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Discrimination of facial features by adults, 10-year-olds, and cataract-reversal patients

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Abstract. In previous studies we created 8 new versions of a single face: 4 differed only in the spacing among features and 4 differed in the shape of the eyes and mouth. Compared to the spacing set, results for this feature set indicated little impairment by inversion, earlier adult-like accuracy (Mondloch et al, 2002 *Perception* **31** 553 – 566), and normal performance after a history of early visual deprivation from bilateral congenital cataract (Le Grand et al, 2001 *Nature* **410** 890, **412** 786). Here we addressed the possibility that this pattern might have resulted from our having inadvertently selected easily discriminated features or including some faces with make-up. We created 20 featural versions of a single female face and asked adults, 10-year-old children, and patients treated for bilateral congenital cataract to make same/different judgments for 120 pairings (half different). The results confirm that adults easily discriminate facial features, even after early visual deprivation from cataract, and that inversion has only a small effect. By the age of 10 years, children are close to, but not quite at, adult levels of accuracy. The previous findings cannot be attributed to our having inadvertently created a feature set that was unusually easy to discriminate.

1 Introduction

Adults use several cues to facial identity, including the shape and colour of individual features (eg the eyes and mouth), the shape of the external contour, and the spacing among features (eg the distance between the eyes), also called *second-order relations* (see Maurer et al 2002 for a review). Many recent studies, including several from our own lab, have attempted to determine the contribution of each of these cues to adults' expert face recognition (eg Freire et al 2000; Mondloch et al 2002; Rotshtein et al 2007), the other-race effect (ie better recognition of own-race than other-race faces—Hayward et al 2008; Rhodes et al 2006), and developmental prosopagnosia (Barton et al 2003; Le Grand et al 2006; Yovel and Duchaine 2006). Other researchers have investigated the neural mechanisms underlying sensitivity to each of these cues (Maurer et al 2007; Rotshtein et al 2007; Scott and Nelson 2006; Yovel and Kanwisher 2004), the development of sensitivity to each of them (Baenninger 1994; Campbell et al 1995; Freire and Lee 2001; Gilchrist and McKone 2003; McKone and Boyer 2006; Mondloch et al 2002, 2006a; Sugita 2008), and the role of experience in driving that development (Le Grand et al 2001, 2003; Sugita 2008).

To test sensitivity to different cues to facial identity, we developed the 'Jane task'. We created twelve versions ('sisters') of a single Caucasian female face, which we called 'Jane'. Four sisters differed in the spacing of facial features. This set was created by moving the eyes up/down/closer together/farther apart and by moving the mouth up/down; these changes resulted in a set of faces that spanned most of the natural variation among Caucasian faces in the real world but that stayed within normal limits (Farkas 1994). Four sisters differed in the shape and colour of the eyes and mouth. This featural set was created by replacing Jane's original eyes and mouth with the eyes and mouth of four different faces. Features were matched for horizontal length so as to minimise differences in the spacing among features. The remaining four sisters differed in the shape of the external contour. This contour set was created by pasting the internal portion of Jane's face into four different head outlines (see Mondloch et al 2002 for more details). In each of our studies with these stimuli participants were shown pairs of faces from the same set (ie spacing, feature, or contour) sequentially and asked to make a same/different judgment. The three face sets were always presented in separate blocks in order to encourage viewers to emphasise a particular type of processing.

A series of studies using this 'Jane' task revealed several important findings. First, adults were more accurate on the featural set (mean, $M = 0.89$) than either the spacing ($M = 0.82$) or contour ($M = 0.76$) sets (Mondloch et al 2002). Second, inversion reduced adults' accuracy more for the spacing set (M decrement $= 0.19$) than for either the featural ($M = 0.06$) or contour ($M = 0.09$) sets (Mondloch et al 2002). Third, adult-like accuracy developed more slowly for the spacing set than either the contour or feature sets. Whereas 6-year-olds were adult-like on the contour set and 10-year-olds were adult-like on the featural set (with 6-year-olds being nearly adult-like), even 14-year-olds made more errors than adults on the spacing set (Mondloch et al 2002, 2003b). Fourth, early visual deprivation caused by bilateral congenital cataracts led to permanent impairments in accuracy on the spacing set, but not the featural or contour sets (Le Grand et al 2001). Finally, an fMRI study revealed neural mechanisms that differentiate processing of the featural versus spacing set (Maurer et al 2007). A region of the right fusiform gyrus (near, but not overlapping, the localised fusiform face area) showed greater activity during the spacing task, along with multiple areas of right frontal cortex, whereas left prefrontal activity increased for featural processing. Several research groups have used this task to study a variety of special populations: individuals with autism (Nishimura et al 2007), Williams syndrome (Karmiloff-Smith et al 2004), developmental prosopagnosia (Le Grand et al 2006), congenital deafness, focal brain lesions, and hemispherectomy, as well as children exposed to lead prenatally, shy children, and older adults. These stimuli have also formed the basis of a neural network model (Zhang and Cottrell 2004).

