Experimental Aging Research
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713722867

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Online publication date: 05 March 2010

To cite this Article Jäger, Theodor, Mecklinger, Axel and Kliegel, Matthias(2010) 'Associative Recognition Memory for Faces: More Pronounced Age-Related Impairments in Binding Intra- than Inter-Item Associations', Experimental Aging Research, 36: 2, 123 — 139
To link to this Article: DOI: 10.1080/03610731003613391
URL: http://dx.doi.org/10.1080/03610731003613391

Experimental Aging Research, 36: 123–139, 2010

ISSN: 0361-073X print/1096-4657 online
DOI: 10.1080/03610731003613391

Routledge
Taylor & Francis Group

ASSOCIATIVE RECOGNITION MEMORY FOR FACES: MORE PRONOUNCED AGE-RELATED IMPAIRMENTS IN BINDING INTRA- THAN INTER-ITEM ASSOCIATIONS

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Performance in recognition memory for associations between arbitrarily paired items is substantially disrupted in old age. The present study examined whether older adults show more or less of a deficit when the to-be-associated items can be 'unitized' into a single representation during encoding. Results revealed that older adults are disproportionately

Received 7 August 2007; accepted 7 September 2008.

This work was supported by the German Research Society (grant FOR448 awarded to Axel Mecklinger). The authors wish to thank Barbara Zimmerli and Martina Hubo for their helpful assistance in data collection.

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impaired in their memory for unitizable face-pairs, suggesting substantial age deficits in unitization processes required for the formation of associations between highly overlapping stimuli. Potential compensatory mechanisms are discussed that may account for these preliminary results of a selective age deficit in the encoding or retrieval of intra-item associations.

Recognition memory refers to the ability of becoming aware that a currently presented item or information has already been encountered some time in the past. Dual-process models propose that, in general, recognition memory is subserved by two qualitatively distinct processes termed *familiarity* and *recollection* (Aggleton & Brown, 2006; Jacoby, 1991; Mandler, 1980; Yonelinas, 2002). Familiarity is conceptualized as an item-specific, noncontextual memory process that seems to be generated by the cortex of the anterior medial temporal lobe (e.g., Henson, Cansino, Herron, Robb, & Rugg, 2003; Norman & O'Reilly, 2003). By contrast, recollection-based recognition is thought to enable the retrieval of contextual information, such as the spatiotemporal context in which an item was encountered, and is assumed to be strongly dependent on the hippocampal formation (e.g., Montaldi, Spencer, Roberts, & Mayes, 2006; Yonelinas, Otten, Shaw, & Rugg, 2005).

Within the field of cognitive aging, some studies revealed that older adults show smaller deficits in familiarity than in recollection (e.g., Bastin & Van der Linden, 2003; Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006; Howard, Bessette-Symons, Zhang, & Hoyer, 2006). However, it should be noted that the pattern of age differences in familiarity and recollection is still highly controversial (see e.g., Davidson & Glisky, 2002; Duarte, Ranganath, Trujillo, & Knight, 2006; Li, Morcom, & Rugg, 2004; Toth & Parks, 2006), as different studies, different theoretical assumptions on the relation between familiarity and recollection, and different operational definitions for both processes have produced inconsistent results (for reviews see Light, Prull, LaVoie, & Healy, 2000; Prull, Dawes, Martin, Rosenberg, & Light, 2006). For instance, Duarte et al. (2006) provided combined behavioral and electrophysiological evidence that familiarity, rather than recollection, is more sensitive for the deleterious effects of normal aging in a recognition memory paradigm using pictorial stimuli. Li et al. (2004) found that in one of their conditions older adults achieved equal performance as younger adults in source recognition memory judgments despite poorer performance in item recognition memory, indicating that the older adults evidenced reduced familiarity but intact recollection for the applied pictorial stimuli.

