Aging Faces and Aging Perceivers: Young and Older Adults are Less Sensitive to Deviations from Normality in Older than in Young Adult Faces

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Abstract

Past studies examining the other-age effect, the phenomenon in which own-age faces are recognized more accurately than other-age faces, are limited in number and report inconsistent results. Here we examine whether the perceptual system is preferentially tuned to differences among young adult faces. In Experiment 1, young (18-25) and older adult (63-87) participants were shown young and older face pairs in which one member of each pair was undistorted and the other had compressed or expanded features. Participants indicated which member of each pair was more normal and which was more expanded. Both age groups were more accurate when tested with young compared to older faces—but only when judging normality. In Experiment 2, to examine the differential pattern of results between the normality and discrimination tasks, we tested a separate group of young adults on the same two tasks but with upright and inverted face pairs. Inversion impaired performance on the normality task but not the discrimination task and eliminated the young adult advantage in the normality task. Collectively, these results suggest that the face processing system is optimized for young adult faces and that abundant experience with older faces later in life does not reverse this perceptual tuning.

Keywords: other-age effect, expertise, face space, early experience

Adults are considered experts in face processing; however, their expertise is limited to the face categories with which they have the most experience—for example, faces of their own race (Rhodes et al 2006) and age (Anastasi and Rhodes 2005; Kuefner et al 2008). A wealth of studies have investigated one insidious social phenomenon—inferior recognition of other-race compared to own-race faces (reviewed in Meissner and Brigham 2001). Here we investigate the roots of another—reduced recognition of older adults' faces compared to those of young adults.

The majority of research investigating limitations in expertise has examined the other-race effect, the finding that own-race faces are recognized more accurately than other-race faces. Two potential explanations have been posed to account for this effect. According to the perceptual expertise hypothesis, reduced experience with other-race faces leads to their being processed less holistically (eg Michel et al 2006; Tanaka et al 2004; but see Mondloch et al 2010a) and to reduced sensitivity to differences among faces in the shape and spacing of facial features (eg Hayward et al 2008; Mondloch et al 2010a). In contrast, the socio-cognitive hypothesis states that different social cognitions are elicited by own- and other-race faces; other-race faces are classified as out-group members and are thus processed at the categorical rather than the individual level (Hugenberg et al 2010; Sporer 2001). This tendency to focus on category membership leads to decreased motivation to attend to other-race faces (Rodin 1987) and reduced encoding of the individuating features of other-race faces (Ge et al 2009; Levin 2000).

Although a large body of literature exists on the other-race effect, much less is known about a closely related phenomenon—the other-age effect. Several studies have found that own-age faces are recognized and processed more efficiently than other-age faces (Anastasi and Rhodes 2006; Wright and Stroud 2002). For example, young adults show a reduced inversion effect when recognizing child and newborn faces relative to adult faces (Kuefner et al 2008) and decreased holistic processing when examining child faces relative to adult faces in a composite face task (de Heering and Rossion 2008). Although the other-age effect is generally quite robust among young adults, there is inconsistent evidence among older adults and children (for a review, see Rhodes and Anastasi 2012), with some studies showing that older adults and children exhibit enhanced recognition for own-age relative to other-age faces (Anastasi and Rhodes 2005; Perfect and Harris 2003) and other studies showing that they perform equally well with young adult and own-age faces (Fulton and Bartlett 1991; He et al 2011; Wiese et al 2008).

Better recognition of adult versus child faces has been attributed to early experience. During infancy, young adult faces are typically the most frequently encountered in daily life (Rennels and Davis 2008), a bias that may contribute to a recognition advantage for faces in this age range (Macchi Cassia 2011). The importance of early experience is evident in a series of elegant studies demonstrating the impact of exposure to younger/older siblings. Young children who have infant siblings demonstrate enhanced recognition for infant faces relative to children who do not have younger siblings (Macchi Cassia et al 2009a), and 3-year-old children with older siblings (ie who received experience with child faces during infancy) are equally skilled in recognizing child and adult faces whereas children without older siblings are best at recognizing adult faces (Macchi Cassia et al 2012). Early and continuous exposure throughout development to young adult faces may set up the perceptual system in a way that is preferentially tuned to differences among young adult faces rather than faces of children or older adults.

There is some evidence that extensive experience in adulthood can mitigate or eliminate perceptual biases acquired early in life. For example, young adults working as preschool teachers are equally accurate in recognizing young adult and child faces (Harrison and Hole 2009;

Kuefner et al 2008) and show comparable levels of holistic processing for adult and child faces (de Heering and Rossion 2008). Furthermore, maternity ward nurses exhibit a smaller recognition advantage for young adult relative to infant faces than young adults who lack experience with infants (Macchi Cassia et al 2009b; but see Yovel et al 2012). Although these findings suggest that the face processing system remains malleable throughout life, experience acquired in adulthood may not modulate the system to the same degree as experience acquired in infancy and childhood. For example, exposure to infant faces during adulthood improves recognition for infant faces most in individuals who had a younger sibling (ie who received abundant exposure to infant faces early in life) (Macchi Cassia et al 2009a). Likewise, in terms of race effects, plasticity for other-race faces is limited after 9 years of age (Sangrigoli et al 2005); Korean children adopted into Caucasian families by 9 years of age recognize Caucasian faces more accurately than Asian faces as adults, plasticity that is not observed in Korean individuals who moved to France during adulthood. Thus experience with a new class of faces may exert greater influence on the perceptual system during childhood than adulthood.

One conceptualization of perceptual tuning is norm-based coding, a process by which individual faces are encoded relative to a face prototype that represents the average of all faces previously encountered (Valentine 1991); “Bob”, for example, is recognized because his nose is wider and his eyes are closer together than average. This prototype rests at the center of a multidimensional face space that is likely optimized for the dimensions of the face categories most frequently observed (Valentine and Endo 1992). Norm-based coding influences the perception of attractiveness and normality, such that faces that are close to the prototype are rated as more attractive and normal looking than those that are distant (Rhodes and Tremewan 1996). There is widespread agreement among adults regarding the attractiveness and normality of faces (eg Cross and Cross 1971), and even infants look longer at faces that have previously been rated as attractive by adults—at least when the faces are those of young adults (Langlois et al 1987).

