Representing Young and Older Adult Faces: Shared or Age-Specific Prototypes?

Lindsey A. Short[1,2], Valentina Proietti[1], & Catherine J. Mondloch[1,3]

[1]Department of Psychology, Brock University, St. Catharines, Canada

[2]Department of Psychology, Redeemer University College, Ancaster, Canada

[3]ARC Centre of Excellence in Cognition and its Disorders, School of Psychology, University of Western Australia

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Address Correspondence to:

Lindsey A. Short
Department of Psychology
Redeemer University College
777 Garner Road East
Ancaster, Ontario
Canada L9K 1J4
e-mail: lshort@redeemer.ca
Phone: (905) 648-2139 ext. 4249
Fax: (905) 648-2134

Abstract

Young adults recognize young adult faces more accurately than older adult faces and are more sensitive to how individual young faces deviate from a norm/prototype. Here we used an adaptation paradigm to examine whether young and older adult faces are represented by separable norms and the extent to which the coding dimensions for these two categories overlap. In Experiment 1, following adaptation to oppositely distorted young and older faces (e.g., expanded young and compressed older faces), adults' normality judgments simultaneously shifted in opposite directions for the two face categories, providing evidence for separable norms. In Experiment 2, participants were adapted to distorted faces from a single age category (e.g., compressed young); aftereffects transferred across face age but were larger for the face age that matched adaptation. Collectively, these results provide evidence that young and older faces are processed with regard to separable norms that share some underlying coding dimensions.

Keywords: aftereffects, face age, face prototypes, face space

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Expertise in face processing has traditionally been attributed to the use of norm-based coding, a process in which individual faces are encoded relative to a face prototype/norm that represents the average of all faces previously encountered (Valentine, 1991). Individual faces differ on a variety of dimensions, and each dimension is represented as a unique vector in a multidimensional face space. The dimensions have been characterized as specific features and the distance between them (e.g., width of mouth, distance between the eyes) or as more abstract dimensions (e.g., eigenfaces; Hancock, Burton & Bruce, 1996). Within this face space, individual faces are represented as distinct points and are organized such that the farther the face is from the norm, the more distinctive and the less attractive it appears (Potter & Corneille, 2008; Rhodes & Tremewan, 1996; Valentine, Darling, & Donnelly, 2004). There is ample evidence that norm-based coding underlies the perception of face identity (e.g., Robbins, McKone, & Edwards, 2007; but see Ross, Deroche, & Palmeri, 2014) and has a functional role in face recognition (Dennett, McKone, Edwards, & Susilo, 2014; Rhodes, Jeffery, Taylor, Hayward, & Ewing, 2014), perhaps by reducing redundancy in the information shared by all faces and thus freeing neural resources and allowing for greater sensitivity to the distinctive characteristics of individual faces (Rhodes & Leopold, 2011; Rhodes, Watson, Jeffery, & Clifford, 2010; Webster & MacLeod, 2011).

The face prototype is dynamic and continuously updated by experience, as evidenced by studies using both behavioral (e.g., Rhodes, Jeffery, Watson, Clifford, & Nakayama, 2003; Webster & MacLin, 1999) and neural (Fu et al., 2014) adaptation paradigms in which repeated exposure to faces distorted in a similar direction (e.g., features expanded outward) produces a temporary shift in the prototype. This shift subsequently alters perceived attractiveness of other

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faces such that unaltered faces appear distorted in the opposite direction while similarly distorted faces appear more attractive. These perceptual phenomena, called figural aftereffects, demonstrate the malleability of the prototype and provide evidence that the norm is continuously recalibrated based on experience.

