Psychology and Aging

Older Adults' Configural Processing of Faces: Role of Second-Order Information

Laurence Chaby, Pauline Narme, and Nathalie George

Online First Publication, October 25, 2010. doi: 10.1037/a0020873

Psychology and Aging

0882-7974/10/$12.00 DOI: 10.1037/a0020873

Older Adults' Configural Processing of Faces: Role of Second-Order Information

Laurence Chaby
Université Paris Descartes, and Centre National de la Recherche Scientifique

Pauline Narme
Université de Picardie Jules Verne, and Centre National de la Recherche Scientifique

Nathalie George
Centre National de la Recherche Scientifique, and Université Pierre et Marie Curie

Problems with face recognition are frequent in older adults. However, the mechanisms involved have only been partially discovered. In particular, it is unknown to what extent these problems may be related to changes in configural face processing. Here, we investigated the face inversion effect (FIE) together with the ability to detect modifications in the vertical or horizontal second-order relations between facial features. We used a same/different unfamiliar face discrimination task with 33 young and 33 older adults. The results showed dissociations in the performances of older versus younger adults. There was a lack of inversion effect during the recognition of original faces by older adults. However, for modified faces, older adults showed a pattern of performance similar to that of young participants, with preserved FIE for vertically modified faces and no detectable FIE for horizontally modified faces. Most importantly, the detection of vertical modifications was preserved in older relative to young adults whereas the detection of horizontal modifications was markedly diminished. We conclude that age has dissociable effects on configural face-encoding processes, with a relative preservation of vertical compared to horizontal second-order relations processing. These results help to understand some divergent results in the literature and may explain the spared familiar face identification abilities in the daily lives of older adults.

Keywords: aging, face perception, configural processing, second-order information, face inversion effect

Humans successfully encode a large number of new faces throughout their lifespan. However, with advancing age, older adults frequently complain about their difficulties in daily life when it comes to reliably recognizing unfamiliar faces (for a review, see Chaby & Narme, 2009) and memorizing proper names (e.g., James, 2004). Behavioral studies of aging in the past two decades have established that there is an age-related decline in face recognition (Bäckman, 1991; Bartlett, Leslie, Tubbs, & Fulton, 1989), with subtle alterations in the recognition of facial identity from the age of 50 years (Chaby, George, Renault, & Fiori, 2003; Chaby, Jemel, George, Renault, & Fiori, 2001; Nakamura et al., 2001), and increased difficulties after 70 (e.g., Crook & Larrabee, 1992).

These findings are generally attributed to neurological factors, such as the disproportionate effects of aging on frontal lobe structures (Decarli et al., 2005; Pfefferbaum, Adalsteinsson, & Sullivan, 2005). More specifically, several age-related modifications in functional brain organization underlying face recognition have been described, including greater activation of left prefrontal regions during face recognition (Grady, Bernstein, Beig, & Siegenthaler, 2002), reduction of hemispheric asymmetry associated with additional brain region recruitment (Chaby et al., 2003; Gao et al., 2009), and alteration in white-matter connectivity in the right inferior fronto-occipital fasciculus (Thomas et al., 2008).

At the behavioral level, several explanations have been formulated to explain age-related decline in recognition memory for faces. First, some researchers have proposed that there is a response bias, governed by the frontal lobes, which results in an increase in false alarms in response to unfamiliar faces (Crook & Larrabee, 1992; Searcy, Bartlett, Memon, & Swanson, 2001; but see also Huh, Kramer, Gazzaley, & Delis, 2006). A second hypothesis presumes the existence of an own-age face recognition bias across the lifespan. Thus, individuals may acquire expertise and demonstrate superior recognition for faces from their own age group. Although there is some evidence supporting this proposi-

Laurence Chaby, Institut de Psychologie, Université Paris Descartes, and Laboratoire de Psychologie et Neuropsychologie Cognitives, CNRS, Boulogne-Billancourt, France; Pauline Narme, UFR de médicine, Université de Picardie Jules Verne, and Laboratoire de Neurosciences Fonctionnelles et Pathologies, CNRS, Amiens, France; and Nathalie George, CNRS, UMR 7225, Paris, France, and Centre de Recherche de l'Institut du Cerveau et de la Moelle èpiniére, Université Pierre et Marie Curie-Paris 6, UMR-S975, Paris, France.

We are grateful to all the volunteers who generously gave up their time to participate in the study. The authors would like to thank Emilie Cloarec and Magali Boibieux for their technical assistance and Nicole Fiori for her help with this project. We would also like to thank Georges Dellatolas and Henri Cohen for their valuable comments on the manuscript.

Correspondence concerning this article should be addressed to Laurence Chaby, Laboratoire de Psychologie et Neuropsychologie Cognitives, Institut de Psychologie, Université Paris Descartes, 71 avenue Edouard Vaillant, Boulogne Billancourt Cedex 92774, France. E-mail: laurence.chaby@parisdescartes.fr

tion (Bäckman, 1991; Perfect & Harris, 2003), an own-age bias has not been consistently observed, particularly in the elderly (Bartlett & Fulton, 1991; Lamont, Stewart-Williams, & Podd, 2005; Wiese, Schweinberger, & Hansen, 2008). Other explanations have been essentially based on memory mechanisms and have included factors such as confusion errors due to the increased number of faces that are memorized with increasing age (Chaby et al., 2001), deficits in correctly matching test faces with representations stored in memory (Bartlett et al., 1989) or difficulties recollecting contextual information (Memon & Bartlett, 2002; Searcy, Bartlett, & Memon, 1999).

The decline in face recognition performance with advancing age may not be solely related to responses biases and/or memory functioning. First, studies that specifically investigated the influence of memory load on age-related decline in face recognition have yielded inconclusive results (e.g., Lamont et al., 2005). Second, perceptual mechanisms such as reduced contrast sensitivity in older adults have been proposed to contribute to this decline (Lott, Haegerstrom-Portnoy, & Schneck, 2005; Rizzo, Corbett, Thompson, & Damasio, 1986). Furthermore, it has been suggested that age-related differences in face recognition may be related to changes in visual scanning behavior (Firestone, Turk-Browne, & Ryan, 2007). Thus, older and younger adults may differ in the extent to which facial features are viewed and encoded. This suggests that older adults' problems with unfamiliar face recognition may be partly related to changes in the face-encoding process.