Given the wealth of experience we have with young adult faces, it is likely that the dimensions of face space are optimized for young adult faces. As adults age, their faces change in both texture (eg wrinkles develop) and shape (eg redistribution of adipose tissue, lengthening of the ears and nose) (Burt and Perrett 1995), a process that may increase distance from the prototype. The norm-based coding model predicts worse recognition and reduced sensitivity to variation in attractiveness/normality for faces from categories with which we have less experience because those faces are located quite distant from the prototype (ie the average face) and are tightly clustered in multidimensional face space (Valentine 1991). Recent evidence suggests that adults may possess multiple face prototypes/norms that represent the different face categories (eg race, age) encountered in the environment (Jaquet et al 2008; Little et al 2008); however, the norm and underlying dimensions for some categories (eg other-race, other-age) appear to be less well refined, as reflected by poorer recognition and discrimination for face categories less frequently encountered (reviewed in Meissner and Brigham 2001). In the current study, we directly tested the hypothesis that age-related changes in the faces of older adults may make a face space potentially optimized for young adult faces less effective for perceiving older adult faces and, more specifically, for judging normality. Thus, regardless of whether there is a single face prototype or multiple face prototypes for faces of different ages in face space, the dimensions of face space may be optimized for the face age category with which we have the most experience (eg young faces).

We used participants' normality judgments as a tool to examine individuals' sensitivity to the dimensions on which young and older adult faces vary. Participants viewed young (19 to 24 years) and older adult (71 to 79) face pairs; one member of each pair was undistorted and the other had features that were compressed towards the center of the face or expanded outward (as in a concave/convex mirror). Participants were asked to indicate which member of each pair was more normal to test the hypothesis that judgments of normality would be more accurate for young faces. We tested both young and older adults to determine whether abundant experience with older faces later in life increases sensitivity to deviations from the norm. Given that young adults have a wealth of experience with young adult faces and consistently show an own-age recognition bias (Macchi Cassia 2011), we hypothesized that young adults would show an advantage for young faces in the normality judgment task. Evidence for an own-age bias in older adults is less consistent (eg Anastasi and Rhodes 2005; Fulton and Bartlett 1991), and thus we made no single prediction as to whether older adults would show an advantage for young versus older adult faces in the normality judgment task. If the perceptual system is set up during infancy and childhood based upon early experience (typically with young adult faces) and becomes relatively inflexible later in life, then older adults should show an advantage for young adult faces. However, if recent, extensive experience with one's age group is sufficient to alter the perceptual system and optimize face space for own-age faces, then older adults should show an advantage for older faces.

The normality judgment task required participants to rely on norm-based coding and to have an understanding of how faces deviate from a prototypical face. Nonetheless, two potential mechanisms could explain lower accuracy for older faces than young faces in the normality judgment task: deficits in norm-based coding or mere deficits in discriminating older adult faces.

To determine the extent to which differential accuracy in normality judgments could be attributed to impaired discrimination of older adult faces rather than norm-based coding per se, we also tested participants on a discrimination task in which they viewed the same face pairs shown in the normality judgment task, which allowed us to directly compare performance across the two task types. In the discrimination task, participants were simply asked to indicate which member of each face pair was more expanded. We hypothesized that any advantage for young adult faces in the normality task would be reduced or eliminated in the discrimination task; the discrimination task did not require perceptual expertise, a hypothesis we directly tested in Experiment 2, and thus served largely as a control task to ensure that participants were capable of telling the two faces in each pair apart.

Experiment 1

Method

Participants. Sixteen Caucasian undergraduate students from Brock University (12 female; *M* = 19.81 years, age range = 18-25) and 16 Caucasian senior citizens living in independent housing in the Niagara region of Ontario (11 female; *M* = 71.69 years, age range = 63-87) participated in this experiment. Senior citizen participants were all in good health and had at least 20/30 vision when tested from a distance of 8 feet; no older adult participant reported farsightedness or difficulty in viewing items shown on a computer screen. Undergraduate participants received research credit or a small honorarium and senior citizens received a gift card for their participation in the study. Participants completed a questionnaire assessing their weekly face-to-face contact with both young and older adults. Undergraduate participants reported an average of 58.27 hours per week interacting with young adults and 11.53 hours per week interacting with older adults. In contrast, senior citizen participants reported an average of

4.38 hours per week interacting with young adults and 27.10 hours per week interacting with older adults.

Materials. Both practice and test stimuli consisted of colored photographs of Caucasian young (age range = 19-24) and older adult faces (age range = 71-79). All stimuli were acquired from the Center for Vital Longevity Face Database (Minear and Park 2004) and resized such that the distance from hairline to chin was approximately 450 pixels. Twelve young adult (6 female) and 12 older adult (6 female) faces were used as test stimuli. We used the spherize tool in Adobe Photoshop Version 8.0 to expand and compress the internal features of each face (see Figure 1); using this technique, we created six new versions of each identity (-30%, -20%, -10%, +10%, +20%, +30%). For each identity, we then created six face pairs such that each level of distortion was paired with its undistorted same-identity counterpart (eg an undistorted face was paired with a +10% face of the same identity). The left/right positioning of the undistorted member of each pair was counterbalanced such that for each age of face and each distortion level (eg undistorted paired with -10%), the undistorted face appeared on the left for half of the trials. The same identities and pairings were used in both the normality judgment task and the expanded discrimination task.

An additional four identities (two older adult) were used as practice stimuli in both tasks. Each practice trial (n = 4) consisted of a ±40% face paired with an undistorted face of the same identity. The distorted face appeared on the right on two of these trials. All stimuli were presented and responses were recorded using SuperLab 4.5 software.

Procedure. The procedure received clearance from the Research Ethics Board at Brock University, and participants gave written informed consent prior to their participation. Upon arrival to the lab, participants were seated approximately 60 cm in front of a 23-inch computer screen. The order in which participants completed the two tasks was counterbalanced such that half of the participants completed the normality judgment task followed by the expanded discrimination task, and the other half completed the two tasks in the reverse order.

In the normality judgment task, participants were told that they would be shown a series of face pairs and that they were to select the more normal-looking face in each pair. Prior to testing, participants were shown four practice trials to ensure that they understood task instructions. Practice trials consisted of an undistorted face paired with a ±40% face of the same identity, and each pair was shown for 3000 ms. Participants were asked to verbally indicate whether the face on the right or on the left appeared more normal looking; verbal responses were used because pilot testing revealed that senior citizen participants preferred giving verbal responses rather than using a joystick because it made the testing session more interactive for them. Following the practice trials, participants were shown 144 face pairs (12 identities across 6 levels of distortion for each of the two age categories). The order in which the pairs were shown was fully randomized. Each trial consisted of a 500-ms fixation cross followed by a face pair that appeared for 3000 ms. The face pair was then replaced by a screen prompting participants to select the more normal-looking face in each pair. Participants verbally indicated “left” or “right” and the experimenter entered their response in the computer before advancing to the next trial.

The procedure of the expanded discrimination task was identical to that of the normality judgment task, except that participants were asked to select the more expanded face in each pair rather than identify the more normal-looking face. An expanded face was defined as having larger, more stretched out features than its same-identity counterpart.