Although it was initially assumed that all faces are encoded relative to a single face prototype (Valentine, 1991), recent research has revealed that adults possess multiple face prototypes that represent the different face categories encountered in their environment (e.g., race). Evidence for such category-contingent prototypes stems from studies examining opposing aftereffects. Following exposure to face categories distorted in opposite directions (e.g., compressed Caucasian and expanded Chinese faces), adults' judgments of attractiveness/normality simultaneously shift in opposite directions, which is possible only if these faces are represented with regard to separable norms and at least some category-specific coding dimensions (e.g., Jaquet, Rhodes, & Hayward, 2008). Reliance on such separable norms may enhance recognition and increase coding efficiency (Rhodes et al., 2011); for example, identification thresholds are lower around a race-specific relative to a mixed-race/race-generic average (Armann, Jeffery, Calder, & Rhodes, 2011). Opposing aftereffects indicate that faces from different categories are coded with regard to some category-specific dimensions; however, partial transfer of aftereffects studies reveal that there is also some overlap in the coding dimensions used for these faces (Jaquet & Rhodes, 2008). For example, when adults are adapted to distorted faces of one race, significant aftereffects emerge for a face race that was never shown during adaptation but these aftereffects are smaller than those of the adapted race (Jaquet et al., 2008).

Opposing aftereffects have been found for faces that differ based on race (Jaquet et al., 2008; Little, DeBruine, Jones, & Waitt, 2008), sex (Jaquet & Rhodes, 2008; Little, DeBruine, & Jones, 2005), orientation (Rhodes et al., 2004), and species (Little et al., 2008). However, a face category that has received little attention in the opposing aftereffects literature is face age. This is surprising given that age impacts the accuracy with which a face is recognized; enhanced recognition for young relative to older adult faces is a robust phenomenon among young adults (reviewed in Rhodes & Anastasi, 2012; see Kuefner, Macchi Cassia, Picozzi, & Bricolo, 2008 for a similar advantage for young adult relative to child faces), suggesting that young adults have a more well refined representation of own-age faces likely resulting from abundant experience with young adult faces early in life (Rennels & Davis, 2008). A similar advantage for own-age faces has not always been found among older adults. Although a recent meta-analytic review by Rhodes and Anastasi (2012) showed a small own-age bias among older adult participants, many individual studies have reported comparable recognition for young and older adult faces among older adults (Proietti, Macchi Cassia, & Mondloch, 2014; Short, Semplonius, Proietti, & Mondloch, 2014b; Wallis, Lipp, & Vanman, 2012; Wiese, Schweinberger, & Hansen, 2008; Wolff, Wiese, & Schweinberger, 2012). Evidence that older adults continue to perform well with young adult faces despite minimal recent exposure to young faces suggests that continuous abundant experience with young adult faces across the lifespan sets up and maintains a life-long perceptual bias for these faces (Macchi Cassia, 2011). Consistent with this argument are findings that both young and older adults show greater holistic processing for young relative to older faces (Wiese, Kachel, & Schweinberger, 2013) and that enhanced discrimination for young relative to older faces emerges as early as three years of age (Proietti, Pisacane, & Macchi Cassia, 2013; Short, Mondloch, & Hackland, 2015). Such performance benefits for young adult faces may be indicative of reliance on a face space that is optimized for the dimensions of young adult faces.

The purpose of the current set of studies was to investigate whether young and older adult faces are represented by separable prototypes and the extent to which the coding dimensions for these two categories overlap. To date, only three studies have investigated face age as a dimension susceptible to adaptation; these studies have demonstrated that young adults' perception of face age is altered following adaptation to a young or older adult face (e.g., a test face appears younger after adaptation to an older face than after adaptation to a young face; O'Neil & Webster, 2011; Schweinberger et al., 2010) but not after adaptation to a middle-aged face (O'Neil, Mac, Rhodes, & Webster, 2014). More directly related to the topic of the present investigation is a study conducted by Little and colleagues (2008, Exp. 2), which found that young adults exhibited age-contingent opposing aftereffects for infant versus adult faces. However, no study to date has examined whether opposing aftereffects emerge for young versus older faces. Better understanding the representation of young and older faces in face space might shed light on the underlying causes of differential recognition for adult faces of different ages.