The present work examines age effects on *associative* recognition memory, which requires individuals to retrieve particular pairings of stimuli rather than purely judging the old/new status of single items as in *item* recognition memory tasks. Importantly, recollection is thought to be imperatively needed for the retrieval of item-pairings, as is the case in associative recognition memory tasks (e.g., Yonelinas, 1997, 2002). In contrast, due to its proposed item-specific and noncontextual character, familiarity is not assumed to support associative recognition memory.

However, the claim that associative recognition memory is only supported by recollection without benefiting from familiarity has been challenged. Yonelinas, Kroll, Dobbins, and Soltani (1999) postulated that familiarity can contribute to associative retrieval given that the to-be-associated stimuli are encoded as a coherent whole and form a bound or 'unitized' representation. *Unitization* refers to conditions in which two or more previously separate items become represented as a single unit (Graf & Schacter, 1989). Thus, the unitization hypothesis posits that associations can be retrieved independently from recollection given that the associations have been unitized and by this, support familiarity-based memory (Quamme, 2004). This has indeed been found to be possible for to-be-associated items that are perceived as a coherent entity (e.g., facial features that are holistically perceived as forming a face; Yonelinas et al., 1999), for pairs of items that frequently co-occur and thus share strong preexperimental associations (e.g., word-pairs such as *sea-food* or *traffic-jam*; Giovanello, Keane, & Verfaellie, 2006; Quamme, 2004; Rhodes & Donaldson, 2007), for pairs of unrelated stimuli that are encoded as if they referred to a single object (Quamme, 2004; Quamme, Yonelinas, & Norman, 2007), or for pairs of words rated to reflect unitized representations to a high degree (Rhodes & Donaldson, 2007).

Further support for the unitization hypothesis was provided in an event-related brain potential (ERP) study on associative recognition memory for face-pairs conducted in our lab (Jäger, Mecklinger, & Kipp, 2006). In a first condition, participants memorized *inter-item associations*, i.e., associations between pairs of face stimuli depicting two *different* persons. In a second condition, participants memorized *intra-item associations*, i.e., associations between pairs of physically different faces that were highly similar and thus perceived as depicting the *same* person, which enables the unitization of stimuli into the representation of a single item (i.e., person). Consistent with the assumptions of the dual-process account, we found that performance in the *inter*-item condition mainly relied on *recollection* without

benefiting from familiarity. By contrast, in line with the unitization hypothesis, we found evidence that the retrieval of *intra*-item associations was supported by *familiarity* without the contribution of recollection. In terms of ERP correlates, we revealed that the retrieval of *intra*-item associations elicited the putative ERP correlate of familiarity, namely the *early frontal old/new effect*, whereas there was no putative ERP correlate of recollection, namely the *late parietal old/new effect*, indicating that memory for intra-item associations mainly relied on familiarity. Conversely, in the *inter*-item condition, we observed a strong late parietal old/new effect but no early frontal old/new effect, indicating that memory for inter-item associations exclusively relied on recollection and was not subserved by familiarity.

Within respect to the effects of cognitive aging on the memory for associations between items, it has been found that normal aging is associated with a substantial deficit in associative recognition memory for different types of arbitrary associations (Bastin & Van der Linden, 2006; Castel & Craik, 2003; Naveh-Benjamin, 2000; Naveh-Benjamin, Brav, & Levy, 2007; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003). This age deficit is assumed to result from a reduction of recollection due to a disproportionally large loss of hippocampal volumes in old age (Raz et al., 2005). However, it should be noted that in some situations older adults may successfully compensate their lower memory performance for unrelated associations by recruiting strategic cognitive processes (Cabeza, Anderson, Locantore, & McIntosh, 2002; cf. Naveh-Benjamin et al., 2007; see Buckner, 2004, for a review) such as effective encoding, strategies that older adults seem to apply as efficiently as younger adults do (see Hertzog & Dunlosky, 2004, for a review). By contrast, there is so far no direct test of whether older adults also show disrupted memory performance for associations between stimuli *that can be unitized* at the time of encoding and thus may benefit from familiarity-based recognition at the time of retrieval.