Two other groups have investigated a subset of these questions using faces differing only in the shape of internal features versus their spacing, with the spacing changes, as in our studies, kept within natural limits (Freire et al 2000; Rotshtein et al 2007). Freire et al created featurally and spatially altered versions of a single male Caucasian face, and Rotshtein et al created new combinations of features and spacing from 30 original faces placed in a common external contour. Like us, they found that adults' accuracy for the featural set was higher than that for the spacing set (Freire et al 2000; Rotshtein et al 2007) and affected less by inversion (Freire et al 2000). Using an fMRI repetition protocol, Rotshtein et al also found distinctive neural correlates of repeated features versus repeated spacing.

Collectively, studies using the Jane test (and similar approaches with other stimulus sets) provide a wealth of information about expert face recognition and its development. However, they have been criticised on two grounds. First, because adults' accuracy was higher on the featural set ($M = 0.89$) than on the spacing set ($M = 0.82$), it is possible that differences in task difficulty may account for all of the findings. Adults' accuracy may have dropped more when faces in the spacing set were inverted because the spacing set was more difficult, rather than because the processing of spacing is more disrupted by inversion (Yovel and Kanwisher 2004). Although that argument has surface validity, it is not the only way to conceptualise the relationship. Rossion (2008) points out that this argument is "rather surprising because, if anything, a higher performance for featural than configural trials at upright orientation leaves more room for inversion costs in the former condition" (page 5). This prediction is consistent with a recent finding reported by Rhodes et al (2006). They created morphed continua between two versions of a single face that differed in spacing or in the shape and colour of individual features and asked viewers to choose which one of two morphed faces matched the face they had just seen. Accuracy was higher for upright than inverted faces, especially for spacing changes, and as discriminations became easier (by increasing the distance between the two morphed versions) both upright face accuracy and the size of the inversion effect increased for both sets, consistent with Rossion's (2008) prediction. In addition, Rossion notes several studies in which larger inversion effects were found for spacing cues than featural cues, despite accuracy being equated when the stimuli are presented upright. Nonetheless, if our original featural set contained features that were unusually easy to discriminate, performance on that task may have been impervious to inversion effects. Similarly, the slow development of adult-like performance on the spacing set and the impairments following early visual deprivation have been attributed to task difficulty: children may perform worse than adults on more difficult tasks (Gilchrist and McKone 2003; McKone and Boyer 2006) and early visual deprivation may impair performance on difficult tasks more than performance on easier tasks. We have argued (Mondloch et al 2002) that difficulty cannot offer a complete account of our previous findings, because adults' accuracy on the contour set was even lower ($M = 0.80$) than their accuracy on the spacing set, and yet the inversion effect for the contour set was small ($M = 0.09$), performance was adult-like by 6 years of age (Mondloch et al 2002), and accuracy was not impaired following early visual deprivation (Le Grand et al 2001).

The second criticism comes from the fact that two of the sisters in the original featural set were wearing make-up (Yovel and Duchaine 2006). This is problematic, because make-up may have enhanced featural differences so much that adults' accuracy on the task may not reflect their sensitivity to featural differences among faces in the real world—at least among individuals who do not wear make-up. Thus, 40% of the trials in our original study may not have tapped face-specific mechanisms (see Yovel and Duchaine 2006), although Rossion (2008) points out that colour and texture cues do facilitate face recognition and may be processed by face-specific mechanisms. Nonetheless, when Yovel and Duchaine created a new set of featural stimuli with especially dramatic changes in luminance (by adding heavy make-up), they found no inversion effect in adults, and patients with severe deficits in face recognition (prosopagnosia) performed as well as controls.