Although it has been suggested that the dimensions of face space may be more finely tuned for young than older adult faces (e.g., Macchi Cassia, 2011), only one study to date has directly examined the representation of young and older faces in multidimensional face space. Short and Mondloch (2013) showed participants young and older adult face pairs comprising an undistorted face paired with an expanded or compressed version of the same identity. Participants were asked to indicate which member of each pair appeared more normal looking (assessing their ability to rely on a well-defined norm) and which appeared more expanded (assessing discrimination). Both young and older adults were more accurate in judging the normality of young adult faces, despite being able to discriminate young and older faces with equal ease. This suggests that the perceptual system may be preferentially tuned to the dimensions of young adult faces, perhaps because older faces are 1) clustered together in an area distant from a norm in which age is simply represented as a dimension(s) or 2) processed with regard to a poorly defined older norm that is separate from a well-specified young adult norm. It is currently unknown which of these two possibilities best describes how young and older faces are represented in face space, and thus the current study was designed to address this question.

In Experiment 1, we used an opposing aftereffects paradigm to examine whether young adults show evidence for the use of separable young and older adult face prototypes. Participants were adapted to young and older faces distorted in opposite directions; before and after adaptation, participants made normality judgments of young and older face pairs that were moderately expanded and compressed. We hypothesized that similar to what has been found for adult versus infant faces (Little et al., 2008, Exp. 2), participants would show opposing aftereffects for young versus older faces. In Experiment 2, we examined the degree of overlap between the coding dimensions used for young and older faces. To that end, we employed a transfer of aftereffects paradigm to determine the extent to which aftereffects generalize across face age categories. Participants were adapted to distorted faces from a single age category and judged the normality of both young and older adult face pairs before and after adaptation. Complete transfer of aftereffects across age categories (i.e., no difference in the magnitude of aftereffects for the face age that was adapted versus the face age that was not) would suggest fully overlapping representations and coding dimensions for young and older faces. In contrast, no transfer of aftereffects across face age would indicate that the norms for young and older faces are entirely separable from one another. Lastly, partial transfer of aftereffects would indicate separable age-specific representations that share some underlying dimensions.

Experiment 1

Method

Participants. Forty Caucasian undergraduate students from Brock University (39 female; *M* = 20.18 years, age range = 17-27) participated in this experiment and were included in the analyses. Participants received research credit or a small honorarium for their participation. All participants completed a questionnaire assessing their experience with individuals belonging to different age groups. The survey contained specific inquires about the composition of the participant's family (e.g. "Think about family members with whom you have regular contact (at least once per month. How many of those people are in each of the following age groups?"), and about the weekly face-to-face interaction with young and older adults (e.g. "Please estimate how many hours you usually spend per week interacting with people in each of the following age groups"). Participants reported an average of 50.78 hours per week interacting with young adults and 6.00 hours per week interacting with older adults [range = xx to xx]. An additional three participants were tested but excluded from all analyses due to experimenter error (n = 2) or failure to pass criterion trials (n = 1; see below).

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Materials. Stimuli consisted of colored photographs of Caucasian young (age range = 19-27 years) and older adult female faces (age range = 70-75 years). All stimuli were acquired from the Center for Vital Longevity Face Database (Minear & Park, 2004) and resized such that the distance from the hairline to chin was approximately 450 pixels for test and criterion faces and 550 pixels for adapting faces.

Twelve female identities (six young adult, six older adult) were used as test stimuli. We used the spherize tool in Adobe Photoshop Version CS5 to expand and compress the internal features of each face by ±20%. For each identity, we then created two face pairs, one such that the +20% face was on the right and the -20% face was on the left and the other in the reverse position (i.e., +20% face on the left and -20% on the right). The same face identities were used as test faces during pre- and post-adaptation trials. Faces of 12 different identities (six young adult, six older adult) were used as adaptation stimuli. We created two versions of each identity, one in which the internal features were expanded by 60% and another in which the internal features were compressed by 60% (see Figure 1 for examples of test and adapting stimuli).

