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When does the Inner-face Advantage in Familiar Face Recognition Arise and Why?

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Known faces are recognized better from their inner than outer parts (Ellis, Shepherd, & Davies, 1979). This has previously been demonstrated with cropped images. Using a blurring technique to defocus different parts of the face image systematically, we confirmed the effect for adults viewing famous faces (Experiment 1). Children aged 5–13 years showed an *outer*-face advantage (Experiments 2 and 3). The inner-face advantage was found only at 15 years (Experiment 3). Experiment 4 showed an outer-face advantage in familiar face recognition when

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the viewers were adolescents with a mental age of under 10 years. The emergence of the inner-face advantage is a developmental rather than a maturational phenomenon. We discuss the implications of the failure to show a qualitatively adult-like pattern of face recognition before adolescence in relation to theories and models of face recognition.

INTRODUCTION

In recognizing known, familiar faces, a robust finding is that the inner-face parts are more useful than those of the outer face (Ellis, Shepherd, & Davies, 1979). Inner-face parts comprise eyes, nose and mouth; outer-face parts include the hair, hairline, jaw and ears. *Only* familiar faces seem to be so favoured: No studies have reported that unfamiliar face images, presented in old-new recognition tests, show an inner-face advantage. The inner-face advantage, then, is associated with the "memorial representation of the known individual". In keeping with this, it does not seem to be primarily image-based, for it disappears under simple picture matching conditions, but returns when the match is made across different views (Young et al., 1986). In turn, this suggests that the inner face delivers more reliable information about individual face structure than the contour of the head or the outer features. Since familiar faces have usually been seen and learned under a variety of viewing conditions, it might be thought that it is the ability to recognize a face across a number of different views that is critical to the inner-face advantage. However right-lesioned patients who have difficulty in matching objects across different views (Warrington & James, 1986), as well as left-lesioned patients, show the effect (De Haan & Hay, 1986). It is unlikely that it is just the matching of the three-dimensional face structure that subserves the inner-face advantage for familiar faces.

In previous studies (Campbell & Tuck, 1995; Campbell, Walker, & Baron-Cohen, 1995), no inner-face advantage for known faces was found by the middle childhood years. When children aged 5–8 years were presented with pictures of their schoolmates for identification, they tended to be better at recognizing them from the outer rather than the inner parts. The inner-face advantage appeared only in the oldest group aged 10–11 years. When tested with photographs of familiar faces from other sources (television characters and presenters, pop-stars), a similar pattern was evident. Only the oldest children showed a clear inner-face advantage. Children younger than 9 years tended, once more, to be better at identifying faces from their outer parts or showed no preference for one part of the face than the other. Before considering possible theoretical reasons for this developmental tendency, it is important to establish the reliability and validity of the effect. There are a number of reasons, other than those concerned with developing face-processing abilities, that might lead to this pattern.

Cropping and Blurring

All studies to date have presented face parts cropped from photographs. The inner face was seen as a trapezoid with the eyebrows comprising one horizontal line, parallel to another, shorter one just below the mouth. Face pictures cropped to show just the inner features may be interpreted by younger children as whole heads; that is, the child may misread the cropped image as an unusually shaped head in which the eyes, nose and mouth fill the face area completely. If this is so, it would not be surprising if they failed to recognize faces from the inner features. The present study attempts to control this by selectively blurring (defocusing) the inner or outer parts of the face image. By this means, a face image can be presented in which the inner features are less likely to be misparsed, since they will appear in the appropriate visual context. Blurring allows the contour of the head to be seen with no useful identifying information (see Figure 1).

The experiments reported here explore the identification of known faces using a blurring technique to selectively lose inner- or outer-face part information. Experiment 1 tests this method with adults, Experiments 2 and 3 with schoolchildren aged 5–15 years, and Experiment 4 uses the same technique to test familiar face recognition in a group of young people with learning disabilities. The questions of interest are: Does selective blurring lead to a similar pattern (inner-face advantage in adults) as cropping the face image? Can the age at which this effect emerges be determined? If there appears to be a switch from an outer- to an inner-face advantage at a specific stage, is this stage dependent on chronological or on mental age?

EXPERIMENT 1

This study examined the recognition of famous faces by young adults, when the inner and outer parts of the face were selectively blurred. It was predicted that, in line with earlier findings using cut faces (Ellis et al., 1979), faces in which the inner parts were clear and the outer parts were blurred would be better recognized than those in which the inner parts were blurred and the outer parts were clear.

Method

Subjects. Forty undergraduates at Goldsmith's College London participated in the experiment as part of a course requirement. We used a repeated-measures design, in which all participants were presented with inner-face and outer-face clear images, and in which the dependent variable was accuracy of recognition.

