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Age-Related Deficits in Face Recognition are Related to Underlying Changes in Scanning Behavior

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ABSTRACT

Previous studies demonstrating age-related impairments in recognition memory for faces are suggestive of underlying differences in face processing. To study these differences, we monitored eye movements while younger and older adults viewed younger and older faces. Compared to the younger group, older adults showed increased sampling of facial features, and more transitions. However, their scanning behavior was most similar to the younger group when looking at older faces. Moreover, while older adults exhibited worse recognition memory than younger adults overall, their memory was more accurate for older faces. These findings suggest that age-related differences in recognition memory for faces may be related to changes in scanning behavior, and that older adults may use social group status as a compensatory processing strategy.

Older adults typically perform less accurately than younger adults on recall and recognition tests of memory for a variety of stimuli (for a review, see Light, 1996). Perhaps most disconcerting for everyday functionality is the finding that older adults are impaired relative to younger adults in recognizing previously viewed faces (Ferris et al., 1980; Fulton & Bartlett, 1991). Here we explore the relationship of this memory impairment for faces to underlying differences in how faces are processed.

During viewing of faces, both humans and other primates largely concentrate their eye movements on internal features, e.g., the eyes, nose and mouth (Althoff & Cohen, 1999; Keating & Keating, 1982; Nahm et al., 1997; Walker-Smith et al., 1977; Wilson & Goldman-Rakic, 1994). Such patterns of eye movements are fundamentally related to subsequent recognition.

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For example, Henderson et al. (2005) found that recognition memory for faces was significantly impaired when participants were prevented from freely making saccades to examine facial features. One possible mechanism for this link is that eye movements may permit the encoding of relations among facial features and/or allow specific feature details to be encoded. Given that eye movements are important for face memory, changes in eye scanning behavior during the initial viewing of novel faces may underlie older adults' impairment in subsequent face recognition memory. If this is the case, one straightforward prediction is that scanning behavior should differ between younger and older adults.

One way that scanning behavior could differ is in terms of the amount of sampling of facial features. Previous work has suggested that older adults have a binding deficit that causes them to have difficulty associating distinct features into lasting representations (Chalfonte & Johnson, 1996; Mitchell et al., 2001; Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2004). Age-related binding deficits would impact not only later recognition memory for faces, but the very way in which facial features are sampled during initial encoding of faces (i.e., the binding process itself). If eye movements aid in determining the relations among features (Henderson et al., 2005), a binding deficit would disrupt the processing and storage of those relations and could manifest itself as an increase in sampling behavior among facial features. If, instead, eye movements are important for extracting specific detail regarding individual facial features, then older and younger adults may differ in the extent to which particular facial features are viewed. Alternatively, age-related deficits in face recognition may be due to difficulties in retrieving the previously formed memory representations of the faces (Craik & McDowd, 1997; Grady et al., 2005). In this case, eye movement scanning behavior during initial encoding should be similar between younger and older adults despite impaired face recognition for the older adults.

Finally, the age-related deficits in face recognition may have less to do with changes in eye movement scanning and more to do with the social group status of the face that is being viewed. That is, processing strategies might vary depending on whether an observer is studying a face belonging to a member of his or her own social group (social in-group) or that of a member belonging to a different group (social out-group; Simons & Levin, 1998). If a viewer were studying a face from his/her own social group, eye movements may be directed towards differentiating features, whereas when studying a face from an “out-group”, eye movements may be directed towards general attributes that define their respective out-group status and not specific facial features.

This latter alternative is supported by findings of “other-race” recognition effects in which viewers are more accurate for recognizing faces of their own race compared to a different race (Levin, 2000; Malpass, 1981; Meissner &

Brigham, 2001). As well, there appears to be an "other-age" bias in face recognition. Anastasi and Rhodes (2005) demonstrated that both children and older adults recognized faces of their respective age groups more accurately than other-age faces. This other-age bias has also been demonstrated in studies of face recognition in young, college-aged adults and older adults; such studies reveal that older adults are impaired for recognizing younger versus older faces (Fulton & Bartlett, 1991; Memon et al., 2003), and in some cases older adults do not even show a recognition impairment when compared to younger adults when recognition accuracy is assessed in terms of "own-age" versus "other-age" (Lamont et al., 2005; Wright & Stround, 2002). Such findings not only underscore the importance of using faces from the viewers' own age groups to assess face recognition, but further suggest that social groups (whether "group" is identified via race or age) may confer certain advantages in processing (Anastasi & Rhodes, 2005; Lamont et al., 2005). The impact of social group status on face processing can be assessed by examining the extent to which eye movement behavior differs when viewing faces of the same or different age group. If social group status impacts viewing behavior, interactions should be observed between the age of the viewer and the age of the face being viewed.

