertal status which would not imply any direct hormonal or other physical influence on the neural substrate for face encoding.

How might we discover the mechanism accounting for the relation between pubertal status and the decline in face encoding? Levine (1981)

showed that the normal left visual field (l.v.f.) advantage for the encoding of unfamiliar faces that is present both in adults and in 10-year-olds is lost at ages 12 and 14. We are currently determining whether, during adolescence, the magnitude of this l.v.f. advantage changes with maturational status. Such an association would be expected if hormonal events at puberty directly affect the functioning of the posterior portion of the right hemisphere or the balance between right and left hemisphere involvement in some tasks. Unfortunately, an association of maturational status and a reduced l.v.f. advantage for faces is also consistent with a mechanism by which physical changes at puberty affect face encoding indirectly. A change in the kind of information extracted from faces (for any reason) could alter the degree of lateral asymmetry (cf., Bertelson *et al.*, 1979).

In our view, discovering the mechanism by which the decline in face encoding skills is timed by pubertal development must await an information processing analysis of the decline. Klatsky *et al.* (1980) showed that adults encode new faces with reference to social stereotypes (e.g., athlete, model, accountant). It seems likely that 10-year-olds have not yet organized their knowledge of faces in terms of such stereotypes. This possibility could (and should) be tested, using Klatsky *et al.*'s methods. Evidence that the decline at age 12 reflects a reorganization of the encoding process in terms of social stereotypes, would be consistent with an indirect mechanism underlying the timing of the decline. For example, awareness of body changes at puberty may focus the child's interest on other people's appearance, or the child's own changing social role may focus her interest on adult social roles.

If the relation between puberty and the decline in face processing takes the indirect path sketched above, encoding of non-face stimuli should be unaffected. However, if there is a direct effect of pubertal change on the functioning of the neural substrate for face encoding, it would be plausible to expect some other tasks to suffer as well. Perhaps the encoding of all subtle spatial configurations is less efficient at this time, or perhaps recognition memory for all meaningful material is impaired during these years. It is much more difficult to imagine an indirect relation between puberty and the decline in face encoding that would implicate such general pattern encoding skills.

To summarize. Experiments 2 and 3 show that pubertal development at least partly controls the timing of the adolescent decline in face encoding skills. While such a relation rules out some explanations for the dip, explanations very different from each other remain compatible with the data now available. An important step in understanding this relation is finding an information processing account of what about face encoding is changing in these years.

The relation between maturation rate and EFT has also not been explained. Waber (1977) proposed that increasing differentiation of left- and right-hemisphere functioning may end at puberty so that later maturers are more lateralized than early maturers. Assuming also that greater lateralization of function yields better performance on tasks such as EFT and Block Design, the association between maturation rate and performance on these tasks would be explained. According to this hypothesis, late maturers should show greater asymmetries in dichotic listening tasks, dichaptic tasks, and visual field asymmetry tasks. Waber (1977) did find that indeed late maturers were more lateralized on a dichotic listening task, but only for the older groups in the sample. Attempts at replicating this relation between maturation rate and degree of hemispheric specialization have failed, even in studies where the relation between maturation rate and spatial skill was supported (Herbst and Peterson, 1980a; Newcombe and Bandura, 1981). Furthermore, the assumption that there is increasing lateralization of function with age has no firm support (see Springer and Deutsch, 1981, for a review).

Explaining the relation between maturation rate and EFT must await the resolution of one crucial outstanding issue—when does the effect first become established? Are events during adolescence itself even implicated? It is perfectly possible that 8-year-olds or 6-year-olds who will be late to mature already perform better on EFT and Block Design than children of the same sex who will be early to mature. While sex differences on the class of spatial tasks related to maturation rate often do not emerge reliably until adolescence (Harris, 1980; Maccoby and Jacklin, 1974), the advantage of boys on EFT is present as early as age 10 (Witkin *et al.*, 1967). An information processing account of how early and late maturers perform the EFT would also help in our search for an explanation of the relation between maturation rate and solution speed. We do not know what early maturers do that makes them take up to 30 seconds more per item to find the embedded line drawing.

In conclusion, both maturational hypotheses were supported, providing evidence for a genetic³ component to the developmental course of both face encoding and the EFT. While such results are just a first step, and raise more questions than they answer, there is a moral to the story. The relation between physical and mental growth can be a source of constraint on models of cognitive development.

³In an upper middle-class sample such as this one, where the children were all healthy and well-nourished, it is a safe assumption that the timing of pubertal development is largely under genetic control. This is not to deny that some of the variance in timing of puberty is due to environmental factors.

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Résumé

L'évolution de la capacité à encoder des visages est interrompue au début de la puberté. Ce bouleversement est sous contrôle génétique. Indépendamment de leur âge, les filles en cours de changement pubertaire encodent moins efficacement que leur contrôle pré ou post pubertaire. L'influence de la maturation sur l'encodage du visage est opposé à l'effet du développement pubertaire sur une autre tâche visuo-spatiale, le test des figures enchassées (EFT). Dans ce test, indépendamment de leur statut pubertaire, les filles précocement mûres ont des performances inférieures à celles des filles ayant mûri plus tardivement. Ces résultats confirment des résultats antérieurs montrant la relation entre certaines différences individuelles au moment de la puberté et certaines performances dans des tâches spatiales. Diverses interprétations sont proposées pour chacun de ces effets—celui de l'étape dans la maturation pour l'encodage des visages et de l'âge auquel celle-ci a été déclenchée sur le test EFT. La relation entre la croissance physique et mentale est invoquée comme source de contraintes sur les interprétations du développement cognitif.