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The Influence of Averageness on Adults' Perceptions of Attractiveness: The Effect of Early Visual Deprivation

Larissa Vingilis-Jaremko and Daphne Maurer
McMaster University, Hamilton, ON, Canada

Gillian Rhodes and Linda Jeffery
The University of Western Australia, Perth, Australia

Abstract
Adults who missed early visual input because of congenital cataracts later have deficits in many aspects of face processing. Here we investigated whether they make normal judgments of facial attractiveness. In particular, we studied whether their perceptions are affected normally by a face's proximity to the population mean, as is true of typically developing adults, who find average faces to be more attractive than most other faces. We compared the judgments of facial attractiveness of 12 cataract-reversal patients to norms established from 36 adults with normal vision. Participants viewed pairs of adult male and adult female faces that had been transformed 50% toward and 50% away from their respective group averages, and selected which face was more attractive. Averageness influenced patients' judgments of attractiveness, but to a lesser extent than controls. The results suggest that cataract-reversal patients are able to develop a system for representing faces with a privileged position for an average face, consistent with evidence from identity aftereffects. However, early visual experience is necessary to set up the neural architecture necessary for averageness to influence perceptions of attractiveness with its normal potency.

Keywords
averageness, attractiveness, face perception, amblyopia, early visual experience, development

Early visual experience plays a critical role in shaping the human brain to support the development of expert face processing. Evidence for this generalization comes from a natural experiment: Children born with dense central cataracts in both eyes that blocked patterned visual input until the cataracts were surgically removed and the eyes fitted with

Corresponding author:
Daphne Maurer, Department of Psychology, Neuroscience & Behaviour, McMaster University, 1280 Main Street West, Hamilton, Ontario L8S 4K1 Canada.
Email: maurer@mcmaster.ca

compensatory contact lenses. These patients later develop normal looking preferences for face-like patterns (Mondloch, Lewis, Levin, & Maurer, 2013; Mondloch, Segalowitz, et al., 2013), normal or nearly normal sensitivity to the low and mid spatial frequencies typical adults use for face processing (Ellemberg, Lewis, Maurer, Lui, & Brent, 1999; Gao & Maurer, 2011), and normal sensitivity to biological motion and the shape of facial features (Hadad, Maurer, & Lewis, 2012; Le Grand, Mondloch, Maurer, & Brent, 2001; Mondloch, Robbins, & Maurer, 2010). Nevertheless, even when the initial deprivation lasted only a few months, there are serious deficits in configural processing of faces: Holistic face processing is absent until near adulthood (de Heering & Maurer, 2014; Le Grand, Mondloch, Maurer, & Brent, 2004) and sensitivity to the spacing of facial features (termed second-order relations) is reduced even in adulthood (de Heering & Maurer, 2014; Le Grand et al., 2001; Robbins, Nishimura, Mondloch, Lewis, & Maurer, 2010). Additionally, cataract-reversal patients have difficulty recognizing famous faces or a face in a new point of view (Geldart, Mondloch, Maurer, de Schonen, & Brent, 2002; de Heering & Maurer, 2014). Their face-coding mechanisms are also less readily adapted by experience as manifested in smaller than normal identity aftereffects (Rhodes, Nishimura, de Heering, Jeffery, & Maurer, 2016).

Here we investigated a related aspect of face processing: the influence of averageness on perceptions of facial attractiveness. In typical adults, faces that approximate the population mean are judged to be more attractive than most other faces (Langlois & Roggman, 1990; Rhodes, 2006). This is likely related to the adaptive coding mechanisms used to process faces: Adults and children are hypothesized to represent faces in a multi-dimensional face space centered on a mean, or average face formed from our accumulated experience with faces (Valentine, 1991). Individual faces are represented by their difference and distance from the norm (Valentine, 1991). Faces nearer this implicit prototype may be processed more quickly and easily than more distinctive faces, and consequently preferred (Winkielman, Halberstadt, Fazendeiro, & Catty, 2006).[1] Testing the effect of averageness on perceptions of attractiveness can help to inform on the importance of early visual experience for the development of a normal face space centered on a norm with dimensions that efficiently capture the variability among individual faces. Given that cataract-reversal patients show evidence of norm-based coding, but reduced adaptability to faces (Rhodes et al., 2016), we predicted that averageness might exert a smaller influence on their judgments of attractiveness.