In consequence, the present study examined whether healthy older adults show differential impairments in memory for intra- versus inter-item associations. Although most studies revealed that older adults show smaller deficits in familiarity than in recollection (see above), the pattern of age differences in familiarity and recollection is still highly controversial, with some studies reporting even stronger age effects on familiarity than on recollection (e.g., Duarte et al., 2006; Li et al., 2004). In spite of the inconsistencies in the literature, on the basis of the assumption that older adults may show smaller

deficits in familiarity than in recollection, it could be expected that older adults exhibit only mild impairments in the formation and retrieval of (intra-item) associations between unitizable face stimuli. On the other hand, unitization during memory formation at encoding and familiarity-based recognition at retrieval are not isomorphic cognitive processes. Hence, unitization processes at encoding may be affected by old age even if the process of familiarity-based recognition is spared by cognitive aging. Thus, it is conceivable that older adults are specifically impaired in their memory for intra-item associations due to deficits in forming unitized associations at encoding. Applying a similar associative recognition memory task for unrelated and unitizable face-pairs as in our previous study (Jäger et al., 2006), we expected older adults to demonstrate reliable impairments in memory for inter-item associations. Due to the inconsistent findings in previous aging studies, it was an open issue if and how age may modulate memory performance for intra-item (i.e., unitized) associations.

METHODS

Participants and Design

A total of 40 participants provided informed consent to participate in return for cash payment of 8 Euro/hour. There were 20 younger adults (12 females), mostly undergraduate students who had a mean age of 24.75 years ($SD = 3.60$, range = 20–31) and 20 older adults (10 females), who were community-dwelling volunteers and had a mean age of 66.05 years ($SD = 3.41$, range = 62–76). Older adults showed higher verbal abilities in a German vocabulary test (*Mehrfachwahl-Wortschatztest MWT-B*; Lehrl, 1977) than younger adults (IQ-scores [$M \pm SE$]: younger adults: 110.85 ± 2.58; older adults: 125.40 ± 2.20; $t(38) = 4.29$, $p < .001$). In contrast, the two age groups did not differ in degree of education as measured on a 5-point scale ($t(38) = .15$), number of years of formal education ($t(38) = .59$), self-rated health as measured on a 5-point Likert scale ($t(38) = .92$), and number of currently taken medication ($t(38) = 1.77$, $p = .088$).

Several neuropsychological tests were applied to characterize the participants' cognitive status: (1) The *DemTect* battery (Kalbe et al., 2004) was used to screen participants for mild cognitive impairments; (2) the *digit-symbol substitution task* of the Wechsler Adult Intelligence Scale—Revised (Wechsler, 1981) was used to assess processing speed; (3) a paper-and-pencil version of the *Stroop task* was used to assess inhibitory control (Oswald & Fleischmann, 1997);

and (4) a computerized *operation span task* was used to assess working memory (Conway & Engle, 1996). Results for these screening tests indicated that none of the participants showed signs of mild cognitive impairments, as all DemTect total transformed scores were at least 3 points above the cut-off score for the diagnosis of mild cognitive impairment. However, older adults evidenced slower speed of processing (digit-symbol substitution task: younger adults [$M \pm SE$]: 71.25 ± 2.36; older adults: 45.95 ± 1.75; $t(38) = 8.61$, $p < .001$), poorer inhibitory control (Stroop task: younger adults: $8.80 \pm .93$; older adults: 15.35 ± 1.48; $t(38) = 3.76$, $p < .01$), and reduced working memory capacities (operation span task: younger adults: 22.85 ± 2.21; older adults: 14.95 ± 1.64; $t(38) = 2.87$, $p < .01$).

The design of this study involved a manipulation of the factors age group (younger versus older adults) and condition (intra- versus inter-item condition), varied between and within subjects, respectively.