Here we examine how recognition memory for faces and social status are related to eye movement scanning behavior by presenting younger and older viewers with younger and older novel faces. As cover tasks, subjects were required to judge the age of the presented faces and the quality of the photographs. This was done to ensure that older and younger adults were engaged in the task at a similar level of processing (Craik, 1994). Eye movements were analyzed with respect to the amount of scanning behavior that was directed towards particular facial features (eyes, nose and mouth) and the number of transitions between feature regions. This latter measure provides an index of the extent to which viewers are assessing the relations among the facial features (Althoff & Cohen, 1999; Ryan & Cohen, 2004; Ryan et al., 2000). We further assessed the type of eye scanning behavior during face processing that promotes successful subsequent recognition in younger and older adults by comparing initial viewing behavior for those faces that are later recognized versus those that are not, analogous to methods from neuroimaging studies that have assessed the neural recruitment related to subsequent recognition (e.g., Brewer et al., 1998; Wagner et al., 1998). Numerous studies have examined differences in eye movement scanning behavior between neuropsychological patients and neurologically intact controls for faces (Althoff et al., 1998; Gordon et al., 1992; Manor et al., 1999; Streit et al., 1997); however, similar paradigms have not been implemented to examine age-related changes in face process. Here we report, to the best of our knowledge, the first empirical investigation into age-related differences in face processing as assessed by eye movement behavior.

METHODS

Subjects

Twenty-four young college-age students from the University of Toronto (mean age = 21.7 years; range 18–27; 11 males, 13 females), and 24 older adults from the Toronto area (mean age = 70.54; range 62–85; five males, 19 females) participated in this study in exchange for monetary compensation. Recruitment was conducted through the Rotman Research Institute volunteer pool. Health screening for the older adults was conducted by coordinators of the Rotman Research Institute volunteer pool, such that the participants contacted for the present experiment were healthy older adults who had no previous history of neurological disorder and were not presently on medication for conditions that may otherwise affect cognition (e.g., depression). All subjects reported normal or corrected-to-normal vision.

Apparatus

Stimuli were presented on a 19-inch Dell M991 monitor (resolution 1024 × 768) from a distance of 24 inches. An SR Research Ltd. EyeLink II system was used to collect eye movement data with a temporal resolution of 2 ms. Eye-tracking was highly accurate: if the error at any calibration point was greater than 1° or if the mean error for all nine calibration points was greater than 0.5°, the system was re-calibrated.

Stimuli and Design

The stimuli consisted of 96 novel non-famous faces that were placed against a uniform, black background (480 × 480 pixels), such that only the face and hair were visible. Only Caucasian faces were used. The eyes of each face were centered in the same location. Four different sets of 24 faces were constructed, each set being equivalent on age and gender of the faces, as well as similar on ratings of “famousness” and “nameability”, as assessed through prior norming studies. The faces used in the current study were judged to be nonfamous (average score of less than 2 on a scale from 1 “nonfamous” to 5 “famous”), and without an associated name (average score of less than 2 on a scale from 1 “no associated name” to 5 “first and last name readily available”). This was done to ensure that subjects would not have an encoding advantage for some of the faces based on resemblance to pre-experimentally known people. Half of the faces in the set were judged to be under the age of 35; older faces were those judged to be over the age of 55; as classified by two independent raters. Half of the faces within the younger and the older set were male, half were female; therefore, if there is a gender bias in face recognition, the male and female subjects would be equally disadvantaged for exactly one-half of the faces within each (younger and older) set. Each subject studied one set of 24 faces and was tested with two sets of faces (48 total), including the one they had studied. Thus at test, 24 faces were new and 24 had been previously viewed during the study session. Each set of faces was viewed as "studied" and as "recognition foils". Combinations of sets as "studied" and as "recognition foils" were fully counterbalanced over 12 subjects.