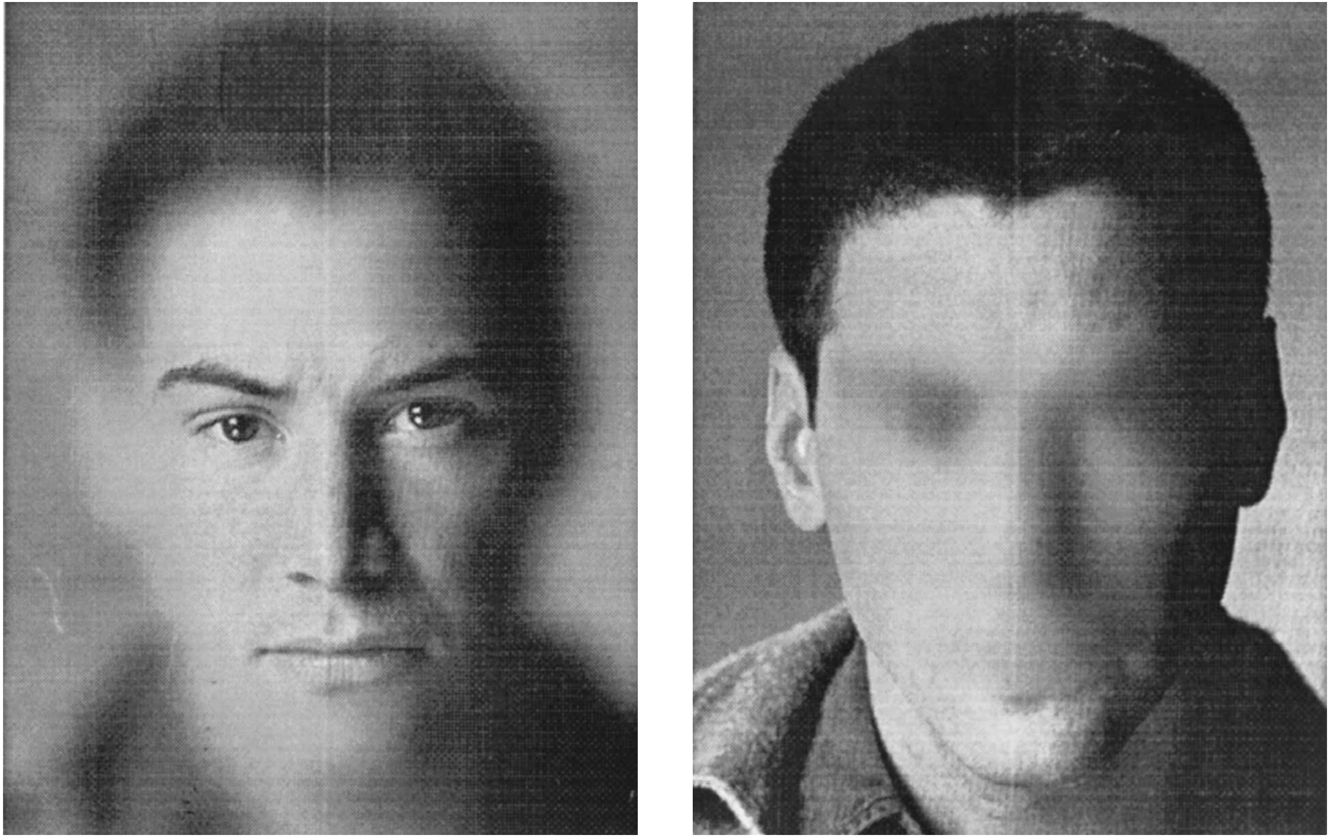

FIG. 1. Keanu Reeves: Outer parts blurred (left) and inner parts blurred (right).

Materials. Full-face photographs of 20 celebrities, which pilot testing had established were identified from the whole face with 70–90% accuracy in this age group, were collected from various printed sources and scanned onto computer (AppleMac). Adobe© Photoshop software was used to normalize the images for shape and size, to crop to head and shoulders only and to convert to 250-bit grey scale. The "blur" option was set to Gaussian blur, at 20 pixels per radian. This level of blur was applied to all the faces, which were pilot-tested on three volunteers, who were unable to identify any of the faces subjected to this level of degradation. Two variants of each of the original face images were then made: In one, the inner features were blurred and the outer parts of the image were clear, and in the other the inner features were clear and the rest of the picture was blurred.

Printed copies of the original (all clear), the inner (clear) and the outer (clear) versions were obtained for each celebrity shot. Each image was approximately 13 × 11 cm. Each image was mounted and laminated for presentation. Two part-face sets, A and B, were then composed from these prints: In each one, 10 outer (clear) and 10 inner (clear) prints were selected. Inner faces in Set A were outer faces in Set B and vice versa.

Procedure. The task was part-face recognition. Subjects were assigned at random to Set A or to Set B, and were asked to name or otherwise identify each part face presented. Within each set, the order of presentation of each face was randomized, with inner and outer faces mixed together. The task lasted about 10 min. Thus each subject was presented with 10 inner faces and 10 outer faces to recognize. Subjects were tested individually, with the pictures arrayed one at a time in front of them on a table.

Correct responses were either the name of the celebrity or, for actors, the name of the character (i.e. Tom Hanks or Forrest Gump were counted correct). Semantic classifications ("film actor", "TV presenter") were counted incorrect unless accompanied by detailed identification details ("the star of 'BIG' ... won an Oscar in 1996").