The process of encoding faces, which is necessary to face individuation, is known to rely critically on the processing of configural information. This can be observed with different paradigms that prevent participants from extracting configural information (for a review, see Maurer, Le Grand, & Mondloch, 2002). Configural information refers to the spatial relations between facial components, including both first-order relations (i.e., the overall organization of facial features with the two eyes above the nose, which itself is above the mouth) and second-order relations (i.e., the distances between features, such as interocular distance, eyes-to-mouth distance, etc.). It also refers to holistic information or the gestalt formed by faces. Here we investigate possible changes in the encoding of different types of configural information with aging.

A key manipulation for the study of configural processing consists in turning the faces upside-down, which dramatically impairs their recognition (Yin, 1969; for a recent review, see Rossion, 2008). This "face inversion effect" (FIE) has been replicated in various studies and is considered to be a hallmark of the human perceptual expertise acquired for face processing over years of exposure (Passarotti, Smith, DeLano, & Huang, 2007). It is generally agreed that the disruption of configural processing is at the basis of the FIE (for reviews, see Maurer et al., 2002; Rossion, 2008). Inversion changes the way faces are processed, impeding configural face encoding and consequently recognition (Freire, Lee, & Symons, 2000; George, Jemel, Fiori, Chaby, & Renault, 2005; Jacques, d'Arripe, & Rossion, 2007). Several carefully controlled studies have shown that the FIE is largely attributable to a disruption in second-order relations processing (for a critical review see Rossion, 2008). However, inversion is not a fully precise way for the study of this kind of processing since it does also interfere with the processing of first-order face configuration, holistic information and featural information (for a review see Maurer et al., 2002).

Another way to study configural processing more specifically is to displace facial features slightly along either the vertical or the horizontal dimension and to ask the participants to discriminate the modified faces from the original ones. This manipulation is of particular interest since it selectively affects second-order relations, and it allows for the separate manipulation of vertical and horizontal relations. The perception of vertical and horizontal relations has recently been proposed to involve different neural processes and to contribute differentially to face individuation, with greater contribution of vertical relations to face configural encoding (Goffaux, Rossion, Sorger, Schiltz, & Goebel, 2009). Consequently, the encoding of second-order spatial relations is unequally influenced by inversion: whereas inversion affects the encoding of vertical relations, it minimally impacts that of horizontal relations. Thus, the FIE is markedly reduced when the faces to be recognized vary along the horizontal axis only (principally inter-eye distance), at least in young adults (Barton, Keenan, & Bass, 2001; Goffaux & Rossion, 2007).

In the current experiment, we aimed at exploring the changes in face configural processing with age using both face inversion and horizontal versus vertical feature displacement. It is unknown to what extent configural processing may undergo changes with age, and more precisely whether the processing of different configural information may be differentially affected by aging. Evidence for an age effect on face encoding processes comes from a previous ERP study (Chaby et al., 2003). However, this effect was not specifically related to configural information processing. To the best of our knowledge, only one study (Boutet & Faubert, 2006) has investigated the question of the changes of face configural processing in aging. It used the face inversion effect and the face composite effect (whereby the upper and lower halves from two different faces are more difficult to recognize when they are horizontally aligned than when they are misaligned). These authors argued that configural and holistic processing are preserved in older compared to young adults. However, the older participants of this study showed increased difficulty in recognizing upright faces and an alteration of the composite effect such that the classical decline in performance for composite face recognition was not observed. Interestingly, some of the inconsistencies in the results obtained by that study may be related to uncontrolled manipulations of the vertical and horizontal relations between facial features.

Here, we used a "same"/"different" discrimination task with intact faces and faces modified along either the vertical or the horizontal axis which were presented upright or upside-down. Our aim was to investigate the FIE together with the encoding of vertical versus horizontal second-order relations in young and older adults. On one hand, since older adults complain about difficulties in recognizing faces, it may be expected that they show some deficit in the use of configural information during face encoding and recognition. On the other hand, these changes in configural processing with aging may not affect similarly the encoding of vertical and horizontal relations. Indeed, since vertical and horizontal relations contribute differentially to face configural encoding and to face individuation, they may be differently altered in aging. In particular, we assumed that there may be a selective pressure on the encoding of vertical relations as they seem particularly important for face encoding and individuation. This may result in relative preservation of the processing of vertical relations with aging, as compared to horizontal relations. Thus, in order to disentangle the FIE from effects specifically related to the encoding of vertical or horizontal relations, we first analyzed the recognition of upright and inverted intact faces ("same" responses), as indicative of the "classical" FIE. Secondly, we examined the detection of vertically and horizontally modified faces in upright and inverted orientation, reflecting the encoding of vertical and horizontal relations and its sensitivity to inversion. We made several predictions. First, we expected a reduced FIE in older compared to younger adults for intact faces. Indeed the recognition of intact faces may involve a combination of vertical and horizontal relations as well as of holistic and featural processing, and some of this processing is likely to be affected in aging as well as to interfere with inversion. Second, with regard to the manipulation of vertical and horizontal relations, we expected to replicate the finding of greater FIE for vertical than horizontal relations in young adults (Goffaux et al., 2009) and to find greater changes with age in the detection of horizontally compared to vertically modified faces.

Method

Participants

The participants were 33 young adults (YAs: 17 females, *M* age = 21.3 years, *SD* = 1.7, age range = 19–25) and 33 older adults (OAs: 17 females, *M* age = 69.9 years, *SD* = 7.2, age range = 60–80). The younger adults were recruited from the student population of Rene Descartes University and were given course credit for their participation. The older participants were recruited from the community and all lived independently. The older group was screened for global cognitive functioning using the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) and for the presence of depression symptoms using the Geriatric Depression Scale (GDS; Yesavage & Brink, 1983). A score below 28/30 for the MMSE and lower than or equal to 10/30 for the GDS was an exclusion criterion. All subjects were right-handed according to the Dellatolas Handedness Questionnaire (Dellatolas et al., 1988) and had normal or corrected-to-normal vision. None of the participants reported neurological or psychiatric disorders or were receiving central-acting medication. Written informed consent was obtained from all participants prior to the experiment.

Materials

The original face stimuli consisted of eight photographs of faces (four young and four old faces, with two males and two females in each age set) taken from the lifespan face database (Minear & Park, 2004). All faces were in full frontal view and portrayed people posing with a neutral expression (wearing no glasses, jewelry, or makeup). They were edited using Adobe Photoshop CS 8.0 software. Each photograph was cropped so that only the face (and not the shoulders or clothing) was visible. All stimuli were converted to gray-scale with a black background, equalized for global luminance, and a Gaussian blur was applied to make the skin look smooth and facilitate feature displacement (see Figure 1).