Several authors have suggested that, in order to compare inversion effects, developmental patterns, and neural mechanisms for featural versus second-order cues to facial identity, it is necessary to equate adults' accuracy for the two face sets when stimuli are upright. One approach is to increase spacing changes until accuracy for the spacing set matches that for the featural set (eg Gilchrist and McKone 2003; McKone and Boyer 2006; Yovel and Duchaine 2006; Yovel and Kanwisher 2004). Although this solves the problem of unequal task difficulty, it may create another. Our measurements of the images provided by Yovel and Duchaine indicate that the eyes of their original face were moved in or out by up to 4.4 standard deviations from the mean interpupillary distance measured in a representative sample of adult Caucasian faces reported in Farkas (1994). Changes of this magnitude make the faces look distorted and unnatural. Perhaps as a result of these unnaturally large spacing changes, Yovel and Kanwisher (2004) found an unusual effect of inversion on behavioural performance: inversion caused a larger drop in accuracy for their featural set than for their spacing set, which is the opposite pattern from what is usually reported (Freire et al 2000; Gilchrist and McKone 2003; Goffaux and Rossion 2007; Mondloch et al 2002). These results suggest that very large spacing differences may be processed differently from those within normal limits. Similarly, studies that show sensitivity to second-order relations in young children typically use large spacing changes that are outside normal limits (see Mondloch and Thomson 2008 for a review). Our goal in creating the original Jane task was to tap adults' and children's sensitivity to differences among faces in the real world. The other way to match accuracy is to make featural differences increasingly subtle, until accuracy for the featural set matches that for the spacing set. Again, however, if the resulting featural differences are much more subtle than differences among faces in the real world, then adults' and children's ability to use featural cues for face recognition may be underestimated. Rotshtein et al (2007) make a similar argument. They argue that although matching difficulty

> "can be experimentally elegant, it runs the potential risk of producing unnatural stimuli that may not reflect the usual roles or relative weights of featural-versus-second-order spatial relation information within real faces. For instance, if features normally differ more between distinct real faces than second-order spatial relations, then the latter cues might have to be 'exaggerated' to match for difficulty, which could then lead to overestimates of their usual weight, or vice versa." (page 1346)

In the current study we took a different approach, which was analogous to the approach of Rotshtein et al (2007) for the study of the neural underpinnings of featural processing. We created a larger set of featural sisters ($n = 20$) that included Jane and the original four sisters. The aim was to test with a number of examples creating a range of difficulties. We asked participants to make same/different judgments for 120 pairs of faces; on half of the trials the two faces in the pair were the same (each of the 20 faces was paired with itself on three trials) and on half of the trials they were different (each of the 20 faces served as the model face on three trials and was paired with a different featural sister each time). We tested three groups of participants on this expanded features task: adults, who were tested on both upright and inverted faces, 10-year-old children, and patients treated for bilateral congenital cataract. The last two groups were tested on upright faces only because the issue being addressed was whether processing of features in upright faces of the type seen in real-world settings is adult-like by the age of 10 years, and normal even after early visual deprivation. To determine whether the conclusions of our previous studies were peculiar to the small set of featural changes we tested, we examined whether accuracy on the expanded set differed between upright and inverted trials for adults, between adults and 10-year-olds, and between adults and cataract-reversal patients. To determine which accuracy for featural differences is enhanced by make-up and luminance cues, we performed a second set of analyses for trials on which the correct response was different. We compared accuracy for all 60 different trials with the subset of trials in which neither face had make-up ($n = 49$) and the subset of trials in which there were no make-up differences and no striking difference in the size or luminance of the iris ($n = 29$). If make-up or luminance cues inflated accuracy in our previous studies, then accuracy should be lower for all groups when the analysis is restricted to subsets without these cues, the inversion effect should be larger in adults, and any difference between patients or 10-year-olds and adults should be enhanced.

2 Method

2.1 *Participants*

We tested twenty-four adults (four males; mean age = 20.3 years; range = 18.0 to 27.3 years) and twenty-four 10-year-old children (twelve males; ±3 months; mean age = 9.96 years; range = 9.9 to 10.2 years). Participants in these two groups were all Caucasian, right-handed, had no history of visual or neurological problems, and had normal vision [20/20 on the Good-lite eye chart and normal stereo acuity; see Mondloch et al (2002) for inclusion criteria]. We also tested eight patients treated for