Materials

Face Stimuli

Face stimuli were gray-scale photographs of unfamiliar and emotionally neutral faces drawn from a picture database (Jäger, Seiler, & Mecklinger, 2005). Among other variables, the database contains continua of *morphed faces*, i.e., sets of two different 'parent' faces that were gradually transformed into each other resulting in intermediate morphed faces. Of the available morph-continua, we selected the 0%, 35%, 70%, and 100% morphed faces to be used in the intra-item condition (see Figure 1 for illustration). Every morph-continuum was rated in a separate study for similarity on physical and identity dimensions (Jäger et al., 2005). For the intra-item condition, we selected 36 morph-continua in which faces of neighboring morph-degrees were rated as clearly physically discriminable but still representing the same person to a high degree (see Jäger et al., 2005, 2006). Additionally, we selected 144 unmodified face stimuli from the picture database to form 72 face-pairs for the inter-item condition.

Associative Recognition Memory Task

The associative recognition memory task was similar to the task used in Jäger et al. (2006), except that no novel faces were presented during the test phase. There were a total of 15 study-test blocks (6 blocks for the intra- and 9 blocks for the inter-item condition). In the *inter-item condition*, participants encoded face-pairs representing two different, but gender-matched persons. In the *intra-item condition*, participants encoded face-pairs consisting of faces that were judged to represent

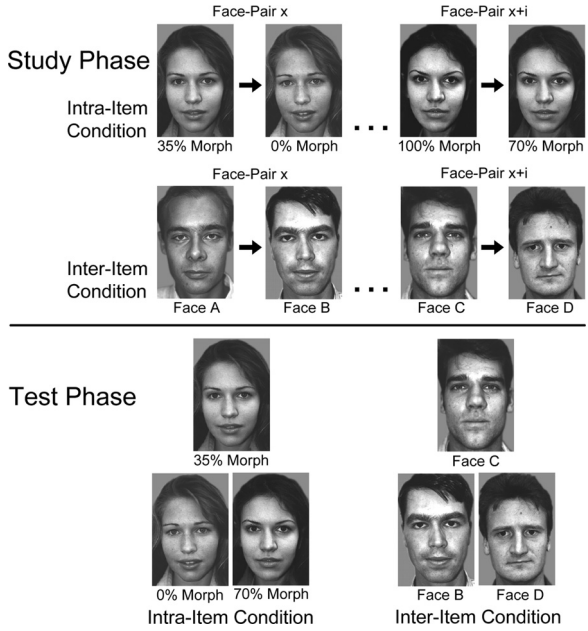


Figure 1. Illustration of the study and the test phase of the associative recognition memory task.

the same person to a high degree. This was achieved by creating face-pairs consisting of a 35% and a 0% morphed face, and face-pairs consisting of a 100% and a 70% morphed face from the same morph-continuum. Participants were instructed that they would be presented with study-test blocks in which two photographs have to be memorized that *either* show two different persons (inter-item condition) *or* the same person twice on physically different pictures (intra-item condition). Each block consisted of a study phase, a distracter task, and a test phase.

For the *study phases*, participants were instructed to memorize particular pairings of faces for a subsequent associative recognition memory test. Participants memorized a total of 12 and 8 face-pairs in the intra- and the inter-item condition, respectively (we used longer blocks in the intra-item condition because performance can be expected to be slightly higher for intra- than for inter-item associations; see Jäger et al., 2006).

The study phase procedure was as follows (see Figure 1A for illustration): Photographs of each face-pair were presented sequentially. Every novel face-pair was first announced by the words 'next pair'

(1500 ms), which were followed by a blank screen (200 ms). Then, the first face of a given face-pair was presented (1500 ms for younger; 1800 ms for older adults). To account for age-related slowing, presentation times of study and test face stimuli were increased by 20% for older adults (see e.g., Naveh-Benjamin et al., 2003, 2007, for similar procedures). Thereafter, a fixation cross appeared (700 ms for younger; 840 ms for older adults). Then, the second face of the face-pair was presented that had to be associated with the first face (1500 ms for younger; 1800 ms for older adults). Again, a fixation cross appeared thereafter (700 ms for younger; 840 ms for older adults), followed by a blank screen (200 ms). After this, the next study trial started.