The spatial relations between the features of these original faces were then manipulated to generate the modified stimulus set. Each original face was modified in four ways (referred to as "twins") by moving the eyes and/or the mouth along the vertical or the horizontal axis. Modifications along the vertical axis consisted in changing the eyes-mouth distance by ± 12 pixels (i.e., moving either the eyes up and the mouth down or the eyes down and the mouth up, by 6 pixels each). Modifications along the horizontal axis consisted in moving the eyes 12 pixels (3.2 mm) apart or closer to each other relative to the original. Thus, the amount of feature displacement was equal in the vertically and horizontally modified faces (see Figure 1). The moderate magnitude of these changes made the faces look natural according to anthropomorphic norms and covered most of natural variations among adult Caucasian faces (Farkas, 1994), while still being accurately detectable (between 75% and 95% of the time) by young adults in a pre-test.

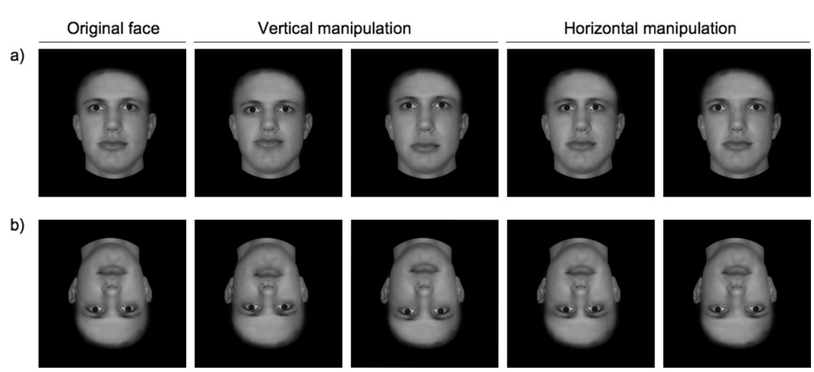

Figure 1. Example of the various types of faces presented upright (a) and inverted (b). A sample original face is presented in the leftmost column. In the vertically modified versions of the face, the eye-mouth distance was changed by moving the eyes and the mouth 12 pixels closer together or farther apart (i.e., 6-pixel displacement for each feature). In the horizontally modified versions of the face, interocular distance was changed by moving the eyes 12 pixels closer together or farther apart (i.e., 6-pixel displacement for each eye). Photographs adapted from "A lifespan database of adult facial stimuli" by M. Minear and D. C. Park, 2004, *Behavior Research Methods, Instruments, and Computers, 36,* 630–633. Copyright 2004 by Denise Park. Adapted with permission.

Every original face underwent the modification procedure. Thus, there were 40 different stimuli: eight original faces and 32 (8 * 4) modified faces. Inverted faces were vertically flipped versions of these stimuli. All stimuli were framed within an area of 500×500 pixels (12.9 cm $\times$ 13.5 cm), corresponding to a visual angle of approximately $9° \times 10°$ at a viewing distance of 80 cm.

Procedure

The experimental protocol was created with E-Prime 1.1 (Psychology Software Tools, Inc., Pittsburgh, PA). Participants were tested individually in a single session that lasted approximately 45 minutes. Each trial started with the presentation of a fixation cross for 500 ms. This was followed by the first (target) stimulus, which was always an original face, presented for 2000 ms. Then, after an interstimulus interval of 500 ms, the second face was displayed for 2000 ms. This probe stimulus could be either the same original face as the target face or one of the four modified versions of that face. Participants had to decide whether the target and probe stimuli were the "same" or "different" faces by pressing one of two buttons placed under their left and right thumbs respectively. The association between the "same"/"different" response and the left/right thumb was reversed for half participants. The response buttons were connected to the parallel port of the computer. Subjects were informed of the subtlety of the changes that they had to detect; they were told that the "probe and target faces [were] like twins," but no further information was given about the nature of the differences between the faces. There was an intertrial interval of 1500 ms.

Upright and upside-down versions of the stimuli were presented in two separate blocks. Thus, in each block, there were 32 "same" trials (eight original faces * four repetitions) and 32 "different" trials (eight original faces * four modifications). The order of the two blocks was counterbalanced across participants and the order of trials was randomized across each block. Resting pauses were provided every 10 trials. Eight additional practice trials were given prior to each block.

Data Analysis

Participants' accuracy (percentage of correct responses, % CR) and corresponding response times (RT) were computed for original and modified upright and inverted faces. The data were screened for outliers (RT below 200 ms or above 3000 ms), and none were found. These data were first entered into an overall analysis of variance (ANOVA) with Age group (YAs/OAs) as between-subjects factor, and Orientation (upright/inverted) and Face type (original/modified) as within-subjects factors. Then, the response accuracy and RT were analyzed separately for original and modified faces, in order first to evaluate the FIE for the recognition of the original faces ("same" responses) and second to examine the detection of vertical versus horizontal modifications ("different" responses) in upright and inverted faces. All values are expressed as means ± standard error of the means (SEM). In addition to F and p values, the partial eta-squared (η_p^2) representing the portion of explained variance in the data are reported for each effect. Partial eta-squared provides a measure of effect size with small, medium, and large effects corresponding to η_p^2 of .01, .06, and .14, respectively (see Cohen, 1988).

Results

As a preliminary analysis, data were examined globally to compare the overall performance and RTs of young and older adults. Older participants (OAs) had poorer overall performance and slower RT than young participants respectively, 60.9 ± 2.8% versus 74.4 ± 1.0%, $F(1, 64) = 73.0$, $p < .001$, $\eta_p^2 = .53$; 1294 ± 45 ms versus 1081 ± 35 ms; $F(1, 64) = 14.0$, $p < .001$, $\eta_p^2 = .18$. Performance did not differ for original ("same" responses) and modified faces ("different" responses) either in OAs [63.2 ± 1.6% and 58.5 ± 1.6% respectively, $F(1, 64) = 3.0$, $p > .05$, $\eta_p^2 = .04$] or in YAs (74.1 ± 2.1% and 74.7 ± 1.7%, $F < 1$, $\eta_p^2 = .001$), giving no indication of a response bias in the data. Moreover, there was a main effect of face orientation on accuracy [$F(1, 64) = 100.0$, $p < .0001$, $\eta_p^2 = .63$]. However, this effect was qualified by an interaction between Orientation and Age group [$F(1, 64) = 24.4$, $p < .0001$, $\eta_p^2 = .27$], which suggested that the FIE varied with age. Moreover, in agreement with our working hypotheses, there was an interaction between Orientation and Face type (original/modified) [$F(1, 64) = 14.1$, $p < .001$, $\eta_p^2 = .18$]. This suggested that the FIE differed for the recognition of original faces ("same" trials) and the detection of vertically and horizontally modified faces ("different" trials). Thus, we first analyzed the recognition of upright and inverted original faces ("same" responses) and then turned to the analysis of the vertically and horizontally modified face conditions ("different" responses). Although the three-way interaction between Orientation, Face type and Age did not reach significance ($F < 1$, $\eta_p^2 = .001$), Age was retained in these analyses as a main factor of interest, following our working hypotheses.