Procedure

During study, each of the 24 faces was presented individually for 7 s. Faces were presented in a different random order for each subject. Subjects initiated the trials by fixating on a central point and pressing a button on a keypad. To ensure that younger and older adults were processing faces at the same level, subjects made two ratings for each of the faces after it had been removed from the screen: the quality of the photograph was rated from 1 to 5 (1 = worst quality, 3 = middle quality, 5 = best quality) and the age of the face was rated from 1 to 5 (1 = 21 – 30, 2 = 31 – 40, 3 = 41 – 50, 4 = 51 – 60, 5 = 61 – 70). During the study phase, participants were not told that a memory test would follow. Subjects were given approximately a 5-min break between the study and the test phases, during which they talked informally with the experimenter; no additional tests were given to the subjects. During the test phase, 48 faces were presented individually, in a random order, and subjects performed an old/new recognition memory task by pressing one of two buttons (counterbalanced across subjects). The face was removed from the screen when the recognition judgment was made.

Analysis

A general interest area template for each of the faces was created, outlining a region for the eyes, nose and mouth. Eye movement scanning behavior was analyzed for the encoding (study) session only. Various measures were derived from the eye movement data, including the viewing time directed to each of these interest areas, the proportion of total viewing time directed to each interest area as a function of the total time spent on the three interest areas, the number of fixations directed to each interest area, the proportion of total fixations directed to each interest area as a function of the total fixations on the three interest areas, and the number of transitions made among the interest areas. Analyses of variance (ANOVAs) were conducted on each of the eye movement measures using the factors of age group (young, old), face age (young, old), interest area (eyes, nose, mouth). Further analyses examined subsequent memory effects by including a study trial factor based on whether the face was later recognized or not (remembered, forgotten).

RESULTS

For the judgments made in the study block, there was a main effect of face age on the judgment of the age of the face [$F(1, 46) = 1532.02$, $p < .0001$];

experimenter-defined younger faces were judged as younger and experimenter-defined older faces were judged as older (mean rating = 1.48 vs. 3.84 corresponding to categories of 21–40 years of age for the younger faces and 51–60 years of age for the older faces). There was no main effect of age on the judgment of the age of the face ($F < 1$); however, there was a significant face age by age group interaction [$F(1, 46) = 15.57$, $p < .0001$]. Younger adults rated the older faces higher on the age scale compared to the older adults (3.97 vs. 3.72), and rated the younger faces lower on the age scale compared to the older adults (1.37 vs. 1.60).

The pictures of the younger faces were judged to be of higher quality (3.99) than the pictures of the older faces [3.43; $F(1, 46) = 62.31$, $p < .0001$], and older adults gave higher quality ratings overall compared to the younger adults [4.02 vs. 3.40; $F(1, 46) = 11.42$, $p = .001$]. There was a significant interaction between the age of the face and age group [$F(1, 46) = 4.54$, $p < .05$]; older adults judged the pictures of younger faces to be of higher quality than the younger adults (4.23 vs. 3.76), and this difference was exaggerated for pictures of the older adults (3.82 vs. 3.01).

A significant effect of age group (younger adults, older adults) was found for the corrected recognition score (hits minus false alarms), $F(1, 46) = 21.775$, $p < .001$, with younger subjects correctly recognizing the faces more often compared to older adults (0.80 vs. 0.64). There was also a significant effect of face age, $F(1, 46) = 13.851$, $p < .01$, with older faces being recognized more often than younger faces (0.77 vs. 0.67). Importantly, an interaction between age group and face age was observed, $F(1, 46) = 5.836$, $p < .05$, with younger subjects recognizing older and younger faces with similar accuracy (0.82 and 0.78, respectively), but older adults more accurately recognizing older than younger faces (0.73 and 0.56).

The eye movement data during the encoding (study) session revealed a main effect of the age of the face that had been viewed. There was greater sampling of the eye, nose and mouth interest areas for younger faces compared to older faces [number of fixations: $F(1, 46) = 6.61$; proportion of total fixations: $F(1, 46) = 14.43$; viewing time: $F(1, 46) = 5.47$; proportion of total viewing time: $F(1, 46) = 6.86$, all p values $< .05$]. More transitions were made between interest areas for younger faces than older faces, $F(1, 46) = 20.640$, $p < .0001$. Thus, older faces, which were subsequently more accurately recognized than younger faces, received less sampling and less transitional behavior during initial encoding. This may suggest that features of the older faces may have been more distinctive compared to the younger faces, perhaps due to the fact that, with age, unique changes occur around facial features.