Although the first evidence of sensitivity to averageness emerges during infancy, it takes many years for averageness to influence children's judgments of attractiveness as strongly as it does those of adults. By 3 months (but not 1 month), infants show an ability to average faces: They treat an averaged composite of four faces as familiar, even though they only saw the individual component faces (de Haan, Johnson, Maurer, Perrett, 2001; see Rubenstein, Kalakanis, & Langlois, 1999 for evidence in 6-month-olds). By 6 months, infants look longer at an averaged face than at faces judged by adults as unattractive (Rubenstein et al., 1999). However, with more subtle stimuli, infants' mean looking time does not differ between faces transformed toward versus away from their group average, even though their mothers judge the more average faces to be more attractive (Rhodes, Geddes, Jeffery, Dziurawiek, & Clark, 2002). By age 5 (youngest age tested), children judge faces transformed toward average as more attractive than those transformed away from average (Vingilis-Jaremko & Maurer, 2013), but the strength of the influence does not become adult-like until age 11 (Vingilis-Jaremko, Sherazadishvili, & Maurer, in prep). Thus, the influence of averageness on face processing emerges postnatally and takes many years of experience to become adult-like.

Here we investigated the influence of averageness on judgments of attractiveness in cataract-reversal patients who had been visually deprived during the first 2 to 8 months of life.

The cataracts were sufficiently dense to have blocked all patterned visual input until they were removed surgically during infancy and replaced by compensatory contact lenses. Thus, the cataracts covered the period during which babies with normal eyes are learning to recognize their mother's face (e.g., Bushnell, 2001; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995), to discriminate faces based on their internal features (e.g. Bushnell, 1982; De Schonen, De Diaz, & Mathivet, 1986), and to form prototypes of the faces they experience (de Haan et al., 2001), especially the female faces they experience most often (Ramsey, Langlois, & Marti, 2005; Ramsey-Rennels & Langlois, 2006; see also Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002). This early visual deprivation when the first evidence of prototyping is emerging and many aspects of face processing are developing, could affect the development of neural architecture underlying the influence of averageness on perceptions of attractiveness.

The patients were tested as adults, after 17 to 32 years of visual input for recovery and after the age at which visually normal children show an adult-like influence of averageness. Their data were compared to those of 36 adults with normal vision. Participants saw pairs of male and pairs of female faces in which one version of each face was transformed toward the group average, while the other was transformed away from the group average. On each trial, participants selected which face from the pair was more attractive. Because of their deficits in configural processing, in remembering faces, and in face adaptation, we predicted that cataract-reversal patients would show no or a reduced effect of averageness on their judgments of facial attractiveness.

Methods

Participants

Visually deprived patients. Participants were 12 patients treated for bilateral congenital cataracts (seven males; mean age = 24 years; range = 17–32; $SD = 6$). All patients but one were White.[2] Patients were included if on their first eye exam before 6 months of age, they had been diagnosed with dense, central cataracts that blocked all patterned visual input to the retina. The cataracts were removed by surgery during infancy and the eyes were then fitted with compensatory contact lenses. Patients' period of visual deprivation until first optical correction after surgery ranged between 65 and 238 days (mean deprivation = 140 days). Visual acuity, measured with a Lighthouse eye chart, ranged from 20/25 to 20/125 in the better eye on the day of testing (median acuity = 20/32).

Normative data. Patients' results were compared to norms collected from 36 adults with normal vision (Vingilis-Jaremko & Maurer, 2013; 18 male; mean age = 21 years; range = 17–28; $SD = 3$). Control participants reported no history of visual or neurological disorders and passed a visual screening exam. Specifically, they had a Snellen acuity of 20/20 or better in each eye, measured with a Lighthouse eye chart, and normal stereoacuity measured with the Titmus test of stereoacuity. To avoid other race effects, all control participants were White, to match the race of the test faces.