For the recognition of original probe faces, a 2 (Age group: YAs, OAs) $\times$ 2 (Orientation: upright, inverted faces) ANOVA with Age group as the only between-subjects factor was conducted on accuracy and RTs (Figure 2). Overall, OAs performed less accurately and more slowly than the YAs [respectively, 63.2 ± 1.6% versus 74.1 ± 2.0%, $F(1, 64) = 17.2$, $p < .001$, $\eta_p^2 = .21$ for % CR, and 1400 ± 49 ms versus 1163 ± 47 ms, $F(1, 64) = 12.3$, $p < .001$, $\eta_p^2 = .16$ for RT]. Importantly, there was a main effect of face inversion on accuracy [$F(1, 64) = 26.6$, $p < .001$, $\eta_p^2 = .29$] together with an interaction between Orientation and Age group [$F(1, 64) = 20.2$, $p < .001$, $\eta_p^2 = .24$]. Planned comparisons on accuracy within each age group indicated that YAs showed the classical FIE [$F(1, 64) = 46.6$, $p < .001$, $\eta_p^2 = .42$], with an accuracy level of 81.6 ± 2.2% for upright original faces that declined to 66.6 ± 2.5% for inverted faces. By contrast, OAs did not show any significant FIE (respectively, 63.7 ± 3.1% versus 62.7 ± 1.8%, $F < 1$, $\eta_p^2 = .003$). For RTs, there was neither a main effect of inversion [$F(1, 64) = 1.1$, $p = .29$, $\eta_p^2 = .02$] nor an interaction between Orientation and Age group [$F(1, 64) = 2.5$, $p = .12$, $\eta_p^2 = .01$]. Note however that the RT data converged with the accuracy data: planned comparisons indicated a marginal FIE for RTs in YAs (1126 ± 48 ms versus 1200 ± 57 ms for upright versus inverted faces respectively, $p = .06$, $\eta_p^2 = .06$), but no such trend in OAs (1411 ± 56 ms versus 1397 ± 47 ms, $F < 1$, $\eta_p^2 = .002$).

We now turn to the analysis of vertically and horizontally modified probe face conditions (Figure 3 and Table 1). We conducted a 2 (Age group: YAs, OAs) $\times$ 2 (Orientation: upright, upside-down) $\times$ 2 (Modification type: vertical, horizontal)

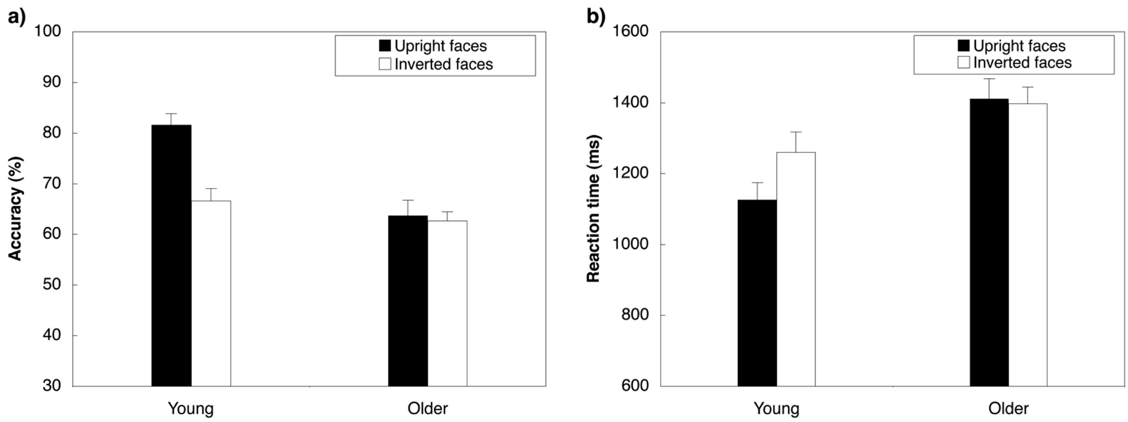

Figure 2. (a) Mean accuracy (in percent correct responses, %) for "original" upright and inverted faces in young and older adults. (b) Mean reaction time (in milliseconds, ms) for "original" upright and inverted faces in young and older adults. Error bars represent the standard error of the mean (SEM).

ANOVA, with age as the only between-subjects factor, on the mean accuracy and mean RT data. Overall, as previously noted, the OAs performed less accurately and more slowly than the YAs [respectively, 58.5 ± 1.6% versus 75.2 ± 1.0%, $F(1, 64) = 43.4$, $p < .001$, $\eta_p^2 = .40$ for % CR and 1185 ± 45 ms versus 1001 ± 28 ms, $F(1, 64) = 11.1$, $p < .001$, $\eta_p^2 = .14$ for RT]. The effect of face inversion was significant on both accuracy [$F(1, 64) = 110.4$, $p < .001$, $\eta_p^2 = .63$] and RT [$F(1, 64) = 18.2$, $p < .001$, $\eta_p^2 = .22$]. Most importantly, there were several two-way interactions.

First, there was a significant two-way interaction between Modification type and Age group [for % CR: $F(1, 64) = 25.2$, $p < .001$, $\eta_p^2 = .28$; for RT: $F(1, 64) = 22.3$, $p < .001$, $\eta_p^2 = .26$]. This interaction reflected that OAs were less accurate [54.5 ± 3.1% vs. 81.7 ± 2.8%, $F(1, 64) = 60.0$, $p < .001$, $\eta_p^2 = .48$] and slower [1213 ± 53 ms vs. 938 ± 46 ms, $F(1, 64) = 18.8$, $p < .001$, $\eta_p^2 = .22$] than YAs for the detection of horizontally modified faces only (Figure 3). By contrast, OAs did not differ significantly from YAs for vertically modified faces [% CR: 62.4 ± 3.1% vs. 66.9 ± 2.5%, $F(1, 64) = 2.09$, $p = .15$, $\eta_p^2 = .03$; RT: 1164 ± 36 ms vs. 1160 ± 45 ms, $F(1, 64) = 3.32$, $p = .07$, $\eta_p^2 = .05$].