An additional four identities (two young adult, two older adult) were used as criterion stimuli. Each criterion trial 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 in both Experiments 1 and 2 received clearance from the Research Ethics Board at Brock University, and participants gave written informed consent prior to participation. Upon arrival to the lab, participants were seated approximately 50 cm in front of a 23-inch computer screen. Prior to testing, participants completed four criterion trials (two young adult, two older adult); each trial consisted of an undistorted face paired with a ±40% face of the same identity. Each face pair was shown for 3000 ms, after which participants verbally indicated whether the face on the right or on the left appeared more normal looking. To be included in the final data analysis, participants had to correctly identify the undistorted face as more normal looking on at least three of the four trials. All but one participant met this criterion; that participant was replaced.

During the pre-adaptation phase, participants were shown face pairs of 12 identities (six young adult, six older adult). Each face pair comprised a compressed (-20%) and expanded (+20%) image of the same identity and was presented twice, once with the expanded image on the right and once with the expanded image on the left. The order in which the pairs were shown was randomized, and there were a total of 24 trials. On each trial a face pair appeared for 3000 ms and was replaced by a screen prompting participants to select the more normal-looking face. To be consistent with Short and Mondloch (2013), participants verbally indicated “left” or “right” and the experimenter entered their response in the computer before advancing to the next trial.

During the adaptation phase, participants were assigned to one of two conditions. Half of the participants were adapted to expanded older adult faces (+60%) and compressed young adult faces (-60%), and the other half were adapted to compressed older adult faces (-60%) and expanded young adult faces (+60%). Each face was randomly presented seven times and was shown for 2000 ms, followed by a 200-ms ISI.

Post-adaptation trials were identical to pre-adaptation trials except that four top-up faces (two young adult, two older adult) preceded each of the 24 face pairs in order to maintain adaptation (see Rhodes et al., 2003). Top-up faces were distorted in a way consistent with adaptation and were shown for 2000 ms followed by a 200-ms ISI. The final top-up face in the series of four always matched the age of the upcoming trial. Similar to pre-adaptation trials, participants were asked to verbally indicate which of the faces in each pair appeared more normal looking.

Results and Discussion

For each participant, the proportion of trials in which they selected the expanded face as more normal looking was calculated for each face age for both pre- and post-adaptation trials. As in Short, Hatry, and Mondloch (2011), change scores were then calculated by subtracting the proportion of expanded faces selected as more normal looking pre-adaptation from the proportion of expanded faces selected as more normal looking post-adaptation for both the expanded face age and the compressed face age. For each adaptation condition, half of the judgments were from young faces and half were from older faces, because half of the participants were adapted to expanded young faces and half were adapted to expanded older faces (see Short et al., 2011; Short, Lee, Fu, & Mondloch, 2014a).

To determine if there were any biases in normality judgments prior to adaptation, we examined whether the proportion of expanded faces selected as more normal looking during pre-adaptation trials differed for the age of face to be expanded and the age of face to be compressed. A paired-samples *t*-test revealed that there was no difference in the proportion of expanded faces selected pre-adaptation for the age of face to be expanded (*M* = .43, *SE* = .04) and the age of face to be compressed (*M* = .45, *SE* = .04), $t(39) = -.59$, $p = .56$, Cohen's $d = .09$. Furthermore, there was no difference in the proportion of expanded faces selected pre-adaptation for young (*M* = .43, *SE* = .04) and older (*M* = .46, *SE* = .04) face pairs, $t(39) = .96$, $p = .35$, Cohen's $d = .12$, supporting our decision to collapse across young and older faces in our analysis of aftereffects.

To determine whether participants showed opposing aftereffects, we examined whether the change in the proportion of expanded faces selected as more normal differed between the age of face that was expanded during adaptation and the age of face that was compressed (i.e., increased for the expanded age but decreased for the compressed age). The decrease in the proportion of expanded faces was greater for the age of face that was compressed (*M* = -.26, *SE*

= .03) than for the age of face that was expanded (*M* = .04, *SE* = .03), $t(39) = 6.53$, $p < .001$, Cohen's $d = 1.49$ (See Figure 2). Such results provide evidence for opposing aftereffects.