Results

From inner features a mean (± SD) of 73.5 ± 10.3% faces were recognized. From outer features, only 59.3 ± 10.7% were recognised. We performed *t*-tests on the individual subject scores and showed this difference to be significant, $t_{39} = 5.67$, $p < .001$. Moreover, the strong effect generalized to stimuli. When the data were recast so that number of correct responses across subjects for inner- and outer-blur images respectively were scored for each face (stimuli as subjects analysis) and the data subjected to a matched-pairs *t*-test (i.e. inner *vs* outer parts of each face), the results were again significant, $t_{19} = 6.83$, $p < .001$.

Discussion

The reliability of the inner-face advantage in recognition effect has been demonstrated again in adults, using a novel technique of blurring inner- and outer-face parts selectively. The effect held statistically both for subjects and for items. The inner-face advantage in recognizing familiar faces appears to be robust and valid across different modes of deformation of the visual stimulus.

EXPERIMENT 2

Pictures of celebrities are recognized better by adults when their inner-face parts are clear and the outer parts are blurred. If children misinterpret cropped (inner-)faces as whole ones and fail to recognize them because of this, we would expect that blurring rather than removing the outer parts should lead to children showing the adult pattern of inner-face superiority. However, if our earlier findings with children reflected a real difference in the salience of representations of inner- and outer-face parts in children and in adults, then using the blurred face procedure may generate different patterns in children than in adults—and the younger the child, the more likely the child will recognize a face by its outer parts.

In earlier studies, we showed that young children, like adults, are better at recognizing whole faces than faces from their parts. However, the whole-face advantage was independent of age, unlike the shift from outer- to inner-face superiority. Our experimental hypothesis was therefore, that although whole faces may be recognized better than either inner or outer parts that have been selectively blurred, an inner-part advantage will only be seen in children aged 11 years or over.

Methods

The design of Experiment 2 differed from that of the adult experiment. In this experiment, whole, inner- and outer-face parts were each presented to every child, as in our earlier studies with children (Campbell et al., 1995; Campbell & Tuck, 1995), to establish the gradient of recognition for whole and part faces.

Subjects. All 136 schoolchildren in a single primary (grades ten through six) school in southeast England, who had volunteered to take part in the study and for whom written consent was obtained, were tested. The age and sex of each child was noted and these are summarized in Table 1.

Materials. Pilot testing of 15 children aged 5–9 years was required to establish celebrity familiarity. The names of 40 celebrities were given to these children, who were asked: “Do you think you would recognize a picture of this person if you saw it? What would he or she look like? The 30 celebrities who generated the most detailed positive answers were used in the experiment proper. These included members of "boy-bands", some members of the Royal Family, one politician, a number of television presenters, including children's television celebrities, and some film stars.

Full-face photographs of the 30 celebrities were collected from various printed sources and scanned onto computer (AppleMac). We followed the procedure outlined in Experiment 1; that is, the face images were first normalized for size and orientation, and then cropped to head and shoulders only. Blur was then applied selectively to the inner and outer parts. Three images were obtained from each source image: whole-face clear (W), inner parts clear/outer parts blurred (I) and outer parts clear/inner parts blurred (O). Each image was about 13 × 11 cm in size; hard copies were printed and laminated.

Three booklets were then assembled. Each booklet comprised 10 images of each type (W, I and O). Each celebrity face appeared once in each booklet, as a whole face, a clear inner face (I) or a clear outer face (O). Across all three booklets, each celebrity face appeared three times in—W, I or O form—once in each booklet. Thus each child saw 30 different face images, in which each celebrity was represented once and in which 10 different faces were seen as W, I and O images, respectively. Within each booklet, these image types were blocked.

Procedure. The children were taken out of class and tested individually in a quiet part of the school. The test lasted up to 15 min. Children were assigned at random to testing with one of the three face-sets (booklets), according to a predetermined order so that equal numbers of children and of boys and girls viewed each of the booklets. The W-stimuli were tested first, since pilot testing had established that this increased the child's confidence in responding. As each image was presented, the child was asked: "Do you know who this is a picture of?" The I- and O-stimuli were then presented in blocks and in a balanced order across children (half saw the I-stimuli, half saw the O-stimuli first). Each child was told: "Now I'm going to show you some pictures of people that have been made blurry. Can you tell me who they are?" Correct answers (name of character, name of actor, or detailed description of the role of the person) were recorded for each condition, for each face, for each child.

Results

Subject Analysis. One subject who did not watch television, and who therefore was unfamiliar with most of the faces, was dropped from the analysis. A multivariate analysis of variance procedure was used to examine the effects of age and part of face on recognition accuracy. The design was a mixed one, with sex[1] and age of the child as the between-subject factors and part of face (whole, inner and outer accuracy scores) as the within-subject factor. In this analysis, the children were divided into three age groups. This grouping was arbitrary, but allowed for roughly equal group sizes of similar statistical profile (i.e. range and standard deviation; see Table 1).

We found main effects of age, $F_{2,129} = 49.4$, $p < .001$, and of part of face, $F_{2,229} = 27.03$, $p < .001$. Planned comparisons confirmed that each of the age comparisons (oldest > middle > youngest) was significant at $p < .01$. Each of the part-of-face comparisons was also significant (wholes > outer > inner features) on planned comparison ($p < .01$). There was no main effect of sex of child and no significant interaction, at any level, between any of the variables entered into the analysis. The theoretically important age × part of face interaction did not approach significance, $F_{4,258} = 1.33$, $p > .3$]. The salient findings are summarized in Table 1.