Second, there was an interaction between Orientation and Modification type [for % CR: $F(1, 64) = 72.9$, $p < .001$, $\eta_p^2 = .53$; for RT: $F(1, 64) = 14.9$, $p < .001$, $\eta_p^2 = .19$]. As expected, the FIE was significant for vertically modified faces only [for % CR: $F(1, 64) = 154.8$, $p < .001$, $\eta_p^2 = .71$; for RT: $F(1, 64) = 39.9$, $p < .001$, $\eta_p^2 = .38$] whereas it did not reach significance for horizontally modified faces ($F < 1$, $\eta_p^2 < .01$ for both % CR and RT). It is noteworthy that this pattern of performance was qualitatively similar in both YAs and OAs (Figure 3). Indeed, planned comparisons on accuracy confirmed that both YAs and OAs showed a FIE for vertically modified faces [respectively, $F(1, 64) = 118.3$, $p < .001$, $\eta_p^2 = .65$ for the YAs and $F(1, 64) = 42.6$, $p <$

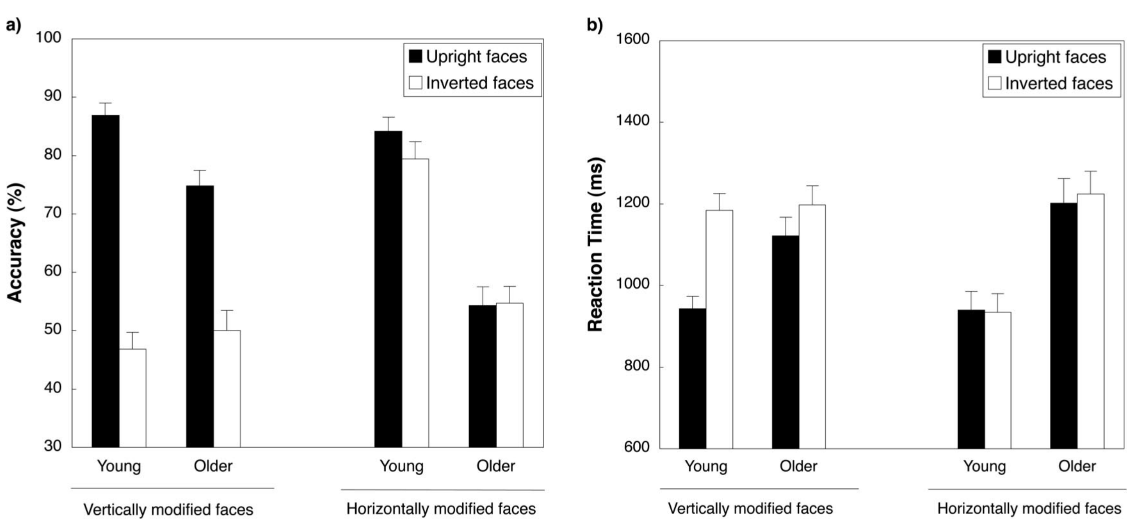

Figure 3. (a) Mean accuracy (in percent correct responses, %) for upright and inverted vertically and horizontally modified faces, for young and older adults. (b) Mean reaction time (in milliseconds, ms) for upright and inverted vertically and horizontally modified faces, for young and older adults. Error bars represent the standard error of the mean (SEM).

Table 1
Mean Accuracy in % (±SEM) and Mean Reaction Time in ms (±SEM) Are Shown for Upright and Inverted Vertically and Horizontally Modified Faces, in Young and Older Adults

	Young adults		Older adults	
	Vertical	Horizontal	Vertical	Horizontal
Upright faces	86.9 ± 2.1%	84.1 ± 2.4%	74.8 ± 2.7%	54.2 ± 3.2%
	943 ± 31 ms	940 ± 46 ms	1122 ± 45 ms	1202 ± 60 ms
Inverted faces	46.8 ± 2.9%	79.4 ± 3.0%	50.0 ± 3.5%	54.7 ± 2.9%
	1184 ± 41 ms	935 ± 45 ms	1198 ± 46 ms	1224 ± 56 ms

.001, $\eta_p^2 = .41$ for the OAs] whereas no such FIE was observed for horizontally modified faces either in YAs or in OAs (both $F < 1$, $\eta_p^2 < .01$).

Third, the interaction between Orientation and Age group was significant [for % CR: $F(1, 64) = 9.8$, $p < .001$, $\eta_p^2 = .13$; for RT, $F(1, 64) = 3.8$, $p = .055$, $\eta_p^2 = .06$]. For accuracy, this indicated that although significant in both age groups, the FIE was more marked in YAs [85.5 ± 2.3% for upright faces versus 65.4 ± 2.7% for inverted faces, $F(1, 64) = 93.1$, $p < .001$, $\eta_p^2 = .59$] than in OAs [64.5 ± 2.9% versus 52.1 ± 3.4%, $F(1, 64) = 27.1$, $p < .001$, $\eta_p^2 = .29$]. Given the limited accuracy in OAs for upright faces, we conducted an additional analysis of covariance (ANCOVA) with accuracy for upright modified faces as the covariate. This analysis was aimed at partialling out accuracy for upright faces and see whether any difference in orientation effect remains. It was not the case (Orientation × Age group interaction: $F < 1$) confirming that this interaction was mainly due to the recognition accuracy for upright faces. For RT, the FIE was significant in YAs [942 ± 39 ms for upright faces versus 1062 ± 44 ms for inverted faces, $F(1, 64) = 19.3$, $p < .001$, $\eta_p^2 = .23$]. It did not reach significance in OAs [1162 ± 47 ms versus 1200 ± 48 ms, $F(1, 64) = 2.7$, $p = .10$, $\eta_p^2 = .04$].

Finally, the three-way interaction between Orientation, Modification type and Age group reached significance on RT data only [$F(1, 64) = 5.6$, $p < .05$, $\eta_p^2 = .07$]. This interaction reinforced the view of a differential change in the processing of vertical versus horizontal relations in aging. Indeed, it indicated that when considering upright and inverted vertically and horizontally modified faces separately, the only RT effect that approached significance in the older group was the faster detection of vertically than horizontally modified upright faces [$F(1, 64) = 3.2$, $p = .07$, $\eta_p^2 = .10$; see Table 1]. By contrast, there was no such trend in YAs ($F < 1$, $\eta_p^2 < .01$) and the only RT effect that was significant in the young group was the inversion effect for vertically modified faces [$F(1, 64) = 24.33$, $p < .001$, $\eta_p^2 = .42$; Figure 3 and Table 1).