Stimuli

Stimuli were the same as those used in Vingilis-Jaremko and Maurer (2013). Specifically, we used faces of 16 young adult men and 16 young adult women. All faces were White, neutral in expression, and faced the camera directly. We manually delineated each face with 189 landmark points outlining the features and face shape, and then created a male and a

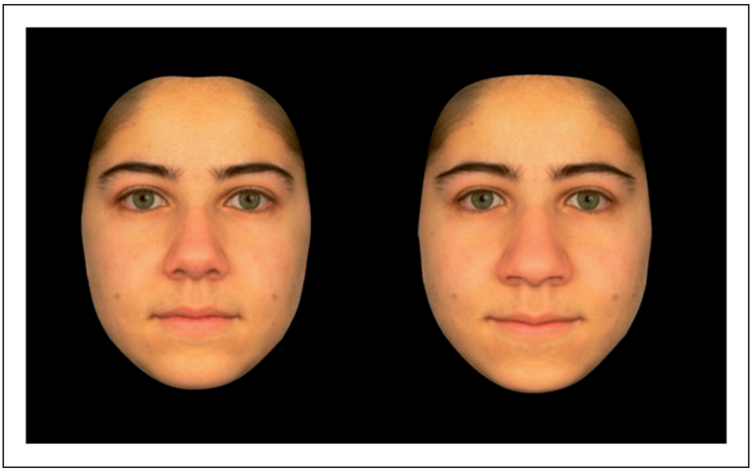

Figure 1. More average (left) and less average (right) versions of a woman's face.

female average from the 16 faces in each group. Each original face was then transformed 50% toward and 50% away from its group average using Psychomorph software. This transformation created a pair of faces that differed in averageness of shape, but maintained the texture of the original face (see Tiddeman Burt, & Perrett, 2001). Because faces become more symmetrical as they are transformed toward average, each face was made perfectly symmetrical by averaging it with its mirror image. To remove any influence of distortions in hairstyle, all external features were removed by placing a black background around the outline of the face. Faces were standardized for size based on interpupilary distance and subtended a visual angle of approximately 12 degrees in height and 7 degrees in width from a viewing distance of 50 cm. Figure 1 contains an example of a woman's face after the transformations.

Procedure

This study received ethics clearance from the institutional Research Ethics Board and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). After explaining the procedure, we obtained written consent from participants. We then explained the instructions in the same game-like format we had used in a previous study of adults (the normative group in the current study) and children with normal vision (Vingilis-Jaremko & Maurer, 2013). Patients were given the same game-like instructions to reduce the likelihood that differences between groups were caused by differences in the task or instructions. Prior to reading the instructions to adults, the experimenter said "Please bear with me; these instructions were originally created for children." None of the adults objected (in fact, some reported liking the child-friendly instructions and task).

To ensure that participants understood the task, they were then presented with nine criterion trials in which they viewed two objects, one of which was a more attractive version of the other (e.g. a fresh apple vs. a rotten apple). On each trial, participants selected which object looked better or nicer. All participants moved onto the main experiment with 100% performance on the criterion trials. During the main experiment, participants viewed pairs of faces of the same identity that differed in averageness.

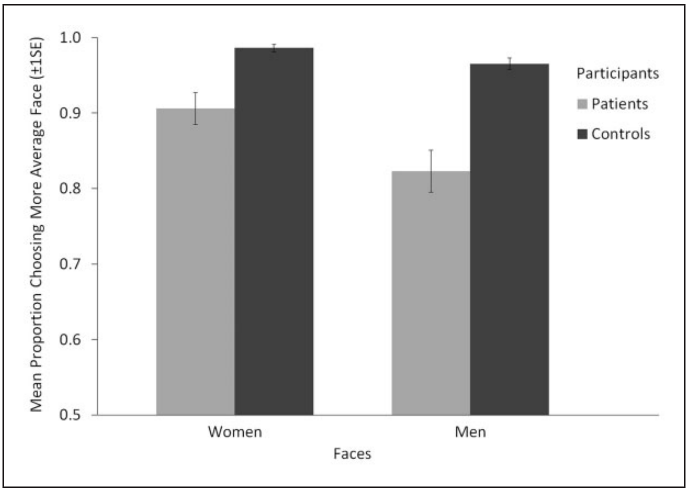

Figure 2. Mean proportion of trials on which adults treated for bilateral congenital cataracts (light bars) and adults with normal vision (dark bars) selected the more average face for male and female faces. Standard error bars represent the between-subject variability. Normative control data are from Vingilis-Jaremko and Maurer (2013).