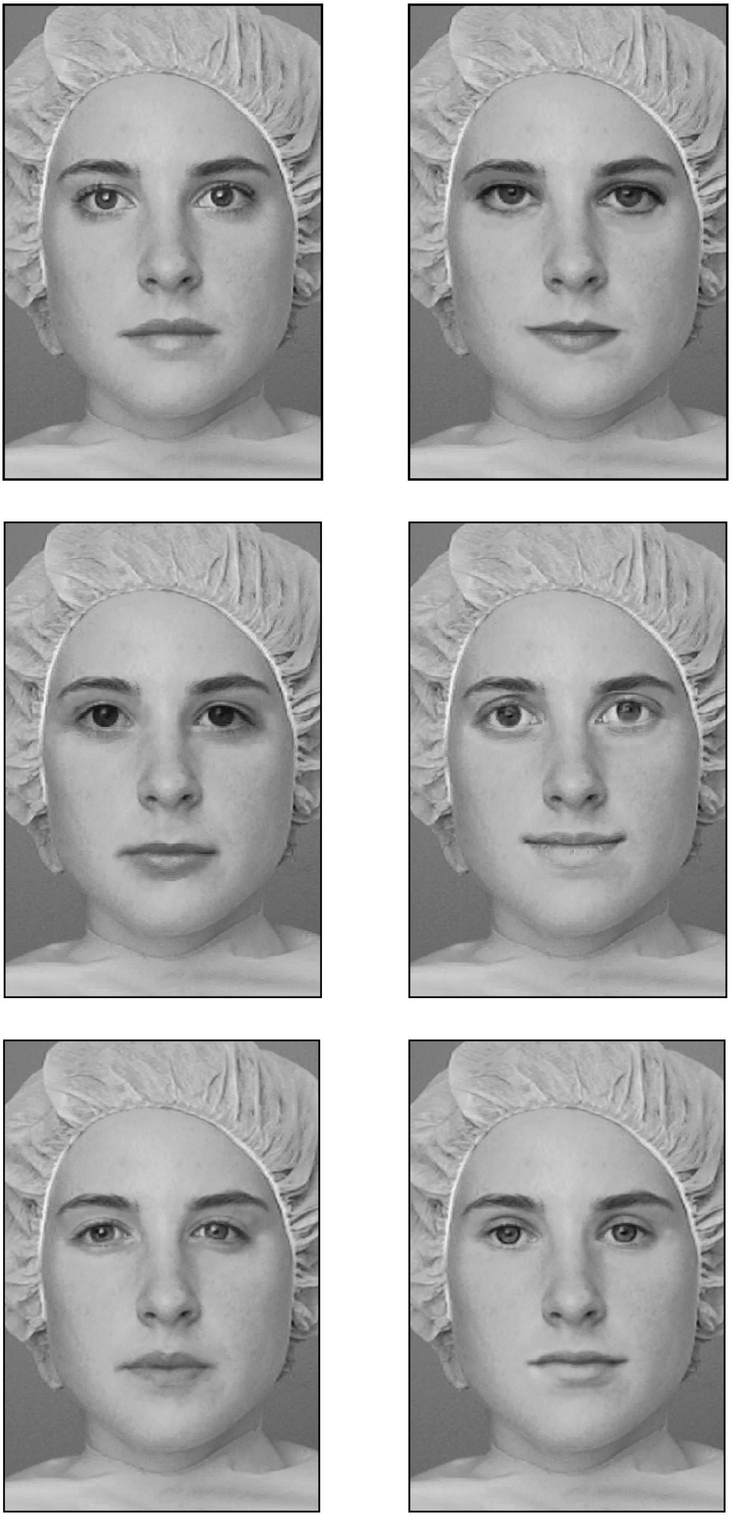

Figure 1. Six of the featural sisters presented in this study. A 'make-up' pair (top row), a 'no make-up' pair (middle row), and a 'shape-only' pair (bottom row) are shown. Accuracy did not differ across these three types of pairings for any group.

bilateral congenital cataract; all patients were Caucasian and at least 10 years of age [$M = 19.3$ years, SD = 6.46 years, range = 12 to 27 years, range of deprivation = 9 to 294 days ($M = 108.9$ days, SD = 69.7 days) from birth to fitting of compensatory contact lens following cataract surgery]. Adults were undergraduate students participating for credit in a psychology course at Brock University. Children with normal eyes were recruited from databases of volunteers maintained at McMaster and Brock Universities. Cataract-reversal patients were recruited from our database of volunteers for ongoing studies at The Hospital for Sick Children.