<Place Figure 1 around here>

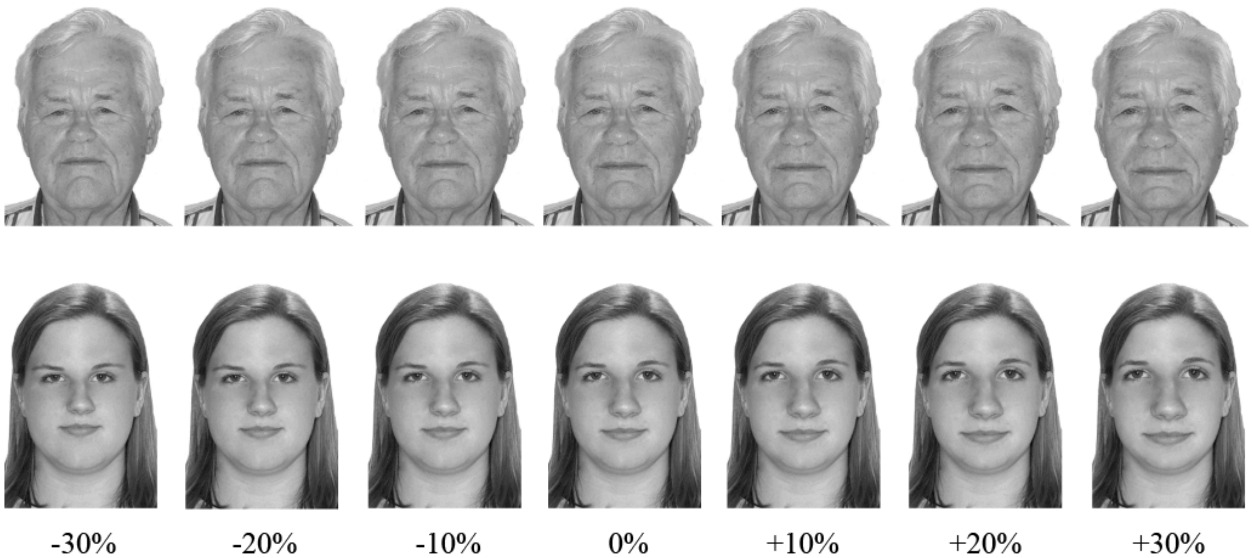

Figure 1. Sample distortion continua for an older adult identity and young adult identity. Each face pair consisted of an undistorted face paired with an expanded or compressed version of the same identity.

Results

To simplify our analysis, we collapsed across expanded and compressed trials within each distortion level[1]. For the normality judgment task, we calculated the proportion of trials on which each participant selected the undistorted face in a face pair as being more normal than the distorted face; we did so for each distortion level within each of the two face age categories. For the expanded discrimination task, we calculated the proportion of trials on which each participant selected the more expanded face in a face pair as being more stretched out than its same-identity counterpart.

Preliminary analyses indicated that task order did not have a significant effect on accuracy nor did it interact with any other variables, all *p*s > .10; thus we did not include order in any subsequent analyses. We conducted a 2 (task: normality, discrimination) x 2 (face age: young adult, older adult) x 3 (distortion: 10%, 20%, 30%) x 2 (participant age: young adult, older adult) mixed ANOVA to examine whether face age differentially influenced young and older adults' accuracy across distortion levels in the two types of task. As shown in Figure 2, young adults performed with greater accuracy than older adults in both tasks; however, both age groups were more accurate with young faces than older faces in the normality task but not in the discrimination task. There was a main effect of participant age, $F(1, 30) = 18.02$, $p < .001$, $\eta_p^2 = .38$, such that young adults' accuracy ($M = .82$, $SE = .02$) was higher than older adults' ($M = .68$, $SE = .02$). There was also a main effect of task, $F(1, 30) = 5.58$, $p = .03$, $\eta_p^2 = .16$, and a main effect of face age, $F(1, 30) = 15.46$, $p < .001$, $\eta_p^2 = .34$. Accuracy was higher in the discrimination task ($M = .78$, $SE = .03$) than in the normality task ($M = .72$, $SE = .02$), and for young adult faces ($M = .77$, $SE = .02$) than older adult faces ($M = .73$, $SE = .02$). Lastly, there

[1] An examination of accuracy at the level of specific face identities indicated that errors were randomly distributed across identities, with the difference in accuracy between expanded and compressed distortions not differing between young and older faces at each level of distortion, all *p*s > .30.

was a main effect of distortion level, $F(2, 60) = 150.38$, $p < .001$, $\eta_p^2 = .83$, such that accuracy increased as distortion level increased.

Both young and older adults were more accurate when tested with young faces compared to older faces—but only when judging normality. This task by face age interaction, $F(1, 30) = 23.63$, $p < .001$, $\eta_p^2 = .44$, was significant. The participant age by distortion, $F(2, 60) = 5.07$, $p = .01$, $\eta_p^2 = .14$, and the task by distortion, $F(2, 60) = 10.16$, $p < .001$, $\eta_p^2 = .25$, interactions were also significant. Most notably, there was a three-way interaction of task by face age by distortion, $F(2, 60) = 6.64$, $p = .002$, $\eta_p^2 = .18$. To examine the nature of the three-way interaction, we conducted a 2 (task) by 2 (face age) repeated-measures ANOVA for each distortion level to determine whether the differences in accuracy between young and older adult faces varied across task type at each level of task difficulty (see Figure 2). Because age of participant did not influence this interaction ($p > .10$), we collapsed across participant age in all subsequent analyses.