Discussion

Although several studies have shown a decrease in face recognition abilities associated in aging, the processes involved in this decline remain unclear. The aim of the present study was to investigate whether age differences in face recognition may be related to changes in configural face processing. To assess different aspects of configural processing in young and older participants, we conducted a same/different discrimination task with intact faces and faces modified along the vertical or horizontal axis that were presented either upright or inverted.

Our data show a reduced "face inversion effect" (FIE) for the older participants. This was particularly evident on the recognition of original faces where young participants show the classical FIE (with lower accuracy and slower reaction times for inverted than upright faces) while older participants do not demonstrate the classical FIE. This result is consistent with a recent ERP study conducted by Gao and colleagues (2009) who found a reduced inversion effect on the N170 evoked by faces in old (~70 years) compared to young participants. The FIE is classically explained by a disruption of the capacity to process configural information when viewing inverted faces (for a review, see Rossion, 2008). This is emphasized by the lack of FIE in prosopagnosic patients who are known to process faces analytically (Barton, 2009; De Gelder & Rouw, 2000; Ramon & Rossion, 2010), as well as by the weak FIE described in children, for whom face processing relies more on featural information (Mondloch, Leis, & Maurer, 2006; Pellicano, Rhodes, & Peters, 2006). Taken together, these results suggest that the decline in face recognition in elderly subjects could be at least partly attributable to changes in the configural processing of faces. However, the recognition accuracy for intact faces may have been the result of different types of processes, including both horizontal and vertical configural relations encoding, as well as holistic, featural and first-order configural processes. By contrast, the modified faces and associated FIE allowed us examining the processing of vertical and horizontal relations separately. In this respect, it is important to note that the mean performance of the older adults was similar for original faces and vertically modified faces (respectively 63.2 ± 1.6% and 62.4 ± 3.1%), yet the inversion effect was significant for the vertically modified faces only. Furthermore there was not any inversion effect for horizontally modified faces in either young or older adults when the performance level for these faces was clearly different between the two groups (81.7 ± 2.8% in YAs versus 54.5 ± 3.1% in OAs). Overall, these results emphasize that the lack of FIE was not an all-or-nothing phenomenon, as there was a dissociation between the FIE for original faces and the FIE for vertically and horizontally modified faces.

More precisely, our specific manipulation of second-order vertical and horizontal relations revealed a differential pattern of age-related impairment for horizontal versus vertical relations, together with a qualitatively preserved pattern of FIE for vertical—but not horizontal—relations. First, older participants were preserved at detecting changes of vertical distance between features but were extremely poor at detecting changes of horizontal ones. It seems that horizontally relations were virtually not encoded, whatever the face orientation, with performance close to chance level for horizontally modified faces in the older group (Figure 3). This contrasted with young observers' performance who efficiently detected changes in horizontal as well as vertical relations. The differential impact of aging on the encoding of horizontal versus vertical relations is consistent with studies of saccadic eye movements that suggested that aging slows down the latency of horizontal saccades but does not affect vertical ones (Yang & Kapoula, 2008; Yang et al., 2006). Moreover, eye-tracking studies using face stimuli have shown that elderly subjects tend to focus their gaze on the mouth area, whereas young adults focus attention onto the eyes (Firestone et al., 2007; Wong, Cronin-Golomb, & Neargarder, 2005). A bias toward exploring the inferior region of faces could explain the disruption in the detection of horizontal modifications which concerned the eye region. It is also noteworthy that horizontal and vertical relations are not held to play equivalent roles in face individuation (Goffaux et al., 2009). According to these authors, vertical relations are critical to the recognition of a person's identity because they are more easily available than horizontal relations, which cannot be extracted from frequently encountered three-quarter or side views of faces. Thus, there could be greater pressure to encode vertical relations, and this may explain why the processing of vertical, as opposed to horizontal, relations is better preserved with age. This relative preservation could account for the spared ability to identify familiar faces in older subjects.

In addition, our results showed an asymmetrical detrimental effect of face inversion upon the processing of vertical and horizontal second-order information, with a significant FIE for the vertically modified faces only. This result is in line with the idea of a greater contribution of vertical than horizontal relations to face configural encoding and replicated previous findings obtained in young adults (Barton et al., 2001; Goffaux, 2009; Goffaux et al., 2009; see also Freire et al., 2000). It extended these findings to older adults in whom the asymmetrical pattern of inversion for vertical versus horizontal relations was also observed. This result reinforces the idea of a preservation of the encoding of vertical relations in older adults.

Our findings may shed light on some discrepancies observed in previous studies. In particular, Boutet and Faubert (2006) found preserved FIE in older subjects and concluded that structural encoding of faces was spared despite the lower performance of these subjects (compared to young adults) in recognizing upright faces added to a lack of the composite face effect (also known to be related to configural face processing). The discrepancy between Boutet and Faubert's results regarding FIE and ours may first be attributable to differences in experimental design. Boutet and Faubert used a two-alternative forced choice recognition task, where the target face was presented together with a new face on each test trial. This may have favored familiarity-based responses. In addition, as can be seen by comparing overall performances in their study and ours, it constituted an easier task than the current same/different discrimination task, which included a working memory component (see below). Second, Boutet and Faubert used only "original" faces meaning that the target and new faces were always the faces of different individuals. Our results show that some aspect of configural processing, namely vertical relation processing, is relatively preserved with aging. Boutet and Faubert's (2006) study and test faces included uncontrolled differences in this type of second-order relations, in addition to possible featural differences, which may account for the preserved FIE that they found in older participants. Note that featural processing was not assessed either here or in Boutet and Faubert (2006), and was beyond the scope of the present work. In addition, it is interesting to note that the lack of composite effect in Boutet and Faubert (2006) seemed to be due to the older adults' poor performance for the noncomposite (misaligned) faces, in which vertical—but not horizontal—relations are greatly affected. Thus, the relative sparing of vertical relations processing in the older subjects may have been of no help for noncomposite face recognition, whereas the detrimental encoding of horizontal relations may have contributed to the difficulty of the older subjects in the recognition of the noncomposite faces.