Male and female faces (16 per group) appeared in separate blocks for a total of 32 trials per participant. For controls, the order of the blocks was counterbalanced (Vingilis-Jaremko & Maurer, 2013). For patients, male faces always appeared as the first block followed by female faces. Order was kept constant for patients so as to not affect correlations with the duration of deprivation and acuity. The order of the face pairs within each group was randomized, as was the side of the more average face. Trials were self-paced and participants used a mouse to make selections. Participants did not receive feedback during criterion trials or in the main experiment. Participants completed visual screening at the beginning of the experiment and took breaks as needed. The task took approximately 10 minutes, although both groups participated as part of a longer testing session in which they viewed other face categories (controls) or participated in other studies of vision (patients).

Results

We calculated the mean proportion of trials on which each participant selected the more average face separately for male and female faces. Because each participant saw 16 pairs of faces of each sex, each face pair represents 6.25% of the male or female face mean. To assess whether patients selected the more average faces more frequently than expected by chance, we calculated one-sample *t*-tests comparing whether the mean choices were significantly different from 0.5, controlling for multiple comparisons with Bonferroni correction ($\alpha = .025$). For female faces ($M = .906$, $SD = .078$), patients' means were significantly higher than a chance value of .50, $t(11) = 18.11$, $p < .001$. The same was true for male faces ($M = .823$, $SD = .113$), $t(11) = 9.94$, $p < .001$ (see Figure 2). Thus, averageness influenced the attractiveness judgments of patients for both male and female faces.

To compare whether the influence of averageness on judgments of attractiveness was as strong in patients as in the normative group, we performed a repeated measures ANOVA with the between-participants factor of participant group (patient, control) and the within-participants factor of face sex.[3] The analysis revealed a main effect of participant group, $F(1, 46) = 56.41$, $p < .001$, $\eta_p^2 = .551$, with averageness influencing attractiveness judgments more strongly in controls ($M = .976$, $SD = .030$) than patients ($M = .865$, $SD = .073$). The analysis additionally revealed a main effect of face sex, $F(1, 46) = 18.34$, $p < .001$, $\eta_p^2 = .285$,