The distribution of eye movements across interest areas revealed differences in how younger and older faces are processed. Regardless of face age, the eyes were sampled more often than the nose and the mouth; in turn, the nose received more eye movement behavior than the mouth [number of fixations: $F(2, 92) = 196.73$; proportion of total fixations: $F(2, 92) = 229.41$; interest area viewing time: $F(2, 92) = 211.07$; proportion of total viewing time: $F(2, 92) = 217.55$, all p values < .0001]. There were significant interactions between face age and interest area [number of fixations: $F(2, 92) = 10.21$; proportion of total fixations: $F(2, 92) = 10.41$; viewing time: $F(2, 92) = 11.71$; proportion of total viewing time: $F(2, 92) = 11.38$, all p values < .0001] due to an increase in sampling of the eyes, and a decrease in sampling of the nose and mouth for older compared to younger faces (see Figure 1).

The distribution of eye movements across interest areas also revealed differences in how younger and older subjects process faces. Regardless of face age, older adults made a greater number of fixations than younger adults, $F(1, 46) = 8.80$, $p < .01$, and more transitions between interest areas, $F(1, 46) = 9.23$, $p < .01$. Interactions were found between age group and interest areas: younger subjects spent more time viewing the eyes compared to older subjects, whereas the older adults spent more time viewing the nose and, to a lesser extent, the mouth, compared to younger subjects [proportion of fixations: $F(2, 92) = 2.60$, $p = 0.08$, viewing time: $F(2, 92) = 3.11$, $p < .05$; proportion of total viewing time: $F(2, 92) = 2.47$, $p = .09$]. A trend was observed between age group (older and younger adults) and face age (older and younger faces) on the number of transitions made between interest areas [$F(1, 46) = 3.58$, $p = .065$] suggesting that scanning of the faces is impacted

FIGURE 1. The amount of viewing time (ms) directed to the face features (eyes, nose and mouth) is depicted for younger and older faces. More viewing is directed to the eyes of the older, compared to the younger, faces, whereas more viewing is directed to the nose and the mouth of the younger, compared to the older, faces.

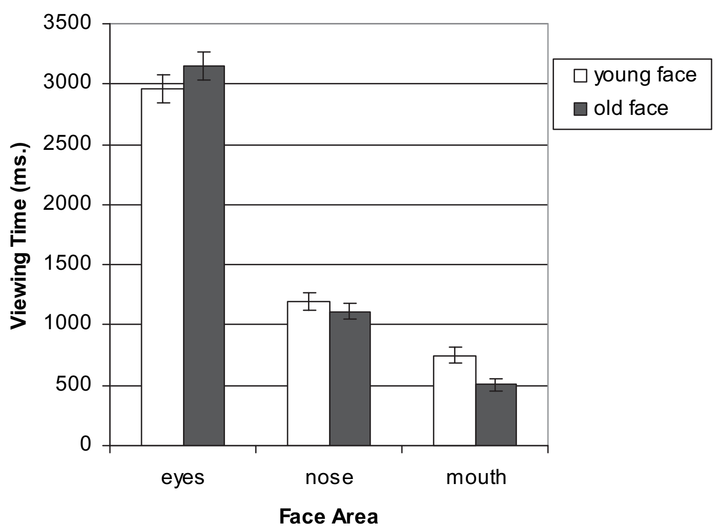
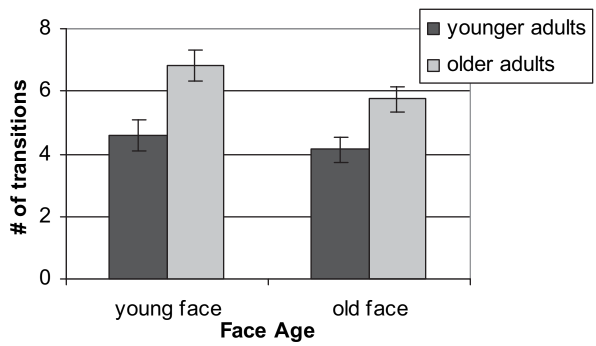


FIGURE 2. The number of transitions made between facial features (eyes, nose and mouth) is depicted for younger and older adults viewing younger and older faces. Older adults made more transitions between facial features than younger adults, particularly for younger faces for which older adults had poorer recognition performance. Group means and standard errors are depicted.



to some extent by relative group status. Younger adults made approximately the same amount of transitions for both young and old faces, whereas older adults made more transitions for younger faces then older faces (see Figure 2).