For both face ages, aftereffects were carried by the age of face that was compressed, with a similar pattern for young and older faces. Single sample *t*-tests comparing the size of the aftereffect to zero revealed significant aftereffects after adaptation to both compressed young (*M* = -.26, *SE* = .04), $t(19) = -6.38$, $p < .001$, and older (*M* = -.27, *SE* = .06), $t(19) = -4.81$, $p < .001$, faces. In contrast, aftereffects were not significant after adaptation to expanded young (*M* = .004, *SE* = .04), $t(19) = .11$, $p = .92$, and older (*M* = .07, *SE* = .04), $t(19) = 1.69$, $p = .11$, faces.

The results of this study provide evidence for opposing aftereffects for young and older adult faces, suggesting that adults rely on separable norms for faces from these two categories. However, although the results of an opposing aftereffect paradigm may provide evidence for age-selective dimensions coding young and older faces, this method does not allow one to draw conclusions about the degree of overlap between the coding dimensions used for faces from these two categories. For example, it is uncertain whether young and older faces are processed with regard to entirely separable norms or partially overlapping norms that share a number of dimensions. Thus, in Experiment 2, we used a transfer of aftereffects paradigm to investigate the degree of overlap in the coding dimensions used for young and older faces. Participants were adapted to distorted faces from a single age category but judged the normality of both young and older faces during pre- and post-adaptation trials. The extent to which aftereffects transfer to the age of face not seen during adaptation provides a measure of the degree to which young and older faces share coding dimensions, with larger transfer indicating greater overlap.

A secondary goal of Experiment 2 was to investigate whether the direction of the distortion (i.e., expanded versus compressed) significantly influences the magnitude of aftereffects. In Experiment 1, aftereffects were larger for the age of face that was compressed during adaptation than for the age of face that was expanded. Past studies (e.g., Jaquet et al., 2008) have similarly reported that compression produces larger aftereffects than expansion. It may be the case that regardless of face age, compression is a more perceptually salient distortion than expansion, which would then produce larger aftereffects (Robbins et al., 2007). Thus, when the two distortions are simultaneously presented in an opposing aftereffects paradigm, the age of face that is compressed may partially (but not fully) cancel out the aftereffects produced by the expanded distortion. Presenting participants with only one distortion during adaptation would allow us to investigate whether compression continues to produce larger aftereffects than expansion even when the opposing distortions are not presented simultaneously.

Experiment 2

Method

Participants. Eighty Caucasian undergraduate students from Brock University (72 female; *M* = 19.85 years, age range = 18-27) participated in this experiment and received research credit or a small honorarium. All participants completed a questionnaire assessing their weekly face-to-face contact with young and older adults. Participants reported an average of 43.81 hours per week interacting with young adults and 4.72 hours per week interacting with older adults [range = xx to xx]. An additional three participants were tested but excluded from all analyses due to experimenter error (n = 2) or failure to pass criterion trials (n = 1).

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Materials. Criterion and test stimuli were identical to those used in Experiment 1. Likewise, adapting stimuli were the same as those used in Experiment 1; however, during adaptation, each participant was adapted to only one face age (young/older) distorted in only one direction (+60%/-60%). As in Experiment 1, all stimuli were presented and responses were recorded using SuperLab 4.5 software.

Procedure. The procedure was identical to that of Experiment 1; however, adapting and top-up stimuli differed based on the adaptation condition to which participants were assigned. Participants completed the four criterion trials followed by the 24 pre-adaptation trials. During the adaptation phase, participants were randomly assigned to one of four adapting conditions: Compressed older adult faces, expanded older adult faces, compressed young adult faces, or expanded young adult faces. During this phase, each of six adapting face identities was randomly presented nine times. Each face appeared on the screen for 2000 ms, followed by a 200-ms ISI. Post-adaptation trials were identical to pre-adaptation trials, except that two top-up faces preceded each face pair in order to maintain adaptation. Top-up faces consisted of randomly presented adapting stimuli that remained on the screen for 2000 ms followed by a 200-ms ISI.