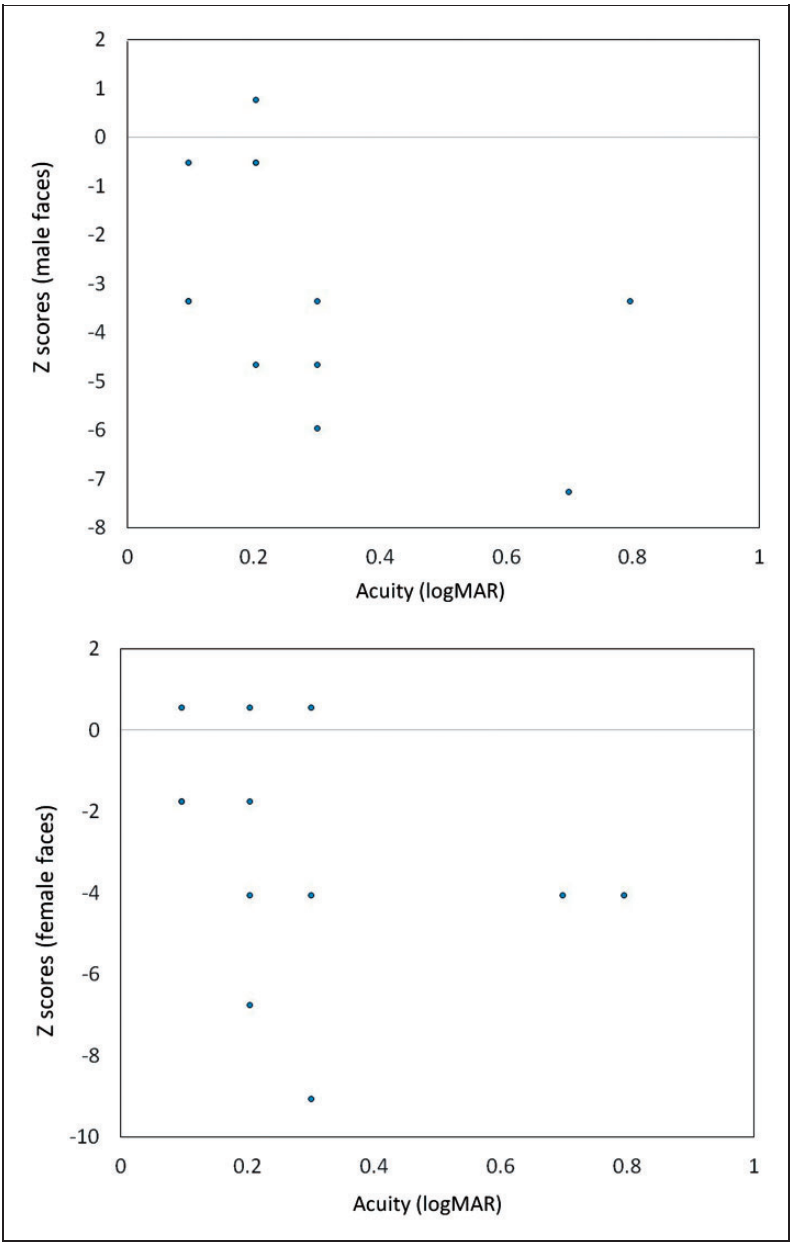

Figure 3. Patients' *Z* scores for male and female faces plotted against acuity, expressed as logMAR (the log of the minimum angle of resolution). High logMAR values indicate low acuity. Most patients' performance was below the control mean, as indicated by a negative *Z* scores, regardless of whether their acuity was in the better range (toward the left side of the graph) or the worse range (toward the right side of the graph).

with a higher mean for female ($M = .966$, $SD = .056$) than male faces ($M = .930$, $SD = .092$), qualified by an interaction between participant group and face sex, $F(1, 46) = 6.64$, $p = .013$, $\eta_p^2 = .126$.

Paired samples *t*-tests (two-tailed) revealed that averageness influenced judgments of attractiveness more strongly in female than male faces in controls (*M female faces* = .986 , $SD = .026$; *M male faces* = .965, $SD = .046$), $t(35) = 2.78$, $p = .009$, $d = .495$, and without Bonferroni correction ($\alpha = .025$), in patients (*M female faces* = .906, $SD = .078$; *M male*