Further Analyses. The three age groups in the above analysis were motivated by trying to equate group size and numbers of girls and boys. The general analysis showed no age-related changes in relative sensitivity to inner- and outer-face parts. But could dividing the children into discrete age groups obscure some effects of age? A relative measure of sensitivity to inner or outer parts of the face is given by the formula (I – O)/(O + I), where O = performance on outer-face parts and I = performance on inner-face parts. If there is an age-related progression in reliance on inner-face parts, this measure may correlate with age. However, this was not significant (Pearson's correlation =

TABLE 1
Experiment 2: Subject Characteristics and Correct Number of Identifications out of 10 for each Presentation Condition (Mean ± Standard Deviation)

Age Group (years: months)	*Mean Age (years)*	*Age Range (years)*	*Sex*	*Condition* *Whole*	*Outer Clear*	*Inner Clear*
5:00–6:11	5.10 ± 0.33	5.0–6.9	22 boys	4.00 ± 1.5	3.25 ± 1.54	2.79 ± 1.89
			24 girls	3.32 ± 1.61	2.77 ± 1.27	2.77 ± 1.77
7:00–8:11	7.87 ± 0.37	7.0–8.6	21 boys	4.95 ± 1.6	4.22 ± 1.68	4.19 ± 2.06
			23 girls	5.17 ± 1.59	4.62 ± 1.86	4.00 ± 2.22
9:00–11:5	10.47 ± 0.43	9.5–11.5	17 boys	7.00 ± 2.18	5.88 ± 1.62	4.82 ± 2.24
			28 girls	7.21 ± 1.77	6.29 ± 1.82	6.04 ± 2.01

[1] Sex was a factor in this analysis, because sex differences in face recognition are common, and these are sometimes reported to interact with age (e.g. Turkewitz & Ross-Kossak, 1984). On the basis of previous findings, however, we had no predictions concerning sex effects in face recognition.

0.053. When $n = 135$).[2] In contrast, taking all children together, the correlation of age with whole-face recognition was significant (Pearson's correlation = 0.68, $p < .001$, as was the correlation of age with I (0.62, $p < .001$) and the correlation of age with O (0.504, $p < .001$).

Stimulus Analysis. Since each face was seen once in each of its three forms (W, I and O) by every child, and the numbers were balanced across the different age-sets and sexes, stimulus analysis was also feasible. Two stimuli that generated less than 3% recognition over all age groups and conditions were dropped from this analysis (Duke of Edinburgh and Sarah, Duchess of York), leaving 28 stimuli in all. For each of these stimuli, correct recognition scores were obtained by summing the correct responses for each of the conditions (W, I and O) for each of the three ages tested (see Table 1). The procedure we adopted was a mixed-design multivariate analysis of variance. The within-subjects (i.e. within-stimuli) factors were age-set and part of face, each with three levels (young, middle and old; whole, outer and inner, respectively). The age effect was confirmed, $F_{2,52} = 24.3, p < .001$, as was the part-of-face effect, $F_{2,52} = 3.09, p = .053$. On planned comparisons, only the whole-to-part comparison was significant, $p < .01$, with no advantage for outer over inner features.

Discussion

The whole-to-part advantage generalizes both to stimuli and subjects, as does the main effect of age on recognition. However, unlike our previous studies, there was no sign that, by the age of 11 years or so, children were using the inner-face parts preferentially in recognition. Indeed, an outer-face advantage was still reliably found in these children.

This outer-face superiority seemed to be relatively unaffected by age over the range we examined. The outer-face advantage, although reliable for subjects, did not generalize reliably to all the images used. Campbell and Tuck (1995) point out that there is a good deal of idiosyncracy in the relative salience of inner- and outer-face parts when a relatively small set—such as the set of faces famous to all children—is considered. The television presenter, Chris Evans, for instance, was identified more easily when his trademark spectacles were on view. This should not obscure the general picture, which is that when a face is identified better from its inner than outer parts by adults, children generally show the opposite pattern. Several of the faces in this set were also presented to adults in Experiment 1 (these included the Queen, Tom Cruise,

[2]It could be argued that the switch to the I-advantage may occur relatively late in childhood; thus a failure to obtain correlation over the whole age range is not surprising. However, when the correlational analysis was restricted to children over 9 years, it remained non-significant (Pearson correlation = – 0.041, $n = 45$).

Tom Hanks and Bianca from *East Enders*). All elicited an outer-face superiority from children and an inner-face superiority from adults.

Thus, using blur to defocus the different parts of the famous face image selectively produces a different pattern than cropping the face (Campbell et al, 1995; Campbell & Tuck, 1995). Our original hypothesis was that blurring of the outer parts might enhance inner-face processing, since the child would be less likely to parse the cut face as a whole one. If anything, however, blurring makes it harder for the child to identify the individual when shown the face in this way—and the childhood pattern shows no sign of change by the age of 11 years.

EXPERIMENT 3

Because Experiment 1 showed a strong inner-face advantage for adults when faces were shown with inner and outer parts blurred, Experiment 3 was conducted to determine at what age the inner-face advantage emerges for blurred face images.