Results and Discussion

For each participant, the proportion of trials in which they selected the expanded face as more normal looking was calculated for each face age for both pre- and post-adaptation trials. For both the age of face that matched adaptation (e.g., young test faces after adaptation to young faces) and the age of face that did not match adaptation (e.g., older test faces after adaptation to young faces), we calculated change scores based on the proportion of faces consistent with adaptation (e.g., expanded faces for those adapted to +60% faces but compressed faces for those adapted to -60% faces) that were selected as more normal looking pre- and post-adaptation. Thus, in all conditions, a positive value indicates that the change score is in the direction consistent with adaptation, whereas a negative value indicates that the change score is in the direction opposite of adaptation.

We conducted a 2 (test condition: face age that matched adaptation, face age that did not match adaptation) x 2 (adaptor age: young, older) x 2 (adaptor distortion: expanded, compressed) mixed ANOVA. There was a main effect of test condition, $F(1, 76) = 6.54$, $p = .01$, $\eta_p^2 = .08$. Aftereffects were larger for the face age that matched adaptation ($M = .38$, $SE = .03$) than for the face age that did not match adaptation ($M = .30$, $SE = .03$), but in both cases aftereffects were significantly greater than zero (face age that matched adaptation: $t(79) = 13.50$, $p < .001$; face age that did not match adaptation: $t(79) = 10.60$, $p < .001$). The main effect of adaptor age was not significant, $F(1, 76) = .97$, $p = .33$, $\eta_p^2 = .01$, nor was the main effect of adaptor distortion, $F(1, 76) = 2.02$, $p = .16$, $\eta_p^2 = .03$. Furthermore, there were no significant two- or three-way interactions, all ps > .55, η_p^2s < .005 (see Figure 3).

Lastly, to further confirm that aftereffects were no larger following adaptation to compressed relative to expanded faces, we examined simple aftereffects for only the face age that matched adaptation. An independent-samples *t*-test revealed that there was no difference in the magnitude of aftereffects among the 40 participants adapted to compressed faces ($M = .41$, $SE = .03$) relative to the 40 participants adapted to expanded faces ($M = .34$, $SE = .05$), $t(78) = 1.13$, $p = .26$, Cohen's $d = .26$.

Overall, our finding that aftereffects transferred across categories (i.e., were significant for the face age that did not match adaptation) provides evidence of overlapping dimensions in the representation of young and older faces. Our finding that aftereffects were larger for the face age that matched adaptation than the face age that did not match adaptation provides evidence for partial transfer of aftereffects across age categories, indicating that some dimensions are not shared. Together with the results of Experiment 1 our findings suggest that young and older faces are processed with regard to separable norms that share some underlying coding dimensions.

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Furthermore, the lack of a main effect of adaptor distortion indicates that there were no significant differences in the magnitude of aftereffects following adaptation to compressed versus expanded faces. This suggests that when presented in isolation (i.e., in a simple aftereffects paradigm), compressed and expanded faces produce aftereffects of a comparable magnitude; however, when expanded and compressed faces directly compete against each other in the context of an opposing aftereffects paradigm, compression generates larger aftereffects, perhaps because the compressed distortion partially cancels out the effect of the expanded distortion. Our results suggest that this is the case for young and older faces distorted in opposite directions; future research should examine whether this also occurs for other face categories (e.g., Caucasian and Chinese faces).

General Discussion

Collectively, the results of the present set of studies suggest that young and older adult faces are processed with regard to separable face prototypes that share some underlying dimensions. Following exposure to young and older faces distorted in opposite directions, participants' judgments of normality shifted in opposite directions, which is possible only if these faces are represented with regard to dissociable norms and at least some category-specific coding dimensions. Moreover, within the context of a simple aftereffects paradigm, aftereffects partially transferred across age categories, indicating that there are also some shared coding dimensions between young and older faces. Such findings are consistent with the pattern of results found for other face categories, such as face race (Jaquet & Rhodes, 2008; Jaquet et al., 2008; Little et al., 2008) and orientation (Jeffery, Taylor, & Rhodes, 2014; Rhodes et al., 2004; Watson & Clifford, 2003).