After the study phase, a *distracter task* had to be performed for 20s in which participants counted aloud backwards in steps of 2, 3, or 4 from a randomly drawn number between 100 and 200. After the distracter task was concluded, the *test phase* started.

In each trial of the test phase (see Figure 1B for illustration), a *single test face* was first presented at the top of the screen (1000 ms for younger; 1200 ms for older adults). The single test faces were faces that were presented in the same fashion as the first faces within study face-pairs (in the intra-item condition, the studied single test faces were always the 35% morphed faces). While the single test faces remained on the screen, two additional faces that were both studied were then presented side by side at the bottom of the screen. Participants indicated by a *forced-choice judgment* which of the two faces at the bottom of the screen was paired with the single test face presented above them by pressing the left or right key (cf. Bastin & Van der Linden, 2006). The three faces stayed on the screen until a response was made or for maximally 3500 ms for younger and 4200 ms for older adults. Before the next test trial started, a blank screen was presented for 1000 ms.

There were six test trials in the intra-item condition and four test trials in the inter-item condition (i.e., half of the trial numbers of the study phase). In the intra-item condition, the target (i.e., correct) photograph of the forced-choice task was the 0% morphed face, whereas the nontarget (i.e., incorrect) photograph was the 70% morphed face of the same morph-continuum. Hence both faces differed by a morph-degree of 35% along the morph-continuum from the single test face (i.e., the 35% morphed face). By this, decisions could not be made solely on the basis of differences in face similarity.

The sequence of *study trials* was pseudorandomly intermixed for every novel participant with the constraints that the same gender did not appear more than twice consecutively, that the face-pairs

belonging to the same morph-continua were separated by at least three intervening study trials, and that the study trials that included the faces used to form recombined pairs for the subsequent test phase were separated by at least three intervening study trials. The *test trials* were pseudorandomly intermixed for every novel participant with the constraints that the same gender and the assignment of the target faces of the forced-choice judgments to the left or right side of the screen did not appear more than twice consecutively.

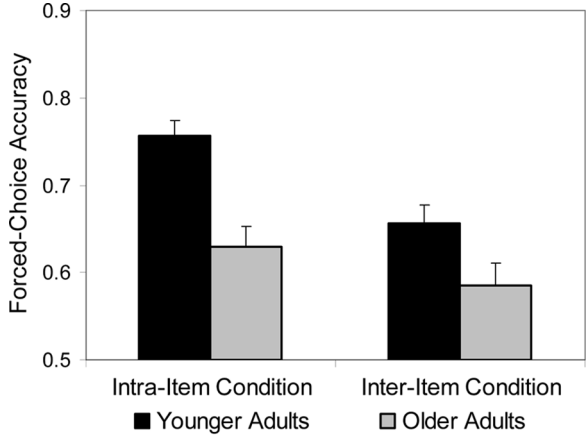
Within all intra- and inter-item condition blocks, half of the face-pairs were female and half were male. The random assignment of the face-pairs to the 15 blocks was kept constant across participants, but the sequence of blocks was pseudorandomly intermixed for every novel participant with the constraints that there were no more than two consecutive blocks from the same condition and that every half of participants of each group started with an intra- or an inter-item block, respectively.

Procedure

Participants were tested individually in sessions lasting ca. 90 min for younger and ca. 120 min for older adults. Participants provided informed consent and sociodemographic information, instructions for the associative recognition memory task were given, and four practice blocks of the task were performed. Then the associative recognition memory task was carried out, with a short break after the first eight blocks. At the end, the neuropsychological tests were administered and participants were debriefed and thanked for their participation.