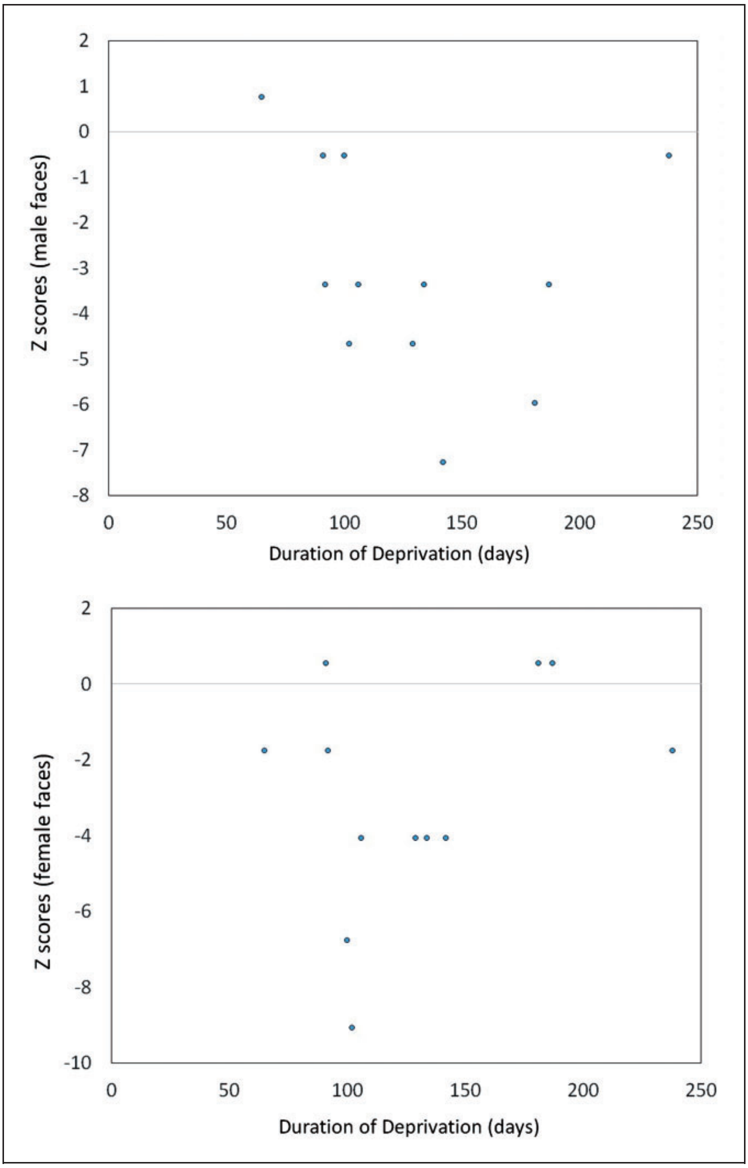

Figure 4. Patients' *Z* scores for male and female faces plotted against duration of deprivation in days. Most patients' performance was below the control mean, regardless of whether their deprivation was relatively short (65 days) or long (235 days).

faces = .823, *SD* = .113), $t(11) = 2.29$, $p = .043$, $d = .677$. Because it is also theoretically interesting to assess the differences between patients and controls, we broke down the interaction a second way. Independent samples *t*-tests (two-tailed) additionally indicated that averageness influenced judgments of attractiveness more strongly in controls than patients for both male faces (*M patients* = .823, *SD* = .113; *M controls* = .965, *SD* = .046), $t(12.24) = -4.27$, $p = .001$, $d = 1.66$, and female faces (*M patients* = .906, *SD* = .078; *M controls* = .986, *SD* = .026), $t(11.85) = -3.49$, $p = .005$, $d = 1.38$.[4] Levene's test indicated unequal variances for both male ($F = 13.97$, $p = .001$) and female faces ($F = 25.61$, $p < .001$), so degrees of freedom were adjusted from 46 to 12.24 and 26 to 11.85, respectively.

We additionally calculated Pearson correlations (two-tailed) to assess whether patients' performance, expressed as *Z*-scores compared to the norms, was affected by two factors: duration of visual deprivation in number of days and the log of their visual acuity in the better eye. Performance did not correlate significantly with duration of deprivation for attractiveness judgments of either male, $r(10) = -.227$, $p = .478$, or female faces, $r(10) = .333$, $p = .290$. Nor did it correlate with visual acuity for judgments of either male, $r(10) = -.481$, $p = .114$, or female faces $r(10) = -.293$, $p = .356$. As shown in Figures 3 and 4, most patients had negative *Z*-scores, reflecting a weaker than normal influence of averageness on judgments of attractiveness, and this was true whether acuity was in the better range (toward the left side of the graph) or in the worse range (on the right side of the graph).

Discussion

As in typical adults and children, averageness influenced the judgments of attractiveness made by the cataract-reversal patients: Whether viewing female or male faces, they chose the face transformed toward average much more frequently than the face transformed away from average (see Figure 2). As in typical adults and children tested with these stimuli (Vingilis-Jaremko & Maurer, 2013; Vingilis-Jaremko et al., 2014), the effect was stronger for adult female than adult male faces. However, the magnitude of the effect of averageness was significantly smaller in the cataract-reversal patients than in the controls. Despite being tested as adults, cataract-reversal patients performed more like 9-year-old children, in whom the effect of averageness is present but not yet as strong as in adults (*M female faces* = .931 in 9-year-olds versus *M female faces* = .906 in patients tested here, $t(46) = 1.11$, $p = .272$; *M male faces* = .865 in 9-year-olds versus *M male faces* = .823 in patients tested here, $t(46) = 1.05$, $p = .299$; Vingilis-Jaremko & Maurer, 2013). Patients' performance was not related to whether the deprivation was relatively short (65 days) or long (238 days), that is, whether it ended before the infant with normal vision begins to demonstrate the formation of facial averages (at 3 months; de Haan et al., 2001), or long thereafter. However, we acknowledge that, because these patients are rare, we were able to test only 12 of them, and more participants would give a better estimate of the correlation with duration of deprivation.