Finally, our task did not require long-term memorization of the target faces. Thus, our results are not ascribable to a long-term memory stage of face processing. However, given the delay of 500 ms between the study (target face) and recognition (probe face) phases, working memory was involved. Although age-related changes are less pronounced when only short-term storage is required (e.g., Gregoire & Van der Linden, 1997), there is some evidence that working memory declines during normal aging (e.g., Schmiedek, Li, & Lindenberger, 2009; Bopp & Verhaeghen, 2009). Thus, our results may be related to encoding and/or working memory of configural information. Furthermore, working memory changes may have contributed to the overall decrease of performance observed in older compared to young adults. However, it cannot account for the selective impairment of horizontal relations processing together with the sparing of the detection of vertically modified faces in older compared to young participants. Similarly, task difficulty and the somewhat unnatural nature of the face stimuli used (i.e. artificially distorted gray-scale photographs) may have contributed to the overall lower performance of the older participants. Yet, their performance was well above chance, except for horizontally modified faces. In sum, these limits of our study cannot account for the dissociation that we show between the encoding and/or working memory for second-order horizontal versus vertical relations. Thus, our separate manipulation of vertical and horizontal relations in combination with face inversion allowed us better specifying the aspects of configural, second-order relation processing that are affected by aging.

To the best of our knowledge, this study provides the first evidence that aging can have dissociable effects on configural face-encoding processes. We show changes in the encoding of second-order relations that affected vertical and horizontal relation processing differentially. Namely, there was a selective preservation of the encoding of vertical relations, whereas, by contrast, the processing of horizontal relations was weak in older participants. Future research will have to determine whether these changes in configural processing may be accompanied by a greater reliance on featural processing, which was not assessed in the present study. In conclusion, our results provide a better understanding of the changes in configural face-encoding processes during aging that might explain the limited impact of these changes on the daily life of older adults.

References

Bäckman, L. (1991). Recognition memory across the adult life span: The role of prior knowledge. *Memory and Cognition, 19,* 63–71.

Bartlett, J. C., & Fulton, A. (1991). Familiarity and recognition of faces in old age. *Memory and Cognition, 19,* 229–238.

Bartlett, J. C., Leslie, J. E., Tubbs, A., & Fulton, A. (1989). Aging and memory for pictures of faces. *Psychology and Aging, 4,* 276–283. doi:10.1037/0882-7974.4.3.276

Barton, J. J. (2009). What is meant by impaired configural processing in acquired prosopagnosia. *Perception, 38,* 242–260. doi:10.1068/p6099

Barton, J. J., Keenan, J. P., & Bass, T. (2001). Discrimination of spatial relations and features in faces: Effects of inversion and viewing duration. *British Journal of Psychology, 92,* 527–549. doi:10.1348/000712601162329

Bopp, K. L., & Verhaeghen, P. (2009). Working memory and aging: Separating the effects of content and context. *Psychology and Aging, 24,* 968–80. doi:10.1037/a0017731

Boutet, I., & Faubert, J. (2006). Recognition of faces and complex objects in younger and older adults. *Memory and Cognition, 34,* 854–864.

Chaby, L., George, N., Renault, B., & Fiori, N. (2003). Age-related changes in brain responses to personally known faces: An event-related potential (ERP) study in humans. *Neuroscience Letters, 349,* 125–129. doi:10.1016/S0304-3940(03)00800-0

Chaby, L., Jemel, B., George, N., Renault, B., & Fiori, N. (2001). An ERP study of famous face incongruity detection in middle age. *Brain and Cognition, 45,* 357–377. doi:10.1006/brcg.2000.1272

Chaby, L., & Narme, P. (2009). Processing facial identity and emotional expression in normal aging and neurodegenerative diseases. *Psychologie et Neuropsychiatrie du Vieillissement, 7,* 31–42. doi:10.1016/S0987-7053(99)90054-0

Cohen, J. (1988). *Statistical power analysis for the Behavioral sciences* (2nd Edition). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Crook, T. H., & Larrabee, G. J. (1992). Changes in face recognition memory across the adult life span. *Journal of Gerontology, 47,* 138–141.

Decarli, C., Massaro, J., Harvey, D., Hald, J., Tullberg, M., Au, R., . . . Wolf, P. A. (2005). Measures of brain morphology and infarction in the Framingham Heart Study: Establishing what is normal. *Neurobiology of Aging, 26,* 491–510. doi:10.1016/j.neurobiolaging.2004.05.004

De Gelder, B., & Rouw, R. (2000). Paradoxical configuration effects for faces and objects in prosopagnosia. *Neuropsychologia, 38,* 1271–1279. doi:10.1016/S0028-3932(00)00039-7

Dellatolas, G., De Agostini, M., Jallon, P., Poncet, M., Rey, M., & Lellouch, J. (1988). Mesure de la préférence manuelle par auto-questionnaire dans la population française adulte. *Revue de Psychologie Appliquée, 38,* 117–136.

Farkas, L. G. (1994). *Anthropometry of the head and face in medicine.* New York: Elsevier.

Firestone, A., Turk-Browne, N. B., & Ryan, J. D. (2007). Age-related deficits in face recognition are related to underlying changes in scanning behavior. *Neuropsychology, Development and Cognition Section B, Aging, Neuropsychology, and Cognition, 14,* 494–607. doi:10.1080/13825580600899717

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini mental state: A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12,* 189–198. doi:10.1016/0022-3956(75)90026-6

Freire, A., Lee, K., & Symons, L. A. (2000). The face-inversion effect as a deficit in the encoding of configural information: Direct evidence. *Perception, 29,* 159–170. doi:10.1068/p3012

Gao, L., Xu, J., Zhang, B., Zhao, L., Harel, A., & Bentin, S. (2009). Aging effects on early-stage face perception: An ERP study. *Psychophysiology, 46,* 970–983. doi:10.1111/j.1469-8986.2009.00853.x

George, N., Jemel, B., Fiori, N., Chaby, L., & Renault, B. (2005). Electrophysiological correlates of facial decision: Insights from upright and upside-down Mooney-face perception. *Cognitive Brain Research, 24,* 663–673. doi:10.1016/j.cogbrainres.2005.03.017

Goffaux, V. (2009). Spatial interactions in upright and inverted faces: Re-exploration of spatial scale influence. *Vision Research, 49,* 774–781. doi:10.1016/j.visres.2009.02.009

Goffaux, V., & Rossion, B. (2007). Face inversion disproportionately impairs the perception of vertical but not horizontal relations between features. *Journal of Experimental Psychology: Human Perception and Performance, 33,* 995–1002. doi:10.1037/0096-1523.33.4.995

Goffaux, V., Rossion, B., Sorger, B., Schiltz, C., & Goebel, R. (2009). Face inversion disrupts the perception of vertical relations between features in the right human occipito-temporal cortex. *Journal of Neuropsychology, 3,* 45–67. doi:10.1348/174866408X292670