<Place Figure 2 around here>

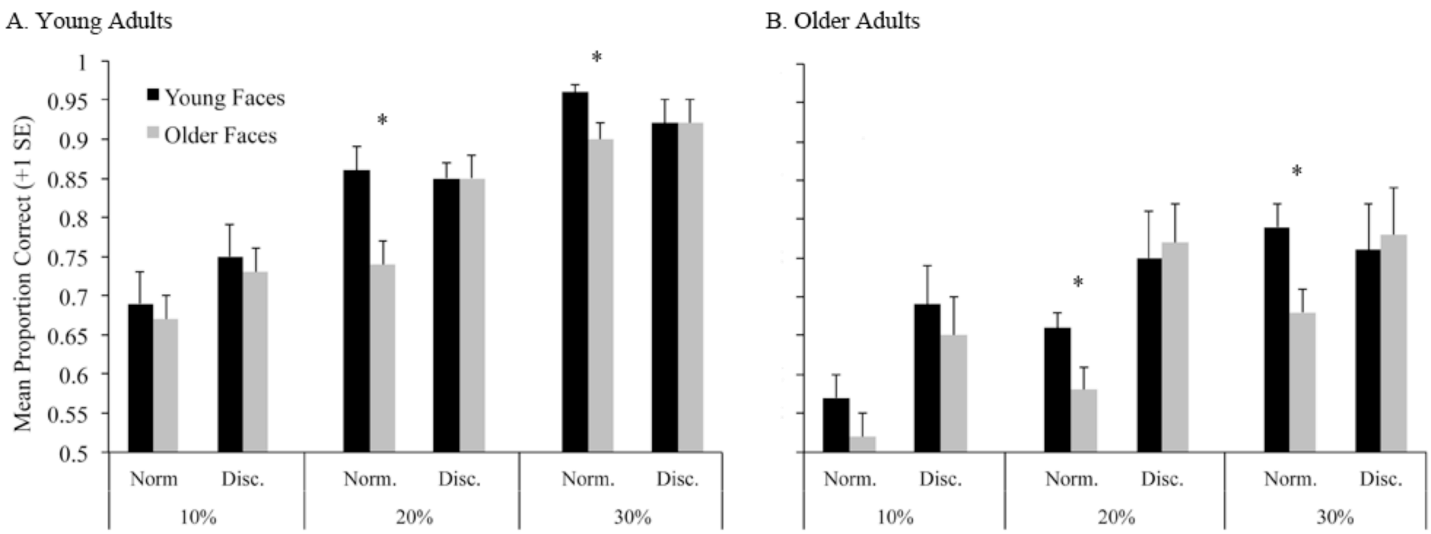

Figure 2. Mean proportion correct (+1 SE) for both the normality and discrimination tasks for young and older adult faces at each level of distortion for young (A) and older adult (B) participants in Experiment 1. Asterick indicates that $p < .05$.

For 10% face pairs, there was a main effect of task, $F(1, 31) = 11.35$, $p = .002$, $\eta_p^2 = .27$, such that accuracy was higher on the discrimination task ($M = .70$, $SE = .03$) than the normality task ($M = .61$, $SE = .02$). No other effects were significant, all *p*s > .10. For 20% face pairs, there was a main effect of task, $F(1, 31) = 9.40$, $p = .004$, $\eta_p^2 = .23$, a main effect of face age, $F(1, 31) = 10.42$, $p = .003$, $\eta_p^2 = .25$, and a significant two-way interaction, $F(1, 31) = 21.58$, $p < .001$, $\eta_p^2 = .41$. Paired-samples t-tests[2] revealed that accuracy was higher for young adult faces ($M = .76$, $SE = .02$) than for older adult faces ($M = .66$, $SE = .02$), $t(31) = -4.96$, $p < .001$, Cohen's $d = .74$, in the normality task, but not in the discrimination task ($M = .80$, $SE = .03$ and $M = .81$, $SE = .03$ for young and older adult faces, respectively, $t(31) = .39$, $p = .70$, Cohen's $d = .06$). For 30% face pairs, there was a main effect of face age, $F(1, 31) = 11.51$, $p =.002$, $\eta_p^2 = .27$, and a significant task by face age interaction, $F(1, 31) = 19.45$, $p < .001$, $\eta_p^2 = .39$. Paired-samples t-tests revealed that accuracy was higher for young adult faces ($M = .88$, $SE = .02$) than for older adult faces ($M = .79$, $SE = .03$), $t(31) = -4.93$, $p < .001$, Cohen's $d = .68$, in the normality task, but not in the discrimination task ($M = .84$, $SE = .04$ and $M = .85$, $SE = .03$ for young and older adult faces, respectively, $t(31) = .46$, $p = .65$, Cohen's $d = .05$).

Although participant age did not influence the task by face age by distortion interaction, we elected to separately examine young and older adults' accuracy in the two tasks to ensure that both age groups showed the same pattern of performance at the 20% and 30% distortion levels. As shown in Figure 2, for young adults, accuracy was higher for young than older faces in the normality task at both 20%, $t(15) = -4.31$, $p = .001$, Cohen's $d = 1.14$, and 30% distortions, $t(15) = -4.21$, $p = .001$, Cohen's $d = .95$. In contrast, there was no difference in accuracy for young and older faces in the discrimination task at both 20%, $t(15) = -.23$, $p = .82$, Cohen's $d = .09$, and

[2] All t-tests were two-tailed unless otherwise noted.

30% distortions, $t(15) = -.19$, $p = .85$, Cohen's $d = 0$. For older adults, accuracy was higher for young than older faces in the normality task at 20%, $t(15) = -2.76$, $p = .02$, Cohen's $d = .84$, and 30% distortions, $t(15) = -3.64$, $p = .002$, Cohen's $d = .95$. There was no difference in accuracy for young and older faces in the discrimination task at both 20%, $t(15) = .73$, $p = .48$, Cohen's $d = 0$, and 30% distortions, $t(15) = .62$, $p = .54$, Cohen's $d = .08$.

Discussion

Older adults were less accurate than young adults on both tasks, which supports previous work suggesting that face processing abilities decline with age (eg Crook and Larrabee 1992). For example, performance on the Cambridge Face Memory Test—a test that requires participants to learn multiple faces and then recognize those same faces under different viewing angles and lighting conditions, begins to steadily decline after 50 years of age (Bowles et al 2009). Although older adults made more errors than young adults in our task, both age groups showed the same pattern of results: despite no difference in the accuracy with which participants were able to discriminate young and older adult faces, judgments of normality were more accurate for young adult faces. Collectively, these results suggest that 1) the perceptual system is preferentially tuned towards the dimensions of young adult faces, perhaps as a result of early experience and 2) abundant experience with older faces later in life does not reverse this perceptual tuning.

The discrepant pattern of results between the normality judgment task and the discrimination task suggests that the deficit for older adult faces is related to decreased expertise in processing the dimensions along which older faces vary, which may reflect reduced efficiency in the use of norm-based coding. Although norm-based coding may facilitate identity discrimination (Armann et al 2011; but see Ng et al 2008), the normality judgment and discrimination tasks likely tapped into different perceptual processes, which may help explain the different pattern of results between the two tasks. The identification of a normal-looking face requires reliance on perceptual expertise, such as a well-defined norm(s) and sensitivity to both featural and configural facial information. In contrast, the identification of the expanded face in a pair does not require norm-based coding; instead, participants can simply use a feature-based approach and make their judgments based on the size of a single facial feature (eg the face with the largest nose). This process does not require expertise whereas high accuracy in the normality judgment task requires fine-tuned sensitivity to multiple facial dimensions. To illustrate this idea, imagine that participants are shown pairs of coffee mugs. In each pair, one coffee mug is undistorted while the other mug is expanded or compressed. Participants could easily identify the expanded coffee mug by focusing on which mug has the largest handle; however, it would be significantly more difficult for participants to identify which mug is more normal-looking unless they have had extensive experience in examining mugs of different shapes and sizes. In this same way, participants in our experiment may be fully capable of identifying expanded young and older faces but may lack the expertise and sensitivity required to gauge the normality of older relative to young faces.

To test the hypothesis that the normality judgment task and the expanded discrimination task tapped into different perceptual processes, we conducted a second experiment in which half of the participants judged the normality and expandedness of upright faces and half completed these same two tasks with inverted faces. Only young adults participated. The primary hypothesis of Experiment 2 was that inversion would differentially affect performance between the two task types such that inversion would reduce the accuracy of normality judgments to a greater extent than the accuracy of discrimination.