The implication of our findings is that early visual input is necessary if the full impact of averageness on judgments of attractiveness is to develop beyond childhood levels. These results are consistent with a body of literature demonstrating a sensitive period for visual development early in life, that is, a period during which patterned visual input is necessary for normal visual development (see Lewis & Maurer, 2005 for a review). Missed or atypical input during this period leads to deficits in adulthood in acuity, global form (Lewis et al., 2002), global motion (Hadad et al., 2012), and the configural processing of faces: Patients show deficits in the perception of spacing of facial features (de Heering & Maurer, 2014; Le Grand et al., 2001; Robbins et al., 2010), face recognition (Geldart et al., 2002; de Heering & Maurer, 2014), identity aftereffects (Rhodes et al., 2016), and the influence of averageness on perceptions of attractiveness (this study). These deficits do not seem to be caused by general poorer performance among cataract-reversal patients across all domains, as some aspects of vision are spared: Patients show normal looking preferences for face-like patterns (Mondloch, Lewis, et al., 2013), normal face detection (Mondloch, Segalowitz, et al., 2013), normal featural processing (Le Grand et al., 2001; Mondloch et al., 2010), normal or near normal sensitivity to low and mid spatial frequencies used for face processing (Ellemberg et al., 1999, Gao & Maurer, 2011), and normal sensitivity to biological motion (Hadad et al., 2012).

The differences between patients and controls are unlikely to be caused by poor motivation or attention, as all participants completed criterion trials with perfect accuracy. It is also unlikely that the differences between patients and controls are caused by patients' reduced acuity because most patients performed more poorly than controls regardless of whether their acuity was in the better or worse range (see Figure 3). However, we acknowledge that, because these patients are rare, we were able to test only 12 of them, and more participants would give a better estimate of the correlation with acuity. Future studies could additionally test adults with normal visual histories during childhood who subsequently developed visual acuities matched to those of the cataract-reversal patients to more strongly assess the role of acuity.

The influence of averageness on judgments of attractiveness in typical adults appears to be related to processing fluency: Faces that are closer to an average face are processed more quickly and easily than more distinctive faces (Winkielman et al., 2006), likely because they lie nearer to the norm or prototypical face at the center of face space (Valentine, 1991). Cataract-reversal patients have deficits in remembering famous and recently learned faces and in perceiving subtle differences among faces that differ in the location of facial features (de Heering & Maurer, 2014; Le Grand et al., 2001; Robbins et al., 2010). They also have reduced adaptability of their face coding mechanisms, as expressed by smaller-than-normal identity aftereffects (Rhodes et al., 2016). Collectively, these deficits are likely to lead to less faithful updating of the norm on which face space is centered and less well-defined dimensions, thereby decreasing the perceived difference between versions of the face moved toward and away from average, and reducing any fluency advantage for the more average face. Indeed, when data were collapsed by participant and analyzed by stimulus pair, Levene's test indicated greater variance in patients than controls for both female ($F = 17.98$, $p < .001$) and male faces ($F = 13.36$, $p = .001$); while patient means ranged between 50% and 100% preference for the more average face across stimulus pairs, control means ranged between 84% and 100%. This pattern is consistent with an increase in patients' threshold for detecting the full range of differences between faces. Such a deficit would be expected to have more impact on the processing of facial identity than of other non-face categories (see Rhodes et al., 2016 for an explanation).

It is also possible that increased internal noise in patients may reduce any fluency advantage for average faces and thereby reduce the impact of averageness on their judgments of attractiveness. Internal noise refers to variability in the processing of identical signals and is known to be increased in typical children compared to adults (Jeon, Maurer, & Lewis, 2012) and in adults with other forms of abnormal early visual experience (Levi, Klein, & Chen, 2008). If increased internal noise makes it harder for patients to process similarities and differences in the faces they experience, it might compromise the updating of the norm and the processing advantage for faces near it. Such internal noise should not only affect the processing of attractiveness in faces, but also the processing of non-face categories.