2.2 *Stimuli*

A single grey-scale Caucasian face (Jane) was modified in order to create 19 new versions. Each version had a different pair of eyes (but the same eyebrows) and a different mouth. The horizontal length of the features was matched so as to minimise any changes in the spacing among features. All other facial characteristics were identical (see figure 1). All stimuli were 10.2 cm wide and 15.2 cm high (5.7 deg × 9.1 deg from the testing distance of 100 cm).

2.3 *Procedure*

All procedures were approved by the Research Ethics Boards at The Hospital for Sick Children, Brock University, and McMaster University. Participants sat 100 cm from a computer monitor on which the faces were presented and signalled their responses via a macally i-shock controller. The experimenter initiated the experiment by saying:

> "This is Jane (the original model was presented on the screen) and these are some of Jane's sisters (6 different sisters were shown). Jane has many sisters. They all look alike, but they are all different people. They are kind of like twins. Do you know any twins? ...They are going to try to trick you. So, you are going to see one face flash up fast on the screen and then another face. You have to show me, using the joystick, if you think the faces are the same or different, OK? Try to answer as fast as possible, but try to give the right answer."

Each participant was then given 5 practice trials in which the first (model) face appeared for 200 ms, and, after an interstimulus interval of 390 ms, the second (test) face appeared until the participant signaled a response with buttons on a joystick. All participants were tested on a block comprised of 120 upright trials, with the same timings as in the practice. On half of the trials the correct response was 'same'; each of the 20 versions appeared as both the model and the test face on three trials. On the remaining trials the correct response was 'different'; each of the 20 versions appeared as the model on three trials and as the test face on three trials. Each participant received a different random order of trials. After being tested on 120 upright trials, adults, but not children or patients, were tested on a block of 120 inverted trials with the same set of faces. The stimuli were presented with Cedrus Superlab 4.0 software.

3 Results

3.1 *Analyses*

One question was whether we had overestimated accuracy in our original investigations by inadvertently selecting features that are unusually easy to discriminate. To address this question, we calculated mean accuracy across the 120 trials for adults (separately for upright and inverted blocks), 10-year-olds, and patients. In three separate comparisons, we assessed whether the accuracy of adults on upright trials was significantly different from their accuracy on inverted trials, the accuracy of 10-year-olds, or the accuracy of cataract-reversal patients. A second question was whether accuracy on different trials would vary as a function of whether make-up or luminance cues were present. We measured accuracy for all 60 pairs, for only the 49 pairings in which neither face had make-up ('no make-up' pairs), and the 29 pairs in which there were no striking difference in the size or colour of the iris and no make-up cues [because both faces ($n = 1$) or neither face ($n = 28$) had make-up; 'shape-only' pairs]. If our previous findings were caused by make-up and luminance cues, then the inversion effect as well as difference between both 10-year-olds and patients versus adults should increase when these cues are removed.

3.2 *Adults' accuracy*

As shown in table 1, across the 120 pairings adults' accuracy on upright trials was almost identical ($M = 0.88$) to that reported in our original study ($M = 0.89$—Mondloch et al 2002). The inversion effect (accuracy on upright trials − accuracy on inverted trials) was also the same size ($M = 0.07$) as that reported previously ($M = 0.06$); unlike in our previous study, the inversion effect in the current study was statistically significant ($t_{23} = 5.41$, $p < 0.001$).(1) We note that this inversion effect is much smaller than that reported previously for the spacing set ($M = 0.19$) (Mondloch et al 2002). Adults' accuracy on upright different trials was identical across the 60 pairings ($M = 0.94$), the 49 'no make-up' pairs ($M = 0.93$), and the 29 'shape-only' pairs ($M = 0.93$). Adults' accuracy on the 120 inverted trials ($M = 0.81$) was similar to that reported in our original study ($M = 0.83$). Most importantly, accuracy on inverted different trials did not decrease when the analysis was limited to the 49 'no make-up' pairs ($M = 0.83$) and to the 29 'shape-only' pairs ($M = 0.81$), relative to when all 60 trials were included ($M = 0.82$). Consequently, there is no evidence that the size of the inversion effect increased when make-up cues were removed and luminance cues were reduced.

Table 1. Mean proportion correct (standard error) for each group shown separately for each trial type.