In this experiment, we showed the faces in Experiment 2 to adolescents aged 12–15 years to establish when the inner-face advantage may emerge for famous faces. Experiment 2 found that recognition of this face-set increased with age. It would therefore be inappropriate to test these faces immediately with older children, for their levels of accuracy would be higher—possibly at ceiling—and inferences would be hard to draw. Experiment 3 was performed 1 year after the Experiment 2 to reduce the familiarity of some of the faces and to bring performance of the older children to a comparable level to that of the younger children tested in Experiment 2.

Methods

Subjects. Forty-nine students at five different schools in London volunteered for the experiment. Their characteristics are shown in Table 2.[3]

Materials and Procedure. The materials and procedure were identical to those outlined in Experiment 2. The subjects were tested individually within their own school.

Results

Table 2 shows the numbers of subjects in each of the age groups tested, and their sex, with the mean number of correct answers to the face pictures for each condition. Delaying test by 1 year to reduce the familiarity of these faces

[3]These youngsters volunteered their age in years and not their date of birth.

TABLE 2
Experiment 3: Correct Number of Identifications out of 10
(Mean ± Standard Deviation)

Age Group (years: months)	*Sex*	*Condition*		
		Whole	*Outer Clear*	*Inner Clear*
12:00–13:11	14 boys	7.36 ± 1.69	5.71 ± 1.37	5.89 ± 2.83
	12 girls	8.79 ± 1.20	6.46 ± 1.58	7.42 ± 2.23
14:00–15:11	15 boys	8.07 ± 1.52	6.20 ± 1.41	6.97 ± 1.91
	9 girls	8.87 ± 1.35	6.75 ± 1.16	8.13 ± 2.17

appears to have been quite successful: None of these scores were at ceiling, as might be expected if these older children had been tested with highly familiar faces. Means for each subject group for each of the three face-part conditions were subjected to a multivariate analysis of variance, in which the between-subject factors were age group and sex and the within-subject factor was face part (whole, outer or inner). This resulted in significant main effects of sex, $F_{1,45} = 7.20$, $p = .01$, and of face part, $F_{2,90} = 21.00$, $p < .001$. Girls were more accurate than boys. There were no further significant main effects or interactions. Planned comparisons on the part-of-face factor showed that only the comparisons between whole- and inner-face parts, and between whole- and outer-face parts, were significant ($p < .05$ in each case), but that there was no significant difference between inner and outer parts.

Because the multivariate analysis of variance showed no significant interaction of part of face with age, the power and significance of specific pairwise tests is contentious. For this reason, non-parametric tests were used to probe the contrasts of interest. Wilcoxon signed-rank pair tests were used to explore whether the inner–outer difference was significant in either age group. While it was not significant in the younger group, in the older group it was, $Z = -2.1202$, two-tailed $p = .034$. We can therefore infer that the inner-face superiority typical of adults emerges at about 14–15 years for this set of images.

Stimulus Analysis. The data were recast so that the number of correct responses, for each condition (W, I and O), for each age group was obtained.[4] With stimuli as subjects, a multivariate analysis of variance confirmed a significant effect of part of face, $F_{2,56} = 7.3$, $p < .01$. This was the only significant effect in the analysis. Planned comparisons confirmed the whole–part superiority was significant $p = .05$, but no further contrasts were significant.

[4]Further analysis of stimuli-as-subjects by sex was not possible; the unequal numbers of girls and boys meant that stimuli were not fully balanced across the sexes.

Discussion

This experiment simply presented the material of Experiment 2 to older children and found a different pattern of results than that for the younger children. Although in both Experiments 2 and 3 whole faces were recognized significantly better than either inner or outer parts, among the 12- to 15-year-olds the advantage of outer-face over inner-face parts was no longer significant. Furthermore, only in the older group (above 14 years) was the inner face recognized better than the outer face, suggesting that the inner-face superiority emerged at 14–15 years of age. In this sample, girls were better than boys at recognizing these faces. We shall not comment on the sex differences further, as they could have been specific to this set of faces, which included a number of "boy-band" members and male actors whose faces may have been more salient to teenage girls, as well as to younger children.

More generally, adult-like patterns of performance on face-processing tasks are not usually reported so late in development. One influential account (Carey, 1992) suggests that face-identification procedures are essentially adult-like in terms of their cognitive components by the end of childhood (i.e. age 11 years). If the inner-face advantage for recognizing faces is an index of expertise in facial processing, it would appear that expertise may take longer to achieve than earlier findings suggest. We will explore reasons for this late-acquired pattern in the General Discussion. Experiment 4 explores (a) whether personally familiar faces are subject to similar effects and (b) whether sensitivity to part of face is determined by age alone, or by other developmental factors.

EXPERIMENT 4

We have established that identifying a famous face from its inner parts may not be achieved in an adult fashion until about age 15 years, much later than predicted by previous studies. To what extent might this be a maturational phenomenon, one that is independent of the developmental cognitive milestones achieved by the child? Simple exposure to a variety of faces—both familiar and unfamiliar—increases with age and this may be sufficient to tune the face-processing mechanisms to first an outer-face and then to an inner-face superiority in processing. One way to answer this question is to investigate adolescents or adults whose measured mental age may be below that of their chronological age. If amount of exposure to faces and other visual stimuli predicts the pattern, then chronological age should be a better predictor than mental age. However, if specific developmental processes are implicated, mental age may be a better predictor of the pattern of face-part recognition than chronological age.