In some ways, it is unsurprising that young and older adult faces are processed with regard to separable prototypes. Past research has revealed that both physical (Short & Mondloch, 2010) and social categorical (Bestelmeyer et al., 2008; Jaquet, Rhodes, & Hayward, 2007) differences between face categories are necessary for opposing aftereffects to emerge. Young and older faces clearly differ along a number of physical dimensions. As faces age, they change in both texture and structure (Burt & Perrett, 1995). Repetitive muscular contractions over the course of the lifespan lead to the formation of wrinkles, and aging skin is further characterized by epidermal thinning and chronic inflammation of the dermis, which is associated with reductions in collagen (Farkas, Pessa, Hubbard, & Rohrich, 2013). Additional texture-based changes include increases in pigmented irregularities (Fink, Grammer, & Matts, 2006) and decreases in facial contrast between the eyes, lips, and skin (Porcheron, Mauger, & Russell, 2013), which tends to make faces appear less sexually dimorphic and take on a more masculine appearance (Etcoff, 1999). Aging also leads to changes in the skeletal structure of the face (e.g., shrinking of the jawbone; Farkas et al., 2013), a redistribution of adipose tissue, and a lengthening of the ears and nose (Burt & Perrett, 1995). Such physical differences between young and older faces likely require the use of separable prototypes and corresponding coding dimensions.

Young and older adult faces also elicit different social cognitions and appear to belong to unique social categories. For example, both young and older adults demonstrate more positive implicit associations and explicit stereotypes for young than older faces (He, Ebner, & Johnson, 2011). Furthermore, when young and older faces are simultaneously presented within the context of complex scenes, both young and older adults allocate greater attention to young faces (Short et al., 2014b), perhaps because they are perceived as more positive and socially rewarding than older faces (Ebner, 2008). Lastly, in line with work suggesting that faster reaction times in categorization tasks reflect increased categorical processing (i.e., evidence that faces are processed at the categorical rather than individual level; Levin, 1996), older faces are categorized faster with regard to age than are young faces by young adult participants (Wiese et al., 2008; but see Wiese, Komes, & Schweinberger, 2012). Collectively, such findings suggest that facial age is sufficient to elicit differing social cognitions, and as such, satisfies one of the necessary conditions for the emergence of opposing aftereffects.

Our finding that the magnitude of aftereffects did not vary as a function of face age is consistent with past adaptation studies that do not show sensitivity to expertise. In their examination of adaptation to Caucasian and Chinese faces, Jaquet et al. (2008) found that although participants reported greater experience with own-race faces, the magnitude of aftereffects was equivalent for own- and other-race faces (see Rhodes et al., 2004 for a similar pattern of results for face orientation), analogous to our findings for face age. Thus although adaptation paradigms provide important insights into how faces belonging to different categories are represented in face space, other experimental protocols are needed to directly test the refinement of these norms and their associated dimensions. Such studies provide evidence of a more well-refined representation of young relative to older adult faces; when asked to explicitly judge the normality of an undistorted face paired with an expanded or compressed version of the same identity, both adults (Short & Mondloch, 2013) and children (Short et al., 2015) are more sensitive to deviations from the norm when viewing young compared to older adult faces.

The results of the present study challenge a previous representational model proposed by O'Toole, Vetter, Volz, and Salter (1997), who demonstrated that the process of caricaturizing 3-dimensional faces produces an increase in perceived face age. This result was interpreted by the authors as indicating that older adult faces are located in the periphery of face space while young adult faces are located closer to the center. This representation implicitly assumes that adults possess a single age-generic norm in which the location of both young and older faces is defined, rather than the separable norms evident in Experiment 1. However, while we used facial photographs as our stimuli, O'Toole and colleagues presented participants with laser scans, which lack the textural cues associated with more realistic images. Thus, whereas caricaturizing shape may increase perceived age, our representation of older faces likely contains a rich set of cues beyond mere shape (e.g., wrinkles, skin coloration and contrast).