RESULTS

Figure 2 shows the proportion of correct forced-choice judgments in the associative recognition memory task. Performance was significantly above chance in both conditions and both age groups, t values $(19) \geq 3.32$, p values $\leq .01$. Because we specifically aimed at investigating age differences in intra- versus inter-item associations, separate planned comparisons were applied to examine age effects in the two conditions. Performance was significantly better for younger than for older adults in the inter-item condition, $t(38) = 2.14$, $p < .05$. However, there was an even greater age deficit in the intra-item condition, $t(38) = 4.23$, $p < .001$. The age effect turned out to be nearly three times larger in the intra- compared with the inter-item condition, as revealed by effect sizes eta squared: intra-item



Notes. Error bars represent standard errors of the means.

Figure 2. Effects of aging on intra- and inter-item associations (Experiment 1). Error bars represent standard errors of the means.

condition: $\eta^2 = .32$, inter-item condition: $\eta^2 = .11$. The observation of a greater age effect in the intra-item condition was also confirmed by an Age Group × Condition analysis of variance (ANOVA). There was a significant main effect of age group, $F(1, 38) = 12.15$, $p < .01$, revealing better performance for younger adults, a significant main effect of condition, $F(1, 38) = 26.26$, $p < .001$, showing higher performance in the intra- than in the inter-item condition, and a significant Age Group × Condition interaction, $F(1, 38) = 4.03$, $p = .05$.

Reaction times for correct forced-choice judgments were analyzed by an Age Group × Condition ANOVA. Reaction times in ms were ($M \pm SE$) 1641 ± 80 and 2420 ± 98 for younger and older adults in the intra-item condition, and 1797 ± 106 and 2560 ± 112 for younger and older adults in the inter-item condition. There were significant main effects of Age Group, $F(1, 38) = 32.91$, $p < .001$, reflecting faster reaction times for younger adults, and of Condition, $F(1, 38) = 12.63$, $p < .01$, revealing faster reaction times for the intra- relative to the inter-item condition. There was no Age Group × Condition interaction, $F(1, 38) < 1$.

DISCUSSION

In the present study, we compared adult age differences in two types of associative recognition memory situations: Participants either

memorized face-pairs depicting two different, arbitrarily paired persons (inter-item condition) or pairs of physically different photographs that were perceived as representing the same person and thus can be unitized (intra-item condition; cf. Jäger et al., 2006). Consistent with previous findings that old age is associated with substantial impairments in memory for unrelated item-pairings (e.g., Bastin & Van der Linden, 2006; Castel & Craik, 2003; Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2003, 2004, 2007), a first finding of our study was a reliable deficit of older adults in the retrieval of inter-item associations between arbitrarily paired face stimuli. In line with previous suggestions and findings, this impairment can be accounted for by an age-related reduction in recollection, as is proposed by dual-process theories of recognition memory (see Prull, Dawes, Martin, Rosenberg, & Light, 2006).

A novel issue addressed in the present study was whether older adults show more or less of a deficit in associative recognition memory when the to-be-associated items *can potentially be unitized into a single representation*. Recent studies found that associative retrieval of items that are unitized during encoding benefits from familiarity-based recognition at the time of retrieval (Giovanello et al., 2006; Jäger et al., 2006; Quamme, 2004; Quamme et al., 2007; Rhodes & Donaldson, 2007; Yonelinas et al., 1999). As some studies revealed that older adults show smaller deficits in familiarity than in recollection (e.g., Bastin & Van der Linden, 2003; Daselaar et al., 2006; Howard et al., 2006), it could have been expected that older adults exhibit only mild impairments in the retrieval of (intra-item) associations between unitizable face stimuli. However, it should be stressed that the data on age effects on familiarity and recollection are controversial, with some studies reporting even stronger age effects on familiarity than on recollection (e.g., Duarte et al., 2006; Li et al., 2004).

In the present study we revealed that—contrary to the possible expectation as described above—older adults were disproportionately impaired in their memory for associations between unitizable face-pairs compared to memory for pairings of arbitrary faces. In fact, the effect size for the age difference was nearly three times larger in the intra- than the inter-item condition. In terms of the dual-process account, one interpretation of these findings would be that familiarity may *not* necessarily be spared by cognitive aging and—in certain situations—can even be more strongly affected than recollection (cf. Duarte et al., 2006; Li et al., 2004). Our data, however, were not developed to resolve the above-mentioned inconsistencies in the literature of age effects on familiarity and recollection.