This experiment investigated face recognition in youngsters with learning disabilities. If their chronological age is the key factor, then those aged 14 years or older may show an inner-face superiority in recognition; if mental age is the better predictor, these youngsters should show an outer-face advantage.

In this experiment, we also used pictures of people familiar to the subjects, rather than famous faces. Pilot testing had established that the range of famous faces known to these youngsters was idiosyncratic. However, because of the way that these subjects were selected (see below), a number of individuals were well known personally to all of them, as well as to a control group of youngsters. Earlier studies had established that, for cropped faces, the outer-face advantage in childhood was not sensitive to whether the face was famous or personally familiar (Campbell et al., 1995, Campbell & Tuck, 1995).

As a control, we also tested adult volunteers who were initially unfamiliar with the face-set used, by exposing them to different pictures of the individuals in the stimulus set and then testing recognition (forced-choice) with inner- or outer-blurred images. This was done to establish that an inner-face advantage can be demonstrated in adults for learned familiar as well as famous faces, and also that this particular set of faces elicited the normal pattern in adults.

Methods

Children with Learning Disabilities. Children who attended a Saturday activity school[5] for adolescents with both learning and physical disabilities were recruited. All had been assessed as having special educational needs by educational psychologists, and they attended a number of different special needs schools and units within mainstream schools.[6] This allowed us to select volunteer subjects and to obtain photographs of family members, helpers and volunteers who they knew well. All subjects and the people whose faces they saw had been a part of the scheme for at least 6 months, and usually several years.

In the pilot study, snapshots of helpers and family members were shown to potential subjects, together with pictures of unknown individuals, for simple forced-choice recognition. Those aged 11 years and over, and whose recognition accuracy was 70% or above, were selected for study ($n = 9$).

The educational classification of the selected individuals was based on their educational records. All had been classified as moderately learning-disabled. Two standardized tests of cognitive ability were administered at the time of testing: the Coloured Progressive Matrices (CPM) test and the British Picture Vocabulary Test (BPVS). The characteristics of the children are summarized

[5]For ethical reasons, the anonymity of the activity school and its location are maintained.

[6]The Saturday school was a voluntary scheme, run by family members and friends, as well as additional helpers who were companions to the students. Written agreement for participation in the study was sought directly from the students and from their responsible carers.

in Table 3. The mental age of the selected learning-disabled children was 5–8 years.

Control Subjects. Six child controls were selected from among families of carers and friends of the experimental subjects. They had a mean chronological age of 6:6 years, with a range of 5:8–7:9 years. They were selected to match the experimental group for (non-verbal) mental age. Eight adult controls also volunteered who did not know the faces to be recognized, but were familiarized with them from snapshots presented for 10 min a day for 4 days (see below for details).

Stimulus Selection. As mentioned above, a pilot test was used to select the subjects for the study; it was also used to select appropriate faces. These were snapshots of faces familiar to the experimental group intermixed with unfamiliar ones, presented for forced-choice recognition to all potential subjects. Only those faces recognized by more than 80% of experimental subjects were used in the study. Eighteen people were selected as suitable familiar faces from those who were reliably recognized. They were re-photographed in head-and-shoulders pose, full face. These photographs were treated in the manner outlined for Experiment 1 to obtain blurred inner- and outer-face parts.

Procedure. The procedure was similar to that of Experiment 2 in that subjects were asked to identify each face. starting with the whole-face image, and any specific identifying information was allowed as a correct response. However, because of the relatively small number of faces used, the subjects saw *all* versions of every face, and the experiment was run in two sessions, 1 week apart. Testing started with 18 exposures to the whole face. One week later, all part-face stimuli were shown in a pre-arranged order, which varied between subjects.

TABLE 3
Experiment 4: Characteristics of the Subjects (Mean ± Standard Deviation)

	Controls (*n* = 6)	*Moderate Learning Disability* (*n* = 9)
Chronological age (years:months)	6:6 ± 1:6	13:4 ± 2:1
Mental age		
CPM	—	6:3 ± 2:1
BPVS	—	4:7 ± 2:1

Note: CPM = Coloured Progressive Matrices test, BPVS = British Picture Vocabulary Test.

Adult Controls, Familiarization and Test. Eight adult volunteers aged 20–34 years were tested to determine if the inner-face advantage holds not only for blurred famous faces, but also for the particular set of faces used in this experiment. If an outer-face superiority effect emerged for the experimental group, it could be that the 18 faces seen were easier to identify from their outer parts.

The adult subjects were familiarized with 9 of the 18 faces by inspecting them for 10 min a day for 4 days. Whole-face snapshots of the target faces were used for familiarization. Half the adult subjects learned 9 of the 18 stimulus faces, and the other half learned the remainder. These were shown with the instruction: "Please learn the identities of these people. Later you will see new images of them and be asked to recognize them". On the fourth day, subjects were tested individually with the experimental material (posed head-and-shoulder shots). They were shown inner- and outer-face part images for all 18 (i.e. 9 old and 9 new) of the experimental faces. These were shown in a counterbalanced fashion, so that for half the subjects five of the (old) faces showed the inner-part of the face and four the outer part; the remaining subjects saw the reverse. Mean correct recognitions were scored as a function of part of face.