Group	Trial type			
	same + different	60 different	no make-up	shape only
Adults up	0.88 (0.01)	0.94 (0.01)	0.93 (0.01)	0.93 (0.01)
Adults inverted	0.81 (0.01)	0.82 (0.02)	0.83 (0.02)	0.81 (0.02)
10-Year-olds (up)	0.82 (0.02)	0.88 (0.02)	0.88 (0.02)	0.88 (0.02)
Patients (up)	0.90 (0.02)	0.91 (0.02)	0.90 (0.02)	0.90 (0.02)

3.3 *Adults versus 10-year-olds*

Across the 120 pairings, the accuracy of 10-year-olds on upright trials was slightly lower ($M = 0.82$) than in our previous study ($M = 0.86$) and their accuracy was lower than that of adults ($M = 0.88$) ($t = 2.32$, $p < 0.05$). Similarly, the accuracy of 10-year-olds on the 60 different trials ($M = 0.88$) was lower than that of adults ($M = 0.94$) ($t_{46} = 2.69$, $p < 0.01$). However, the accuracy of 10-year-olds on different trials did not decrease when analyses were restricted to either the 'no make-up' pairs ($M = 0.88$) or the 'shape-only' pairs ($M = 0.88$). We note that the difference between 10-year-olds and adults in the current study ($M = 0.06$) is only slightly larger than that reported previously ($M = 0.02$).

3.4 *Adults versus patients*

Across the 120 pairings, the accuracy of patients ($M = 0.90$) was slightly higher than that reported previously ($M = 0.85$; Le Grand et al 2001) and did not differ from that of the adult group ($t = 0.02$, $p > 0.40$). Similarly, the accuracy of patients on the 60

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(1) The pattern of results was the same for the four pairings for which the proportion of adults making a correct response was less than 0.85 ($M_{\text{accuracy}} = 0.80$). The mean inversion effect for these four pairs ($M = 0.04$) did not differ from the overall inversion effect ($M = 0.07$). Patients' accuracy for these four pairings ($M = 0.78$) did not differ from that of adults and the difference between adults and 10-year-olds for these four pairings ($M = 0.05$) did not differ from that across all pairings ($M = 0.06$).

different trials ($M = 0.91$) did not differ from that of adults and did not decrease when analyses were restricted to the 'no make-up' pairs ($M = 0.90$) or the 'shape-only' pairs ($M = 0.90$); there were no differences between patients and controls for any set of faces (all ps > 0.10).

4 Discussion

The results suggest that adults are highly accurate at discriminating featural differences in faces. The accuracy of adults was very high (0.88) for the entire set of 120 pairings and remained high for the subsets of those pairings in which make-up and luminance cues were removed. Although some features may be more difficult for adults to discriminate than others (the proportion of adults making a correct response was < 0.85 for 4 of the 60 pairs), the high accuracy in the current study suggests that adults are remarkably good at discriminating faces that differ only in the eyes and mouth, and that much of the time they will be more accurate when making featural discriminations than when making discriminations based on the spacing among features (accuracy for normal adults in our previous studies with the spacing set has ranged from $M = 0.80$ to 0.82)—at least when the spacing of features remains within normal limits. The high accuracy of adults on this expanded set of features is consistent with other studies that have demonstrated higher accuracy for feature discrimination than discrimination based on the spacing of the features (Freire et al 2000; Mondloch et al 2002; Rotshtein et al 2007). Although equating task difficulty by selecting particularly subtle feature differences is appealing, our current approach of using a large set of features has the advantage of using featural differences that are probably representative of featural differences among faces in the real world and allowed us to assess the generality of previously reported inversion effects and developmental patterns.

The accuracy of adults did decline significantly when the faces were inverted, but the size of the drop was small (0.07), similar to the inversion effect previously observed for our original featural set (0.06), and much smaller than that previously observed for the spacing set (0.19). Importantly, the size of the drop was similar for the full set of faces and when colour cues were reduced (ie for the 'no make-up' and 'shape-only' pairs). These findings clearly refute previous criticisms (Yovel and Duchaine 2006) that smaller inversion effects for the featural set than for the spacing set in our previous studies were attributable to two of the original featural sisters wearing make-up. Our finding of a reliable but small inversion effect for featural processing is consistent with recent reports (Rhodes et al 2006; for reviews see Bartlett et al 2003; Rossion 2008) and reinforces our previous caution that the finding of an inversion effect for a given task is not diagnostic for the type of processing used to solve the task with upright faces (Maurer et al 2002).