On the other hand, as an alternative to this retrieval-related interpretation in the dual-process framework, it has to be emphasized that unitization during encoding and familiarity-based recognition *are not isomorphic cognitive processes* and by this may be differentially affected by old age. It is thus conceivable that older adults are specifically impaired in *forming* (i.e., encoding) intra-item associations between highly similar face-pairs, whereas familiarity-based recognition during retrieval is relatively unaffected by cognitive aging, as is suggested by the majority of studies on age differences in familiarity and recollection.

Before elaborating this view in more detail, potential objections against the present findings should be considered. A first objection could be that the results reflect age-related differences in general performance levels across conditions rather than differential memory impairments in old age. We believe that several points argue against this possibility. First, for both age groups and both conditions, performance was well and significantly above chance, but also far from perfect. By this, neither floor nor ceiling effects can account for the pattern of results. Second, there was nearly identical variability of performance within each age group across conditions, indicating that both conditions had a similar discriminating power to detect age differences in performance (cf. Naveh-Benjamin et al., 2004). Third, our findings cannot be explained in terms of an Age × Complexity effect, which is typically raised to explain greater age differences in more difficult compared with easier conditions. In fact, in our study the greater age impairment actually occurred in the *easier* (i.e., intra-item) condition, as indicated by performance of younger adults, which reflected a typical advantage for unitized compared to nonunitized associations (Quamme et al., 2007; Rhodes & Donaldson, 2007). Fourth, as will be described below, we found that even when high-performing older adults were matched to their younger counterparts with respect to performance levels in the inter-item condition, they nevertheless showed a *selective* deficit in the intra-item condition.

Another objection to be addressed is whether the differences in the timing of trial events across the two age groups, which was aimed at adapting the task to the needs of older adults, could potentially account for the effects found in the present study. However, the slight differences in the timing of events is unlikely to account for the pattern of results, because in a previous study with young adults (Jäger, Mecklinger, & Kliegel, in preparation), we found that memory performance for intra- and inter-item associations is not influenced by manipulations of the retention interval (20 versus 40s) or of the time available between the presentation of faces of each face-pair

during encoding (700 versus 1200 ms). In conclusion, the results of our study could be interpreted as evidence that aging has deleterious effects on memory for unitizable associations.

Turning to a more detailed interpretation of the present findings, our study revealed an empirical phenomenon that deserves further studies to examine the potential neurocognitive mechanisms responsible for the disproportionate problems of older adults in the formation of associations between unitizable face-pairs. As indicated above, the age-deficit can probably be traced back to processes occurring during the *encoding* of face-pairs. Because face stimuli are highly overlapping in the intra-item condition, they can engage unitization processes, thereby resulting in the establishment of a single memory representation for each face-pair (Jäger et al., 2006). Unitization may be a neurocomputational mechanism that presumably involves enhanced activation of the two images' overlapping features within the medial temporal lobe cortex and reduced activation of nonoverlapping ones (a process termed 'sharpening'), and may be supported by processes such as Hebbian learning and competitory inhibition (Norman & O'Reilly, 2003). Given the fine-grained nature of such neuronal changes, unitization processes at encoding may be very sensitive for the subtle changes in functional and biochemical attributes of neural networks in old age. We could speculate that pathological changes within the medial temporal lobe such as the accumulation of senile plaques and neurofibrillary tangles that are also present in healthy older adults may be neuronal mechanisms responsible for the age deficit in unitization (see Yang, Ang, & Strong, 2005).