Experiment 2

The purposes of Experiment 2 were two-fold. Our primary goal was to investigate whether inversion would affect the accuracy of normality judgments to a greater extent than discrimination accuracy. Inversion impairs recognition of faces more than recognition of most other objects (Yin 1969) and a large inversion effect is considered a marker of perceptual expertise (Kuefner et al 2008; reviewed in Maurer et al 2002). Inversion disrupts two markers of expert processing: holistic perception (Hole 1994; Mondloch and Maurer 2008; Tanaka and Farah 1993) and sensitivity to feature spacing (Freire et al 2000; Mondloch et al 2002); sensitivity to feature shape is less impaired (Mondloch et al 2010b; Rhodes et al 2006), perhaps because inverted faces are processed by shape-generic rather than face-specific mechanisms (Susilo et al 2010). Thus if performance on the normality judgment task reflects perceptual expertise to a greater extent than performance on the discrimination task, then 1) inversion should impair performance on the normality judgment task to a greater extent than performance on the discrimination task; and 2) it should reduce or eliminate the advantage for young adult faces on the normality judgment task.

Our secondary goal was to replicate the original finding with upright faces using a different set of young and older adult identities and without providing our participants with an explicit definition of an “expanded” face. It is possible that due to the limited number of identities used in Experiment 1, idiosyncratic differences in the original identities may have led to the difference in accuracy for young and older adult faces in the normality task (eg the majority of the older adult identities could have had abnormally large noses and thus the compressed distortion could have moved the faces closer to the prototype). By increasing the number of identities used across the two experiments, we can ensure that idiosyncratic differences in the stimuli do not account for our pattern of results. Furthermore, in Experiment 1, participants were provided with a verbal description of an expanded face and it is possible that this description may have decreased the difficulty of the discrimination task relative to the normality task. Thus in Experiment 2, we did not provide participants with this formal definition and instead allowed them to form their own definition of expandedness. We hypothesized that despite these changes to the task, participants would show an advantage for upright young adult faces in the normality task but not in the discrimination task, which would be consistent with the results of Experiment 1.

Method

Participants. Thirty-two Caucasian undergraduate students from Brock University (30 female; *M* = 19.31 years, age range = 18-27) participated in this experiment. All participants received research credit or a small honorarium for their participation in the study. Participants completed a questionnaire assessing their weekly face-to-face contact with both young and older adults. Participants reported an average of 55.94 hours per week interacting with young adults and 7.11 hours per week interacting with older adults.

Materials. Both practice and test stimuli consisted of colored photographs of Caucasian young (age range = 18-26) and older adult faces (age range = 72-80). Stimuli were acquired from the Center for Vital Longevity Face Database (Minear and Park 2004) or from photographs taken in our lab and were resized such that the distance from hairline to chin was approximately 450 pixels. Twelve young adult (6 female) and 12 older adult (6 female) faces were used as test stimuli; these identities differed from those used in Experiment 1. We used the spherize tool in Adobe Photoshop Version 8.0 to expand and compress the internal features of each face; using this technique, we created four new versions of each identity (-30%, -20%, +20%, +30%). We did not include ±10% distortions because Experiment 1 demonstrated that there were no differences in accuracy between young and older faces at ±10% distortions for either the normality judgment or the discrimination task. For each identity, we then created four face pairs such that each level of distortion was paired with its undistorted same-identity counterpart (eg an undistorted face was paired with a +20% face of the same identity). The left/right positioning of the undistorted member of each pair was counterbalanced such that for each age of face and each distortion level (eg undistorted paired with -30%), the undistorted face appeared on the left for half of the trials. To create the inverted pairs, each upright face pair was simply inverted using Adobe Photoshop. The same identities and pairings were used in both the normality judgment task and the expanded discrimination task.

An additional eight identities (four older adult) were used as practice stimuli. Four practice trials (two older adult) consisted of a ±60% face paired with an undistorted face of the same identity. The distorted face appeared on the right on two of these trials. An additional four practice trials (two older adult) consisted of a ±30% face paired with an undistorted face of the same identity. The distorted face appeared on the right on two of these trials. Both upright and inverted versions were created for each of the practice face pairs. The same practice trials were used in the normality and discrimination tasks. Similar to Experiment 1, all stimuli were presented and responses were recorded using SuperLab 4.5 software.

Procedure. The procedure received clearance from the Research Ethics Board at Brock University, and participants gave written informed consent prior to their participation. Upon arrival to the lab, participants were seated approximately 60 cm in front of a 23-inch computer screen. For half of the participants, all face pairs in both the normality judgment task and the expanded discrimination task were shown in an upright orientation, and for the other half of participants, all face pairs were shown in an inverted orientation. In both orientation groups, the order in which participants completed the two tasks was counterbalanced such that half of the participants completed the normality judgment task followed by the expanded discrimination task, and the other half completed the two tasks in the reverse order.

Prior to beginning the experiment, participants were told that they would be shown pictures of faces, some of which might appear unusual, as though the person were looking at a concave or convex mirror at a funhouse. They were then shown an image of a person's reflection in a concave mirror as well as an image of a person's reflection in a convex mirror.

Following this introduction to the distortions used in the experiment, participants completed the first of the two tasks in the study. In the normality judgment task, participants were told that they would be shown a series of face pairs and that they were to select the more normal-looking face in each pair. Prior to testing, participants completed a series of practice trials to ensure that they understood task instructions. The first four practice trials consisted of an undistorted face paired with a ±60% face of the same identity, and the second four practice trials consisted of an undistorted face paired with a ±30% face of the same identity. Each face pair was shown for 3000 ms, and participants were asked to verbally indicate whether the face on the right or on the left appeared more normal looking. For participants in the upright condition, all face pairs in the practice trials were shown in an upright orientation. In contrast, participants in the inverted condition first completed the same eight upright trials as those in the upright condition and then completed these eight trials in an inverted orientation. This additional practice was given to those in the inverted condition to ensure that they understood the facial manipulations before the task was made more difficult by inverting the faces. Following the practice trials, participants were shown 96 face pairs (12 identities across 4 levels of distortion for each of the two age categories). The order in which the pairs were shown was fully randomized. Each trial consisted of a 500-ms fixation cross followed by a face pair that appeared for 3000 ms. The face pair was then replaced by a screen prompting participants to select the more normal-looking face in each pair. Participants indicated via joystick whether the face on the left or right was more normal looking, and they had an unlimited amount of time to respond. Once participants indicated their response, the next trial began.

The procedure of the expanded discrimination task was identical to that of the normality judgment task, except that participants were asked to select the more expanded face in each pair rather than identify the more normal-looking face. Rather than providing participants with a verbal description of an expanded face, participants were told that an expanded face was similar to the image that was previously shown to them of a person's reflection in a convex mirror.