Issues for Further Investigation

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In addition to providing novel insights about how young vs. older adult faces are represented in face space, our findings raise several issues worthy of further investigation. In the current study we tested only young adults; it would be worthwhile to investigate whether older adults also represent young and older faces with separable norms and partially overlapping dimensions. Evidence that, like young adults, older adults are more sensitive to how young faces deviate from the norm than how older faces deviate from the norm (Short & Mondloch, 2015) suggests that they do. In addition, it would be worthwhile to verify that the pattern of results we obtained for young versus older adult faces would replicate for male faces and that the pattern of results obtained by Jacquet and Rhodes (2008; separable but not distinct representations of male vs. female faces) would replicate for older adult faces.

Second, although aftereffects have provided many important insights about our representation of faces, our findings provide further evidence that the implications of aftereffects are not entirely straightforward. Past studies showed that the magnitude of aftereffects does not vary with expertise (Jaquet et al., 2008; Rhodes et al., 2004), which is surprising if faces from categories with which we have less experience are densely clustered in face space. We reported that differences in the magnitude of aftereffects following adaptation to compressed vs. expanded faces (or lack thereof) did not predict the pattern of results we observed following adaptation to oppositely distorted young and older faces; compressed and expanded faces lead to similar aftereffects in a simple adaptation paradigm (Exp. 2) but compressed faces appeared to have a stronger impact in the context of opposing adaptations (Exp. 1). Furthermore, generalization of adaptation across face categories (e.g., from young to older faces, from male to female faces) indicates that many dimensions are shared. However, currently there is no way to quantify the proportion of shared dimensions between face categories based on the magnitude of the transfer of aftereffects. Thus future research should endeavor to characterize the relationship between the magnitude of aftereffects and our representation of faces in multi-dimensional face space.

Third, our results highlight the need to refine our conceptualization of face space. Category-contingent opposing aftereffects are thought to reflect separable norms for different face categories. However, to date opposing aftereffects have been reported for faces that differ based on race (Jaquet et al., 2008; Little, DeBruine, Jones, & Waitt, 2008), sex (Jaquet & Rhodes, 2008; Little, DeBruine, & Jones, 2005), orientation (Rhodes et al., 2004), species (Little et al., 2008) and age (infant vs. adult, Little et al., 2008; young vs. older adult, Experiment 1). These findings beg the question of how many face prototypes adults possess. It seems unlikely that we possess a well-refined prototype for either inverted or non-human faces—categories with which we have almost no experience. We do, however, have experience with faces that vary in age, sex, and race. Nonetheless, it does not seem parsimonious to possess separate norms for each possible combination of categories (e.g., one prototype for older, female, Asian faces and another for young, male, Caucasian faces). Future studies should investigate the relationships among these category-specific representations and refine our interpretation of aftereffects.

Summary

In conclusion, our results show that age, similar to other salient face categories such as race and sex, is a characteristic that defines the norms used to encode the faces we encounter. Young and older adult faces are processed with regard to category-specific norms; however, despite this separability, there do appear to be some shared coding dimensions. Future research should examine additional aspects involved in the processing of young and older adult faces, as there is emerging evidence that differential performance with young and older faces may depend on the type of task employed (Proietti et al., 2014). In particular, for young adults the processing of older faces is not impaired in all tasks; rather, deficits for older adult faces may be task-dependent and influenced by factors such as motivation, attention, and cognitive load.

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Figure Captions

Figure 1. Sample young and older adult test (A) and adapting stimuli (B).

Figure 2. Experiment 1: Mean change scores for the age of face that was expanded versus the age of face that was compressed during adaptation in Experiment 1.

Figure 3. Experiment 2: Magnitude of aftereffects for the age that matched adaptation versus the age that did not match adaptation as a function of face age and direction of distortion.