An implication of this latter view may be that in the inter-item condition older adults successfully recruit prefrontally mediated, strategic cognitive processes in order to enhance the encoding and retrieval of arbitrary face-pairs, whereas such compensation processes may be less efficient for the encoding and retrieval of unitized associations in the *intra*-item condition. This suggestion dovetails with the finding that bilateral prefrontal cortex activity seems to reflect compensatory mechanisms helping older adults to increase source memory performance (which critically depends on recollection) to a level equivalent to that of younger adults (Cabeza et al., 2002; cf. Naveh-Benjamin et al., 2007; see Buckner, 2004, for a review) and with findings that older adults are able to apply effective encoding strategies to form associations between unrelated items to a similar degree as younger adults do, which may specifically enhance older adults' performance in the inter-item condition (see Hertzog & Dunlosky, 2004, for a review). Examples for such strategic compensatory mechanisms in the inter-item condition may be the assignment of

verbal labels to the arbitrary faces and the formation of associations between these labels, or the application of interactive imagery in order to associate the face-pairs (Hertzog & Dunlosky, 2004). By contrast, as indicated above, such strategic cognitive processes may be less helpful for the formation of *intra*-item associations between highly similar photographs of the same person, resulting in a more pronounced impairment of older adults in this type of associations due to a lack of possibilities for compensation. This latter view is indirectly supported by the outcome of another study (Jäger et al., in preparation), which showed that memory for inter-item associations strongly benefits from the availability of attention that can be allocated to the encoding of arbitrary face-pairs, whereas the encoding of unitizable intra-item associations benefits to a lesser extent from the availability of attentional resources. This may indicate that such unitizable associations can be established relatively automatically.

Importantly, the selective compensation view described above receives more direct support by a post hoc analysis in which we found that high-performing older adults reached equivalent levels of performance in the inter-item condition as their younger counterparts and still showed a *selective* deficit in the intra-item condition (cf. Duarte et al., 2006; Li et al., 2004). Specifically, in this additional explorative analysis, older adults were median split into high- ($n = 12$) versus low- ($n = 8$) performing participants on the basis of performance collapsed across conditions. Forced-choice accuracy of younger adults was .66 and .76 in the inter- and the intra-item condition, respectively. Importantly, although high-performing older adults reached equivalent levels as the younger adults in the inter-item condition (i.e., accuracy of .65), $t(30) = .07$, $p = .946$, they nevertheless showed a significant deficit in the intra-item condition (i.e., accuracy of .68), $t(30) = 2.63$, $p < .05$. By contrast, low-performing older adults showed an impairment in both conditions (i.e., accuracy of .48 and .55 in the inter- and the intra-item condition, respectively), t values >4.99, p values $<.001$.[1]

To conclude, a possible, though preliminary, explanation for the present findings is that (especially high-performing) older adults may at least partly compensate their age-related deficits in memory

[1]Note that virtually the same pattern of results emerged when older adults were split into high- versus low-performing participants either (1) by using another measure of long-term memory abilities, namely the subtest of the DemTect in which delayed recall of a word list was required; or (2) by using scores on a single latent factor derived by factor analysis on the scores of processing speed, inhibitory control, working memory, and four subtests of the DemTect (immediate recall, word fluency, digit span backwards, delayed recall; omitting the number transcoding task because this measure produced strong ceiling effects).

tasks that benefit from the engagement of strategic encoding operations such as the formation of inter-item associations between arbitrary face-pairs. By contrast, older adults may not be able to compensate their reduced ability to encode associations between highly similar and thus unitizable item-pairings (i.e., intra-item associations), because in such tasks the processing components are more automatized and may not strongly benefit from the application of strategic encoding processes to overcome the age-related diminutions in the underlying neurocognitive processes. The literature provides little evidence of research investigating whether older adults may show more or less of a deficit in memory for item-pairings if the to-be-associated stimuli can be unitized into a single representation. The findings of the present study indicate that older adults demonstrate a disproportionate impairment in the formation of associations between highly overlapping face stimuli that presumably relies on unitization processes. Further studies are warranted to examine this empirical phenomenon and to understand its potential neurocognitive mechanisms.

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