Results

Similar to Experiment 1, to simplify our analysis, we collapsed across expanded and compressed trials within each distortion level. For the normality judgment task, we calculated the proportion of trials on which each participant selected the undistorted face in a face pair as being more normal than the distorted face; we did so for each distortion level within each of the two face age categories. For the expanded discrimination task, we calculated the proportion of trials on which each participant selected the more expanded face in a face pair as being more stretched out than its same-identity counterpart. Preliminary analyses indicated that task order did not have a significant effect on accuracy nor did it interact with any other variables, all ps > .10; thus we did not include order in any subsequent analyses.

Our primary goal was to examine whether inversion affected the accuracy of normality judgments to a greater extent than the accuracy of discrimination. We conducted a 2 (task:

normality, discrimination) x 2 (face age: young adult, older adult) x 2 (distortion: 20%, 30%) x 2 (orientation: upright, inverted) mixed ANOVA with accuracy as the dependent variable (see Figure 3). There was a main effect of task, $F(1, 30) = 41.10$, $p < .001$, $\eta_p^2 = .58$, such that accuracy was higher in the discrimination task ($M = .90$, $SE = .02$) than in the normality task ($M = .78$, $SE = .01$). There was also a main effect of face age, $F(1, 30) = 10.31$, $p = .003$, $\eta_p^2 = .26$, and a main effect of distortion, $F(1, 30) = 76.82$, $p < .001$, $\eta_p^2 = .72$. Accuracy was higher for young adult faces ($M = .85$, $SE = .02$) than older adult faces ($M = .82$, $SE = .02$), and for 30% distortions ($M = .88$, $SE = .02$) than 20% distortions ($M = .79$, $SE = .02$). Lastly, there was a main effect of orientation, $F(1, 30) = 7.72$, $p = .009$, $\eta_p^2 = .21$, such that accuracy was higher for those in the upright condition ($M = .88$, $SE = .02$) than for those in the inverted condition ($M = .80$, $SE = .02$).

<Place Figure 3 around here>

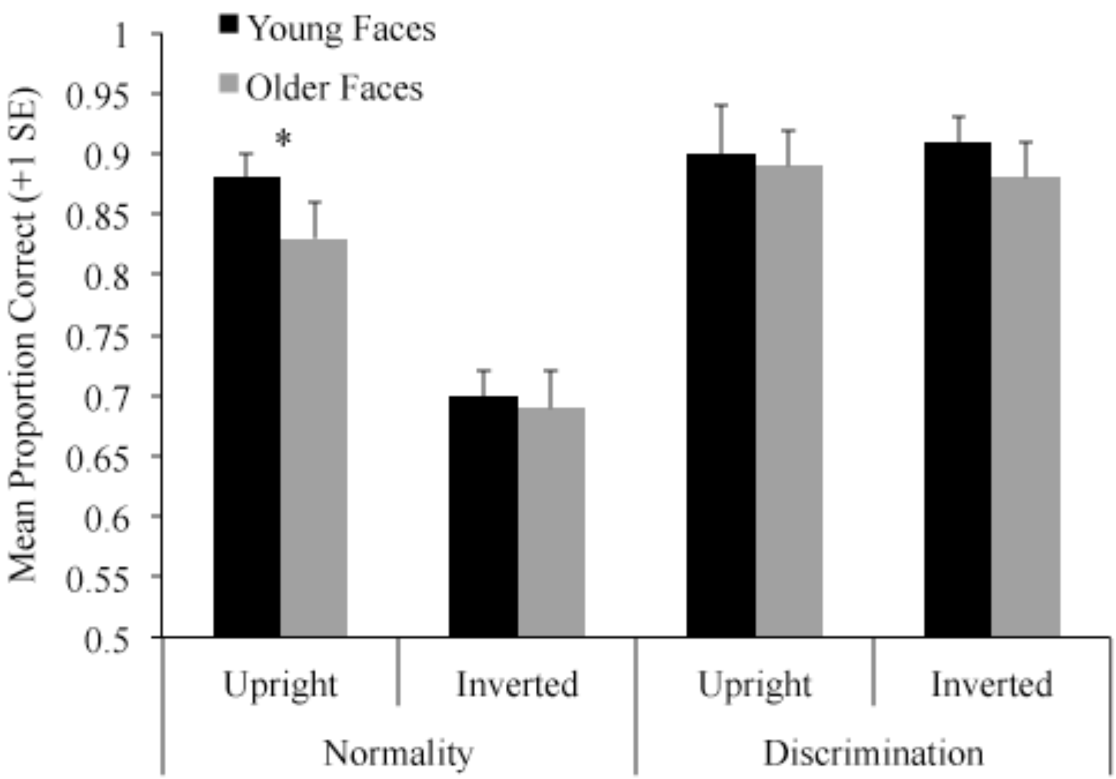

Figure 3. Mean proportion correct (+1 SE) for both the normality and discrimination tasks for young and older adult faces in the upright and inverted orientations (Experiment 2). Asterick indicates that $p < .05$.

Most notably, the predicted task by orientation interaction was significant, $F(1, 30) = 18.07$, $p < .001$, $\eta_p^2 = .38$, consistent with our hypothesis that inversion would impair performance on the normality judgment task more than performance on the discrimination task. In the discrimination task, there was no difference in accuracy between participants in the upright condition ($M = .90$, $SE = .03$) and participants in the inverted condition ($M = .90$, $SE = .02$), $t(30) = -.07$, $p = .95$, Cohen's $d = 0$. However, in the normality judgment task, accuracy was higher for participants in the upright condition ($M = .85$, $SE = .02$) than for participants in the inverted condition ($M = .70$, $SE = .02$), $t(30) = 5.54$, $p < .001$, Cohen's $d = 1.76$. There was also a significant task by distortion interaction, $F(1, 30) = 8.89$, $p = .006$, $\eta_p^2 = .23$, and a marginally significant three-way interaction of task by distortion by orientation, $F(1, 30) = 3.57$, $p = .07$, $\eta_p^2 = .11$. No other effects were significant, all *p*s > .10; most notably none of the two- and three-way interactions with face age were significant, *p*s > .32 and *p*s > .14 respectively.