Based on the subsequent memory paradigm (Brewer et al., 1998; Wagner et al., 1998), faces were binned according to whether they were remembered in the recognition test. Scanning behavior could then be analyzed as a function of encoding quality. When the interest areas were analyzed separately, significant interactions were found between age group and subsequent memory for viewing of the nose. Successful subsequent recognition was associated with an increase in viewing of the nose, but only for younger subjects [proportion of fixations: $F(1, 23) = 5.78$, viewing time: $F(1, 23) = 5.38$; proportion of total viewing time: $F(1, 23) = 5.07$, all p values $< .05$)] This suggests that sampling of the nose is an important feature in determining later recognition for younger adults, even though older adults directed more eye movement behavior towards the nose interest area overall. No other interest areas or viewing patterns showed interactions between age group and subsequent memory.

DISCUSSION

The present findings provide insight into age-related differences in face processing and their relationship to recognition memory. These results have implications for the functional role of eye movements in memory and for the influence of social perception on encoding. The present findings may also speak to the nature of feature-based and holistic processing in older versus younger adults. Each of these topics will be discussed in turn.

Age-related Differences in Face Processing and Recognition Memory

Younger and older adults sampled the facial features in a manner similar to previously reported findings (e.g., Althoff & Cohen, 1999; Walker-Smith et al., 1977): greater scanning behavior was directed to the eyes, followed by the nose and the mouth. However, differences were observed in the way in which younger and older adults scanned faces, regardless of the age of the face. Compared to younger adults, older adults exhibited an increase in sampling behavior (more fixations and more transitions). The observed age-related differences in scanning behavior corresponded to the age-related differences in recognition performance; older adults showed increases in scanning behavior for faces and were subsequently less accurate in their recognition performance for the faces. Subsequent memory analyses provided further evidence that patterns of initial eye scanning are critically related to recognition: viewing of the nose distinguished faces that were subsequently remembered versus forgotten for the younger subjects. The current findings lend support to the argument from Henderson et al. (2005) that eye movements are functional for face learning and provide the first demonstration that there are age-related disruptions in face processing. The current work further demonstrates that such age-related changes in scanning and memory can be altered under particular conditions for the older adults.

Impact of Social Group Status on Face Processing

Older adults showed more sampling of younger than older faces, but had worse memory for these faces in a subsequent memory test. This suggests that older adults were using age as a reference for social group status to direct further processing in line with Simons and Levin (1998) and studies of other-race effects (e.g., Anthony et al., 1992; Levin, 2000) and other-age effects (e.g., Anastasi & Rhodes, 2005; Lamont et al., 2005; Memon et al., 2003; Wright & Stroud, 2002) which suggest that social group status determines the manner in which facial features are processed and maintained in memory. It is important to note that scanning and recognition performance of younger adults were not impacted by the age of the face being viewed. If social group status were a general effect, as suggested by other-race effects, then one might expect younger viewers to exhibit increased scanning and worse memory for older faces. However, it might be the case that face processing performance is at ceiling in younger adults, such that there is little benefit that can be gained from viewing a same-group face for the younger adults. As well, age may not be as strong of an indicator of group status for the younger adults. Further research that examines scanning behavior using different social status groups (e.g., race, employment; Simons & Levin, 1998) may find conditions under which face processing is altered in younger adults.

Another interpretation of the observed age group by face age interaction is that expertise with a particular social group may counteract the scanning changes observed in older adults. This notion of "expertise" has been invoked to explain the other-race effect; according to Sporer (2001), past experience with a particular ethnic group allows the viewer to encode same-race configurations of facial features better than those of another-race faces, which must first be categorized with respect to group membership. This suggests that the processing of social out-group faces may take additional encoding time and/or resources. Additionally, previous research has suggested that aging is associated with a general decline in the amount and rate of processing (Craik & Byrd, 1982; Salthouse, 1999). Older adults then may be at a disadvantage for encoding faces under a fixed presentation time compared to younger adults, and may be particularly disadvantaged for the younger (social out-group) faces which would take even more time and/or resources to encode. Here then, if older adults have a deficit of encoding facial information into a memory representation, natural expertise with older faces may allow them to form a representation of the face more efficiently, leading to reduced sampling behavior and an increase in subsequent memory performance.