Results

Control Experiment: Adults. All nine adults showed the inner-face advantage for familiarized faces, which, even in this small sample, was significant on test: related $t = 4.62$, $p = .002$). This confirms that adults viewing these experimentally learned faces showed the normal inner-face superiority effect in recognition. An items analysis confirmed this; when stimuli-as-subjects were analysed, the related $t = 3.85$, $p < .01$.

Children and Adolescents. A multivariate analysis of variance, with group (control *vs* moderate learning disability) as the between-subjects factor and part of face as the within-subject factor, showed a significant effect of part of face, $F_{2,26} = 243.1$, $p < .001$, which failed to interact with group. Planned comparisons on the within-subjects factor showed each condition to differ significantly from the other: whole > outer-clear, $p < .01$; outer-clear > inner-clear, $p < .05$. There was also an effect of group, $F_{1,13} = 481.9$. The learning-disabled youngsters were poorer at the task.

Further analyses. If maturation predicted the switch from an outer- to an inner-face advantage, we would expect, on the basis of Experiment 3, to see evidence for this in the oldest participants. Seven of the learning-disabled group had a chronological age above 14 years. In Experiment 3, students of this age showed no advantage for outer- over inner-face parts. The mean (± SD) outer- and inner-face scores for this subset of learning-disabled subjects were 9.14 ±

TABLE 4
Experiment 4: Correct Number of Identifications out of 18 by the Learning-disabled and Control Subjects (Mean ± Standard Deviation)

	Condition		
	Whole	*Outer Clear*	*Inner Clear*
Controls (n = 6)	17.17 ± 2.14	9.17 ± 1.47	8.00 ± 1.26
Moderate learning disability (n = 9)	16.00 ± 3.20	9.56 ± 1.88	7.22 ± 1.72

1.46 and 7.57 ± 1.62, respectively. A Wilcoxon signed-rank test showed this difference to be significant despite the small number of subjects, $Z = -2.0226$, two-tailed $p = .04$. All of the oldest learning-disabled youngsters showed an advantage for the outer-face parts. In contrast, in Experiment 3, only 4 of 15 boys and one of 9 girls achieved more correct outer- than inner-face part recognition.

Did the psychometric variables correlate with performance on the face tasks? No correlations between the CPM, the BPVS, chronological age and the face test scores were significant for the learning-disabled group. However, the different face-test scores themselves were highly intercorrelated.

Discussion

Experiment 4 used personally familiar rather than famous faces and found similar results to those reported for children in Experiments 2 and 3 using famous faces (above). A marked outer-face recognition advantage occurred in the context of a large whole–part face advantage. In adults, the expected pattern of an inner-face advantage (Experiment 1) was confirmed and extended to experimentally familiarized faces and to a learn-and-recognize procedure. The outer-face superiority effect in the experimental group was not due to sampling error in the faces seen.

In the oldest of the learning-disabled group, there was no evidence of a switch from outer- to inner-face sensitivity, unlike the older adolescents in Experiment 3. Although the numbers were small and the age of the volunteers was not optimal (not all of the experimental subjects were over 14 years), our results are nevertheless suggestive of the importance of a developmental rather than a maturational factor in the pattern of face-part sensitivity in recognizing known faces. If a developmental factor is important, a clue to its nature might have been predicted in correlations with the two psychometric tests of learning ability. The failure to find any correlation here may simply reflect the small number of subjects tested. It should be noted that, in some learning-disabled groups, especially those with autism, verbal ability can be a better predictor of performance on face tasks than non-verbal mental age (e.g. Boucher & Lewis, 1992; Ozonoff, Pennington & Rogers, 1990). This, in turn, might mean that the key developmental factor in the change in face recognition patterns may be linked with communicative behaviour rather than with visuo-spatial skills. Some other developmental possibilities are outlined below.

GENERAL DISCUSSION

Using differential blurring of the inner and outer parts of the face, we have shown that familiar faces are recognized in a different way in adults than in children, and that the switch to an adult style of processing is relatively—late in the mid-teens. In teenagers with learning disabilities, the pattern resembled that of much younger children matched to them for mental age. If "mere exposure", rather than developmental progression in cognitive skills, determined this, then these learning-disabled youngsters should be starting to show the adult pattern; that is, reduced outer-face sensitivity (i.e. similarity between inner- and outer-face performance) or even an inner-face advantage. The expert pattern is of sensitivity to the inner face, with a superiority for inner- over outer-face parts; the pattern seen in childhood and the early teen years is of sensitivity to the outer-face parts. What do these findings imply?

Why does Blur Produce Different Results from Cropping?