The significant task by orientation interaction and our a priori hypotheses based on Experiment 1 compelled us to conduct separate 2 (task: normality, discrimination) x 2 (face age: young adult, older adult) repeated-measures ANOVAs for participants tested with upright versus inverted faces. Our goal here was to examine whether inversion reduced or eliminated the advantage for young adult faces in the normality task. For participants tested with upright faces, there was a main effect of face age, $F(1, 15) = 10.31$, $p = .006$, $\eta_p^2 = .41$, such that accuracy was higher for young adult faces ($M = .89$, $SE = .02$) than for older adult faces ($M = .86$, $SE = .02$). There was no main effect of task, $F(1, 15) = 1.85$, $p = .19$, $\eta_p^2 = .11$, but the predicted task by face age interaction was marginally significant, $F(1, 15) = 3.48$, $p = .08$, $\eta_p^2 = .19$. To examine the nature of the marginally significant task by face age interaction, we conducted planned paired-samples t-tests comparing accuracy for young adult versus older adult faces in both the normality task and the discrimination task. In the normality task, accuracy was higher for young adult faces (*M* = .88, *SE* = .02) than for older adult faces (*M* = .83, *SE* = .02), *t*(15) = -3.05, *p* = .01, Cohen's *d* = .53. In contrast, in the discrimination task, there was no difference in accuracy for young adult (*M* = .90, *SE* = .04) versus older adult faces (*M* = .89, *SE* = .03), *t*(15) = -.88, *p* = .39, Cohen's *d* = .08. Although the task by face age interaction only approached significance, the results of the t-tests are consistent with the results of Experiment 1.

For participants in the inverted condition, there was a main effect of task, $F(1, 15)$ = 76.85, $p < .001$, $\eta_p^2 = .84$, such that accuracy was higher in the discrimination task (*M* = .90, *SE* = .02) than in the normality task (*M* = .70, *SE* = .02). The main effect of face age was not significant, $p = .13$, $\eta_p^2 = .15$, and the task by face age interaction did not approach significance, $p = .74$, $\eta_p^2 = .01$.

Discussion

The key finding of Experiment 2 was that inversion differentially affected performance on the normality judgment and the discrimination tasks. There was no difference in accuracy between participants in the upright and inverted conditions in the discrimination task, but accuracy was higher for participants in the upright condition than in the inverted condition in the normality judgment task. These results suggest that the two tasks tap into different perceptual processes; performance in the normality judgment task reflects perceptual expertise and requires fine-tuned sensitivity to multiple dimensions of the face (eg distance between the eyes) whereas the discrimination task requires sensitivity only to featural information and performance is not impaired by inversion. This interpretation is consistent with inversion having two other important effects. Inversion eliminated the significant main effect of face age seen in the upright condition; greater expertise for young faces is limited to their canonical upright orientation. Inversion also eliminated any tendency for a task by face age interaction.

The results of the upright condition of Experiment 2 paralleled the results of Experiment 1 and support our conclusion that despite being able to discriminate young and older adult faces with comparable accuracy, adults show greater sensitivity to the dimensions along which young faces vary compared to older faces. The task by face age interaction only approached significance in Experiment 2, likely because the power of Experiment 2 was less than that of Experiment 1. In Experiment 1 both young and older participants were combined ($n = 32$) to examine the effect of face age on normality judgments and discrimination whereas in Experiment 2 only 16 young adults were tested in the upright condition to examine this same effect. Nonetheless, planned t-tests showed that judgments of normality were more accurate for young adult faces than older adult faces whereas discrimination accuracy did not differ between the two face ages. This replication indicates that the findings from Experiment 1 were not unique to the 24 identities used in the first experiment and that the verbal description that we provided for an expanded face in Experiment 1 did not bias our results by making the discrimination task easier than the normality judgment task. In Experiment 2, participants were not given a verbal description of "expandedness" and instead were shown only the pictures of a person looking in a convex and a concave mirror before they completed both tasks. Thus in Experiment 2 participants formed their own definition of "expandedness", yet the results were comparable to those of Experiment 1.

General Discussion

Collectively, our results demonstrate evidence for a young adult face advantage in judgments of normality but not discrimination. This advantage for young adult faces was absent when faces were shown in an inverted orientation, which suggests that greater expertise for young relative to older faces may underlie this effect. Enhanced sensitivity to the dimensions along which young relative to older adult faces vary may be the product of the early and continuous experience we receive with young faces (Macchi Cassia 2011). Our finding of a comparable advantage for young adult faces among older adults suggests that abundant experience with older faces later in life does not reverse this perceptual tuning.

It is well established that perceptual narrowing begins during infancy. By 6 to 9 months of age infants discriminate own-species and own-race faces more accurately than monkey faces and other-race human faces (Kelly et al 2007; Pascalis et al 2002), although this narrowing can be prevented by experience (Pascalis et al 2005; see also Bar-Haim et al 2006). Likewise, by 3 years of age children recognize young adult faces more accurately than child faces (Macchi Cassia et al 2012), perhaps because young adult faces are typically the most frequently encountered during infancy (Rennels and Davis 2008). This narrowing can also be prevented by exposure to young siblings (Macchi Cassia et al 2009a; Macchi Cassia et al 2012). Given the extent to which perceptual narrowing occurs for the most frequently encountered face categories in infancy and childhood, it is possible that early experience with young adult faces enhances sensitivity to the dimensions along which young adult faces vary relative to the dimensions along which older adult faces vary. According to the norm-based coding model (Valentine 1991), individual faces differ on a variety of dimensions (eg distance between the eyes), and each dimension is represented as a unique vector in a multidimensional face space. Our results suggest that face space is optimized for young adult faces and that sensitivity to the dimensions that code for faces that belong to other age categories (notably older adult faces) is less well refined.

Our finding that even older adults showed reduced accuracy in gauging the normality of older adult faces indicates that abundant experience with older faces later in life does not enhance sensitivity to deviations from the average in older adult faces. Just as the other-race effect can be reversed during childhood but not adulthood (Sangrigoli et al 2005), the perceptual system may become specialized for young adult faces early in life and be incapable of acquiring comparable sensitivity to other-age faces later in adulthood. This interpretation contrasts with the recent finding that prolonged experience with elderly individuals equates discrimination accuracy for young and older faces in a two-alternative forced-choice match-to-sample task (Proietti et al 2013) and with studies showing evidence that extensive experience with child (Hills 2012; Hills and Lewis 2011) or older adult faces (Anastasi and Rhodes 2006) can mitigate or eliminate the recognition advantage for young adult faces. For example, in a recent meta-analysis, Rhodes and Anastasi (2012) report evidence for an own-age recognition bias in older adults. Furthermore, senior citizens who report greater daily life contact with older adults than young adults show an own-age bias whereas senior citizens who report comparable daily contact with young and older adults do not (Wiese et al 2012), a pattern of results which suggests that significant meaningful exposure to older adults is sufficient to reverse the young adult recognition advantage that may have been acquired early in life. Nonetheless, evidence for an own-age bias in older adults is inconsistent and not found across all studies (Anastasi and Rhodes 2005; Fulton and Bartlett 1991; Rhodes and Anastasi 2012).