The "expertise" hypothesis should be entertained with caution, however, given that the older adults have had more experience over their lifespan with younger (and older) faces compared to the younger adults. Thus, *a priori*, one might have expected that face age would impact scanning behavior for the younger adults but not for the older adults (see Anastasi & Rhodes, 2005, for similar discussions). As well, for older adults, we did not find any sampling behavior that correlated with subsequent memory. Such effects may have been obscured by variability in the distinctiveness of particular facial features across the younger and older faces.

The Nature of Face Processing in Older versus Younger Adults

The current work may speak to the nature of face processing in younger and older adults. There is evidence that faces are processed holistically, such that the individual features are bound into a single representation (Tanaka & Farah, 1993; see Bruce & Young, 1998, for review). Previous work has reported impaired performance in older adults for associating features of stimuli into a coherent lasting representation (Chalfonte & Johnson, 1996; Mitchell et al., 2001). The increase of sampling within and among features observed for the older adults may be indicative of an age-related change in the binding process. Here, a binding deficit may have caused increases in sampling behavior in an effort to adequately process the face information. However, this increase in transitional behavior was not related to subsequent recognition for the older adults. This may suggest that increased effort towards binding the relations among the face features did not confer a later advantage at recognition; thereby further suggesting that binding is impaired in the older adults. That is, despite increased attempts at binding the relations among the face features, such information may not have been available to the older adults during the later recognition test, or such information was not used to make the recognition decision.

The pattern of eye scanning from the younger adults suggests that the encoding of individual features may be important for later memory (Macho & Leder, 1998). Viewing of the nose distinguished faces that were subsequently remembered versus forgotten for the younger subjects. The nose may have been distinguishing feature among faces and used by the younger adults to support later recognition, in addition to, or perhaps in lieu of, information regarding the bound composite of the face. There was no indication that viewing of a particular facial feature was related to subsequent recognition for the older adults. This may suggest that the older adults were relying on impaired binding processes for face encoding and/or that feature processing is disrupted in the older compared to the younger adults.

It is unclear to what extent the cover tasks given to the subjects (i.e., judgment of age and quality of the photographs), were related to later recognition memory. Younger adults showed similar recognition rates for older and younger faces, although the ratings of quality for those faces differed. Older adults showed less accurate recognition memory for younger compared to older faces, even though the pictures of the younger faces were judged as having a higher quality. However, it is clear that even though younger and older adults were similarly engaged in the encoding of the faces in the current paradigm, different scanning patterns emerged between younger and older adults that were related to differences in memory performance.

CONCLUDING REMARKS

The general differences in scanning behavior and in later recognition between younger and older adults points to the functional role of eye movements in face learning.

Clearly eye movements and memory are related (e.g., Henderson et al., 2005; Ryan et al., 2000, 2004a, 2004b); however, it remains to be determined whether general age-related disruptions in scanning directly caused subsequent recognition to be impaired, or whether underlying age-related changes in the ability to encode information into a lasting memory representation were outwardly manifested as changes in scanning behavior. The effect of social group status on scanning behavior for the older adults may begin to speak to this issue. The current work demonstrates that when scanning behavior is altered in older adults due to differences in social group status of the faces, memory performance for those faces is altered as well. This could suggest that the memory performance is a consequence of, and secondary to, scanning behavior. This argument assumes, though, that what is maintained in memory regarding the faces, across social groups, is similar. It may be that within the same social group, distinguishing facial features are more easily identifiable. As a result, social in-group faces may be represented in terms of these features, while social out-group faces may be represented as a composite of features. In that case, memory *ability* would be left unchanged; rather, the *type* or *amount* of information that is maintained in memory would be altered. Further work should investigate recognition memory for faces in which the initial eye scanning patterns for older adults are made to resemble those of younger adults. As well, studies in which a particular facial feature is highlighted could elucidate the compensatory strategies that are beneficial to older adults. Furthermore, while the current work did not control for the race of the recruited subjects, previous research has demonstrated the strong effects of race on face recognition (e.g., Meissner & Brigham, 2001). Future work could examine whether the own-race bias interacts with the age, or social group bias, on recognition of faces. Other factors, such as the level of education of the subjects, may further invoke general differences in scanning strategy that could be investigated in relation to face recognition.

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