The first question is why should a simple change in stimulus presentation (cropping compared with blurring the face) produce such different effects? In previous studies, in which face parts were seen in isolation rather than in the context of defocused (blurred) other parts, we found an adult-like pattern of sensitivity to the inner face by the end of childhood (Campbell et al., 1995; Campbell & Tuck, 1995). In early childhood (6–7 years), cropped faces produce an outer-face advantage. With blurred rather than cut images, outer-face superiority is evident at the end of childhood, and the switch to the inner face is achieved much later. One possibility is that the defocused part of the image is processed together with the clear part and that this gives rise to weaker specifications of the relevant face. In younger viewers, whose perceptual representations may be less robust, this may be more detrimental than in older viewers. Alternatively, it may be that the attentional requirements of the task differ: A cut face does not require the viewer to process anything other than the image presented, whereas a defocused face requires that the viewer divert attention from the non-informative blurred part to the clear other part. If such attentional disengagement is difficult for younger children to achieve, then the less salient (outer) part of the face may continue to affect performance. Whichever is the closer explanation, both suggest that the whole–part difference should be greater for blurred than cut faces, although neither actually predicts why the inner face should be so vulnerable. To understand this it is necessary to ask first why there should be an inner-face superiority in familiar face recognition in adults.

Inner Face Superiority (the Adult Pattern)

Any explanation of the inner-face advantage in adulthood must necessarily be speculative. The inner-face parts may not themselves be more discriminating than either outer-face parts or any idiosyncratic set of aspects or features of the face or head. Ellis et al. (1979) suggested that the inner face was harder to disguise or change than the outer face, which included hairstyle and colour and some facial hair. But this is, at best, a partial explanation. Chin shape and ears are not so readily disguised (though they can be covered) . But spectacles and make-up, as well as moustaches, are quite easy to add and take off. Disguise of both the outer and of the inner face can be achieved quite readily.

Carey and colleagues (Carey & Diamond, 1977, 1994; Carey, Diamond, & Woods, 1980; Diamond & Carey, 1977, 1986) have suggested that the skill developed by adults is in recognizing individuals from configurations of features, where the spatial relations between features are as much a cue to identity as the description of the features themselves. In contrast, children depend on piecemeal features or holistic representations which cannot be decomposed into lower-level features. The inner-face is certainly configurational in this compositional and hierarchical sense. However, the outer face is not; it is distinctive in terms of its contour (shape) and of the idiosyncratic shapes, sizes and colours of hair, head, chin and ears.

One reason why the inner-face parts may be more reliable as cues to identity could be because they can activate view-variable representations of known individuals more readily than the outer parts. Thus, for example, while hairstyle or ear shape may be specified as a particular and distinctive shape from a full-face view, a profile view may not have any corresponding information: the shape would be entirely different or may be hidden. In contrast, the disposition of the inner features across full, three-quarter and even profile views may be relatively similar—and more similar across these representations than between the same views of different individuals. The inner features may capture the *commonality* of different face-views of an individual better than the outer parts, at least in so far as shapes (or shape-from-shading information in photographs) of face parts is concerned.

The Outer-face Advantage in Childhood

Three possibilities come to mind that may contribute to the outer-face advantage in face recognition in childhood. The first is that the contour of the face may be more attractive to the young viewer as an object of attention, and of the first perceptual pass, and that this leads to relative prioritization of these aspects in building up representations. The second is that, as pointed out above, outer-face parts tend to vary in holistic properties such as shape, texture and colour, and these properties may be easier to encode and to access than configurational features in younger children. Finally, the mobility of the inner face, and the need to interpret its disposition and actions to interpret expression, intention, speech, etc., may lead to a "splitting of resources" in the child: inner face to be "read", outer face to "remember". This last idea also fits with a notion suggested above, that the adult art of face recognition is of skilled access to representations that capture the natural variability of the individual face image. A possible scenario is that, initially, the child views the most reliable (i.e. constant) aspects of the individual's appearance as the shape, colour and texture of the head and hair. With time, the child builds up a representation of a known person in terms of the disposition of the inner face under different expressive conditions as well as different views and lighting conditions. This becomes robust enough to support good face recognition only after extensive exposure to a range of faces under different viewing conditions. This ability, moreover, does not mature in a simple age-related way, but seems to depend on cognitive development (Experiment 4).

These suppositions about the switch from outer- to inner-face recognition depend not only on the idea that multiple encodings of encounters of the face of a known person are achieved and used in face identification, but depend also on an interactive (connectionist) model of learning which associates multiple encodings of a face with just one individual. Both the nature of the representation and its learning will show developmental (i.e. exposure and training) effects.

CONCLUSION

When the visual quality of inner and outer parts of known faces is selectively degraded by blur, the inner-face advantage, first reported by Ellis et al. (1979) using cut parts of faces, is confirmed in adults. However, children showed the converse pattern until mid-adolescence (14–15 years), when the adult pattern started to emerge. Face "expertise" may not always be completely achieved after 10 years or so of exposure. Similar conclusions were drawn by Ellis and Ellis (1994) on the basis of other face tasks, including recognizing unfamiliar faces in and out of context (Markham, Ellis, & Ellis, 1991) and non-adult levels of performance in 11-year-olds for tasks such as recognizing age-transformed unfamiliar faces. However, it has been shown that adult levels of skill fail to be achieved for *unfamiliar* face tasks of various sorts. We have shown that familiar faces, too, do not show adult-like patterns of recognition until the mid-teens, and that when tested appropriately, an outer-face superiority can still be seen after late childhood. Face recognition in learning-disabled adolescents supports the likelihood that this effect has a basis in changes in cognitive processing with development, rather than simply with exposure to faces.

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