The current results also extend our previous findings (Le Grand et al 2001, 2003) that patients with a history of early visual deprivation from bilateral cataracts perform normally on the original feature set. Patients were very accurate on this expanded set of featural differences ($M = 0.90$ compared to 0.88 in the adult control group), and their accuracy did not decrease when make-up and luminance cues were reduced. Like our previous findings, these results indicate that early visual experience is not necessary for the later development of normal sensitivity to featural differences.

Unlike our previous statistical result, adults in this study were significantly more accurate than 10-year-olds in distinguishing features in upright faces, although in both studies the accuracy of 10-year-olds was well above 0.80 (this study: 0.82, previous study: 0.86) and the mean difference from adults was small (this study: 0.06; previous study: 0.03). Importantly, as for adults, the accuracy of 10-year-olds was not affected by make-up or luminance cues. Long before the age of 10 years, the sensitivity of children to the high spatial frequencies that define differences in feature shape is adult-like (Ellemberg et al 1999). The visual improvements that have been documented after the age of 10 years are in higher-order visual integration of information across space (eg contour integration—Kovács et al 1999; Vernier acuity—Skoczenski and Norcia 2002) and are unlikely to account for the small change in sensitivity to features, unlike the role they likely play in improved sensitivity to the spacing of features after the age of 8 years (Mondloch et al 2006b). Rather, the small difference between 10-year-olds and adults may reflect slight refinements in sensitivity to differences among facial features and/or improvements in more general cognitive skills such as memory and attention. Such changes might also lead to small improvements in sensitivity to featural differences in non-face categories (eg cars, birds, houses). Nonetheless, the high accuracy of 10-year-olds, even when there are no make-up or luminance cues, indicates that they will be able to accurately distinguish among faces in the real world on the basis of featural cues. Their above-chance performance when faces differ only in the spacing of features ($M = 0.75$ in Mondloch et al 2002) indicates that 10-year-olds will be also able to use spatial cues to some extent, though not as well as adults. In combination, limitations in children's sensitivity to both features and their spacing may explain why children make more errors than adults when both cues to identity are available (Benton and Van Allen 1973, as cited in Carey et al 1980; Bruce et al 2000; Mondloch et al 2002, 2003b).

We acknowledge that one approach to comparing the sensitivity of adults and children to various cues to facial identity is to equate the performance of adults across conditions. This approach also has value when comparing the effect of inversion on sensitivity to featural versus relational cues. However, faces that we encounter everyday in our social interactions vary around a mean, and most faces we encounter are, by definition, closer to that mean than the few outliers (Valentine 1991). Our approach in previous studies has been to test participants' sensitivity to second-order relational cues to facial identity using faces that represent the variation that is typical among faces in the real world.

Anthropomorphic norms (Farkas 1994) have allowed us to confirm that the spacing changes in our original Jane task span most of the variation among faces in the real world, and that studies that equate featural and spacing accuracy in adults by increasing the size of the spacing differences (eg Gilchrist and McKone 2003; McKone and Boyer 2006; Yovel and Duchaine 2006; Yovel and Kanwisher 2004) have done so at the cost of presenting spatially altered faces that fall at or outside of normal limits. There is no way to measure directly whether the featural differences that we have used were representative of differences in the real world. However, our findings that accuracy on a larger stimulus set matched that of our original set and that accuracy did not decrease when make-up and luminance cues were removed provide evidence that our original set was representative (ie that we did not overestimate accuracy in our previous studies). This conclusion receives further support from Rotshtein et al (2007) who found that adults are more accurate at recognising featural than spacing changes in upright faces even when tested with many examples of each type of change and from Freire et al (2000) who reported a similar pattern for inversion (a significant decrement for spacing but not features) when adults were tested on a similar task involving a male face. It is possible that a different pattern of results would emerge for a large set of featural differences that were particularly subtle and difficult for adults when presented upright. Nonetheless, the results for the large set of features used in the current study suggest that adults, 10-year-olds, and patients treated for congenital cataract discriminate facial features with ease, and that their ability to do so is not dependent on either make-up or large differences in luminance (eg brown versus blue eyes).

In conclusion, accuracy for adults, 10-year-old children, and patients treated for bilateral congenital cataract was remarkably high on the current task and was not influenced by make-up or luminance cues. Collectively, our results suggest that both features and their spacing play an important role in face recognition. Nevertheless, our results suggest that features are typically easier to discriminate than spatial cues and likely play a key role in real-world face recognition, a fact that has been overshadowed in recent years by the emphasis on sensitivity to the spacing among features.

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