Averageness affected participants' judgments of attractiveness more strongly when they were judging female faces than when they were judging male faces and this was true for both controls and patients. That finding replicates our previous findings with children viewing adult faces with this stimulus set (Vingilis-Jaremko & Maurer, 2013; Vingilis-Jaremko, Maurer, & Gao, 2014). It may reflect infants' first and greater experience with female than male faces during the first year of life (Rennels & Davis, 2008; Sugden, Mohamed-Ali, & Moulson, 2014). Indeed, infants at 3 to 4 months show a spontaneous looking preference for female faces and discriminate among female faces but fail the same tests with male faces, unless they were being raised by a male primary caregiver, in which case these patterns appear to be reversed (Quinn, et al., 2002). However, we note that the effect may be particular to this stimulus set, as Rhodes' (2006) meta-analysis did not find any difference in the strength of the effect of averageness for male versus female faces.[5]

It would be of interest to explore other aspects of face processing and attractiveness with patients in future studies. Although averageness influences perceptions of attractiveness, some faces are judged by typical adults to be more attractive than the average; a composite of faces judged as attractive is rated to be more attractive than a composite created from a wider selection of faces (Perrett, May, & Yoshikawa, 1994). Exaggerating these differences along a dimension that has come to be known as "the attractiveness dimension" further increases attractiveness (DeBruine, Jones, Unger, Little, & Feinberg, 2007). Thus, it would be of interest to explore whether "the attractiveness dimension" emerges when visual input was delayed post-natally because of congenital cataracts. Additionally, to further examine the structure of patients' face space, it would be of interest to explore their ability to extract statistical regularities from faces, including not only the average but also the dimensions of maximum variation. The ability to extract both types of regularity has been shown to correlate with memory for faces in typically developing children and adults (Gao, Maurer, & Wilson, 2015; Gao & Wilson, 2014).

In summary, averageness influenced the perceptions of attractiveness of adult patients treated for bilateral congenital cataracts, but to a lesser extent than those of typical adults. The influence of averageness on patients' perceptions of attractiveness demonstrates that they have a system for representing faces with a privileged position of the average, consistent with their pattern of face identity aftereffects (Rhodes et al., 2016). The weaker influence of averageness on perceptions of attractiveness among patients demonstrates the important role of early visual experience in setting up the neural architecture that allows the later development of adult-like perceptions of attractiveness.

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Notes

1. Average faces are also hypothesized to be attractive because of stabilizing selection, which selects for the mean in a population and could be related to good phenotypic condition (Thornhill & Gangestad, 1999; see Rhodes, 2006 for a review of evolutionary influences on perceptions of facial attractiveness). Facial averageness could also signal genetic heterozygosity, providing genetic diversity in defense against parasitic infection (Thornhill & Gangestad, 1993). Indeed, heterozygosity of the major histocompatibility complex, linked to better immune function in humans, is associated with greater averageness and attractiveness in men's faces (Lie, Rhodes, & Simmons, 2008).
2. The Z scores of the non-White participant were less than 0.5 *SD* from the patient mean.
3. We did not add the between-subjects factor of participant sex because the patient sample size is small ($n = 12$; 7 male). However, in the normative group, there was no main effect of participant sex nor any interaction with participant sex and any other factor (see Vingilis-Jaremko & Maurer, 2013).
4. Our prior study with data from children and adults (the controls in this study) found a stronger effect of averageness in later than earlier blocks when participants viewed six categories of faces of children and adults (Vingilis-Jaremko & Maurer, 2013). It is unlikely that the differences between patients and controls were caused by these order effects, as statistical comparisons of patients to the subset of controls who saw adult male faces in the first block and to those who saw adult female faces in the second block (to match the patients) replicate the differences reported here.
5. It is also possible, however, that patients' performance with male and female faces was affected by block order; our prior study with data from children and adults (the controls in this study) found a stronger effect of averageness in later than earlier blocks (Vingilis-Jaremko & Maurer, 2013). Although this cannot account for the differences between male and female faces among controls, for whom blocks were counterbalanced, we cannot rule out this possibility for patients, who always saw male faces followed by female faces so as to not affect correlations with the duration of deprivation and acuity.

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