Although the results of some studies suggest that face space maintains its flexibility throughout life, it is important to note that the aforementioned studies investigated recognition for own- and other-age faces whereas our study directly examined sensitivity to deviations from the norm and did not have a memory component. In our experiment, participants showed comparable accuracy in discriminating young and older face pairs because they could simply rely on a shape-generic feature-based approach and make their judgments based on the size of a single facial feature. Likewise, adults who have ample experience with elderly individuals may become more sensitive to feature differences among older faces and show enhanced recognition accuracy for older faces relative to inexperienced adults without a corresponding improvement in norm-based coding and other markers of perceptual expertise (eg holistic processing, sensitivity to feature spacing).

One marker of expertise is sensitivity to differences among faces in the spacing of features, a sensitivity that is greater for own-race faces than other-race faces (Mondloch et al 2010a), houses (Robbins et al 2011), and monkey faces (Mondloch et al 2006) and is impaired significantly by inversion (Mondloch et al 2002; reviewed in Maurer et al 2002). Future studies could examine the hypothesis that extensive experience with older faces improves accuracy in detecting featural changes to a greater extent than accuracy in detecting spacing changes in older faces by manipulating the featural (eg changing the shape of the eyes) or spacing (eg moving the eyes closer together) information in a set of young and older adult faces and examining performance in a same/different task (see Mondloch et al 2010a). Older adults and young adults who have extensive experience with elderly individuals may show comparable accuracy for young and older faces in the featural condition; however, accuracy for young faces may be higher than that for older faces in the spacing condition despite abundant experience with older adult faces.

According to this hypothesis, experience with older adult faces may increase accuracy on a recognition task without influencing how older adult faces are represented (ie without increasing sensitivity to deviations from a prototypical face). Identity aftereffects provide an additional tool with which to examine whether recognition of older adult faces depends on norm-based coding. Past research (eg Rhodes and Jeffery 2006) has repeatedly shown that young adult face identities are coded relative to a norm, but no study has examined whether older adult identities are coded in a similar manner. Furthermore, identity aftereffects for young adult faces of different categories indicate that face identity is coded relative to sex- (Rhodes et al 2011) and race-specific (Armann et al 2011) norms; thus it is possible that face identity is also coded relative to age-specific norms. To bridge the gap between recognition tasks in which older adults often show an own-age advantage (see above) and our finding of a young face advantage for normality judgments, a future study should examine whether the identity of older adult faces is coded relative to an age-generic (applied to all adult faces but resembling a young adult face) or an age-specific (older face) norm.

The other-age effect is frequently considered analogous to the other-race effect, as both effects are considered examples of the same underlying phenomenon (eg Wiese et al 2012). Two potential explanations have been posed to account for the other-race effect, and by extension, the other-age effect. The perceptual expertise account emphasizes the importance of experience in shaping the face processing system; exposure to a given face category early in life leads to enhanced sensitivity to featural and spacing differences among faces from this category and to a well defined prototype (eg Hayward et al 2008; Mondloch et al 2010a). In contrast, the socio-cognitive account argues that initial in- and out-group biases lead to different processing strategies during the encoding of faces from two categories. Faces classified as belong to one's in-group are processed at the highly specific individual level whereas faces classified as out-group members are processed at the more superficial categorical level (Sporer 2001). Our results support the perceptual expertise account and suggest that the perceptual processing system may be optimized for the category of face with which we have the most experience (ie young adult faces). Our results are inconsistent with the socio-cognitive model because in-group biases cannot account for our findings. Despite belonging to the older adult population, the senior citizens in our study showed enhanced accuracy in detecting normality in young adult faces relative to faces of their own age. Thus merely categorizing older adults as in-group members does not eliminate the effect of early perceptual tuning. We acknowledge, however, that motivational influences may have contributed to the increased accuracy for young adult faces in that both young and older adults have been shown to ascribe more positive attitudes to young versus older adults (He et al 2011).

Despite the commonalities between the other-age effect and the other-race effect, one key difference between the two effects is that race remains consistent throughout the lifespan whereas age does not. Older adults represent a unique population because they have belonged to all ages throughout the lifespan; they have gained experience with numerous face ages and have belonged to each of the different age-related social categories throughout life. Thus by studying older adults it is possible to examine the cumulative effects of experience with different face ages throughout life as well as the specific effects of recent exposure to and social identification with older adults. It is not possible to examine such effects with regard to race, as one's race never changes. Furthermore, older adult faces are unique as a face category because these faces (ie these specific identities) were likely distributed around and close to the young adult prototype earlier in development but gradually acquired novel dimensions and moved systematically away from that prototype as a function of the physical and structural changes that accompany aging. This is in contrast to other-race faces, which remain consistent and do not gradually acquire the dimensions of own-race faces.

Past research has demonstrated that adults rely on dissociable face prototypes that represent the different face categories encountered in the environment. Such results stem from adaptation studies that have yielded evidence for category-contingent opposing aftereffects. Following repetitive exposure to two face categories that are distorted in opposite directions (eg expanded Chinese faces and compressed Caucasian faces), adults' judgments of normality and attractiveness shift in opposite directions, demonstrating that the norms for two face categories are concurrently moving in opposition to one another (Jaquet et al 2008). Such effects have been found for faces that differ according to race (Jaquet et al 2008; Little et al 2008), sex (Jaquet and Rhodes 2008; Little et al 2005), and orientation (Rhodes et al 2004). Although one study has found evidence for dissociable norms for adult and infant faces (Little et al 2008), no study to date has examined whether young and older adult faces are processed with regard to dissociable prototypes. Schweinberger et al (2010) recently demonstrated that adaptation to older and young faces biases the subjective perception of the facial age of test faces; however, no study has yet investigated whether simultaneous adaptation to young and older faces distorted in opposite directions produces age-contingent opposing aftereffects. One possibility is that there is a single norm that codes for both young and older adult faces and age is represented as a dimension within face space or as a set of values along multiple dimensions (eg nose size, amount of wrinkles). According to this model, older adult faces are located quite distant from the prototype and are thus poorly encoded and recognized. A second possibility is that there are separable prototypes for young and older adult faces; however, the older adult prototype is poorly defined and located in the periphery of face space. Future studies should examine whether there are dissociable prototypes for young versus older adult faces and the extent to which these prototypes overlap with one another. Regardless of which model best describes our representation of older adult faces, our results indicate that older adult faces are less well represented than young adult faces.

In summary, we used normality judgments as a tool to examine the refinement of young and older adults' representation of young versus older adult faces. Despite no difference in the accuracy with which participants were able to discriminate young and older adult faces, judgments of normality were more accurate for young than older faces, which may be reflective of increased sensitivity to the dimensions along which young relative to older adult faces vary. Even older adults appear to rely on a face space that is optimized for the dimensions of young faces, which suggests that abundant experience with older faces later in life does not reverse early perceptual tuning. This deficit in the perception of older faces may contribute to an increased tendency to perceive all senior citizens as "being the same" and not having individual personalities and preferences. Given the projected growth in the senior citizen population, it is thus important to focus future research on how face perception varies as a function of participant and facial age and how seniors are perceived by younger members of society and by their peers.

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