Grady, C. L., Bernstein, L. J., Beig, S., & Siegenthaler, A. L. (2002). The effects of encoding task on age-related differences in the functional neuroanatomy of face memory. *Psychology and Aging, 17,* 7–23. doi:10.1037/0882-7974.17.1.7

Gregoire, J., & Van der Linden, M. (1997). The effect of age on forward and backward digit spans. Aging, *Neuropsychology and Cognition, 4,* 140–149. doi:10.1080/13825589708256642

Huh, T. J., Kramer, J. H., Gazzaley, A., & Delis, C. (2006). Response bias and aging on a recognition memory task. *Journal of the International Neuropsychological Society, 12,* 1–7. doi:10.10170S1355617706060024

Jacques, C., d'Arripe, O., & Rossion, B. (2007). The time course of the inversion effect during individual face discrimination. *Journal of Vision, 7, 3,* 1–9. doi:10.1167/7.8.3

James, L. E. (2004). Meeting Mr. Farmer versus meeting a farmer: Specific effects of aging on learning proper names. *Psychology and Aging, 19,* 515–522. doi:10.1037/0882-7974.19.3.515

Lamont, A. C., Stewart-Williams, S., & Podd, J. (2005). Face recognition and aging: Effects of target age and memory load. *Memory and Cognition, 33,* 1017–1024.

Lott, A. L., Haegerstrom-Portnoy, G., & Schneck, M. E. (2005). Face recognition in the elderly. *Optometry and Vision Science, 82,* 874–881. doi:10.1097/01.opx.0000180764.68737.91

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences, 6,* 255–260. doi:10.1016/S1364-6613(02)01903-4

Memon, A., & Bartlett, J. C. (2002). The effects of verbalisation on face recognition in young and older adults. *Applied Cognitive Psychology, 16,* 635–650. doi:10.1002/acp.820

Minear, M., & Park, D. C. (2004). A lifespan database of adult facial stimuli. *Behavior Research Methods, Instruments, and Computers, 36,* 630–633.

Mondloch, C. J., Leis, A., & Maurer, D. (2006). Recognizing the face of Johnny, Suzy and Me: Insensitivity to the spacing among features at 4 years of age. *Child Development, 77,* 234–243. doi:10.1111/j.1467-8624.2006.00867.x

Nakamura, A., Yamada, T., Abe, Y., Nakamura, K., Sato, N., Horibe, K., . . . Ito, K. (2001). Age-related changes in brain neuromagnetic responses to face perception in humans. *Neurosciences Letters, 312,* 13–16. doi:10.1016/S0304-3940(01)02168-1

Passarotti, A. M., Smith, J., DeLano, M., & Huang, J. (2007). Developmental differences in the neural bases of the face inversion effect show progressive tuning of face-selective regions to the upright orientation. *Neuroimage, 34,* 1708–1722. doi:10.1016/j.neuroimage.2006.07.045

Pellicano, E., Rhodes, G., & Peters, M. (2006). Are preschoolers are sensitive to configural information of faces? *Developmental Science, 9,* 270–277. doi:10.1111/j.1467-7687.2006.00489.x

Perfect, T. J., Harris, L. J. (2003). Adult age differences in unconscious transference: Source confusion or identity blending? *Memory & Cognition, 31,* 570–580.

Pfefferbaum, A., Adalsteinsson, E., & Sullivan, V. (2005). Frontal circuitry degradation marks healthy adult aging: Evidence from diffusion tensor imaging. *Neuroimage, 26,* 891–899. doi:10.1016/j.neuroimage.2005.02.034

Ramon, M., & Rossion, B. (2010). Impaired processing of relative distances between features and of the eye region in acquired-prosopagnosia – Two sides of the same holistic coin? *Cortex, 46,* 374–389. doi:10.1016/j.cortex.2009.06.001

Rizzo, M., Corbett, J. J., Thompson, H. S., & Damasio, A. R. (1986). Spatial contrast sensitivity in facial recognition. *Neurology, 36,* 1254–1256.

Rossion, B. (2008). Picture-plan inversion leads to qualitative changes of face perception. *Acta Psychologica, 128,* 274–289. doi:10.1016/j.actpsy.2008.02.003

Schmiedek, F., Li, S. C., & Lindenberger, U. (2009). Interference and facilitation in spatial working memory: Age-associated differences in lure effects in the n-back paradigm. *Psychology and Aging, 24,* 203–210. doi:10.1037/a0014685

Searcy, J. H., Bartlett, J. C., & Memon, A. (1999). Age differences in accuracy and choosing in eyewitness identification and face recognition. *Memory and Cognition, 27,* 538–552.

Searcy, J. H., Bartlett, J. C., Memon, A., & Swanson, K. (2001). Aging and lineup performance at long retention intervals: Effects of metamemory and context reinstatement. *Journal of Applied Psychology, 86,* 207–214. doi:10.1037/0021-9010.86.2.207

Thomas, C., Moya, L., Avidan, G., Humphreys, K., Jung, K. J., Peterson, M. A., . . . Behrmann, M. (2008). Reduction in white matter connectivity, revealed by diffusion tensor imaging, may account for age-related changes in face perception. *Journal of Cognitive Neuroscience, 20,* 268–284. doi:10.1162/jocn.2008.20025

Wiese, H., Schweinberger, S. R., & Hansen, K. (2008). The age of the beholder: ERP evidence of an own-age bias in face memory. *Neuropsychologia, 46,* 2973–2985. doi:10.1016/j.neuropsychologia.2008.06.007

Wong, B., Cronin-Golomb, A., & Neargarder, S. (2005). Patterns of visual scanning as predictors of emotion identification in normal aging. *Neuropsychology, 19,* 739–49. doi:10.1037/0894-4105.19.6.739

Yang, Q., & Kapoula, Z. (2008). Aging does not affect the accuracy of vertical saccades nor the quality of their binocular coordination: A study of a special elderly group. *Neurobiology of Aging, 29,* 622–638. doi:10.1016/j.neurobiolaging.2006.11.007

Yang, Q., Kapoula, Z., Debay, E., Coubard, O., Orssaud, C., & Samson, M. (2006). Prolongation of latency of horizontal saccades in elderly in distance and task specific. *Vision Research, 46,* 751–759. doi:10.1016/j.visres.2005.08.027

Yesavage, J., & Brink, T. L. (1983). Development and validation of a geriatric depression scale: A preliminary report. *Journal of Psychiatric Research, 17,* 37–49. doi:10.1016/0022-3956(82)90033-4

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology, 81,* 141–145. doi:10.1037/h0027474

Received October 28, 2009
Revision received June 30, 2010
Accepted July 14, 2010 ■