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Priming of familiar and unfamiliar visual objects over delays in young and older adults

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Abstract

Although priming of familiar stimuli is usually age invariant, little is known about how aging affects priming of pre-experimentally unfamiliar stimuli. Therefore, this study investigated the effects of aging and encoding-to-test delays (0 min, 20 min, 90 min, and 1 week) on priming of unfamiliar objects in block-based priming paradigms. During the encoding phase, subjects viewed pictures of novel objects (Experiments 1 and 2) or novel and familiar objects (Experiment 3) and judged their left/right orientation. In the test block, priming was measured using the possible/impossible object-decision test (Experiment 1), symmetric/asymmetric object-decision test (Experiment 2), and real/non-real object-decision test (Experiment 3). In Experiments 1 and 2, young adults showed priming for unfamiliar objects at all delays, whereas older adults whose baseline task performance was similar to that of young adults did not show any priming. Experiment 3 found no effects of age or delay on priming of familiar objects; however, priming of unfamiliar objects was only observed in the young subjects. This suggests that when older adults cannot rely on pre-existing memory representations, age-related deficits in priming can emerge.

Keywords

Perceptual priming; aging; unfamiliar visual objects; implicit memory; object decision test

It is well known that normal aging is accompanied by a reduction in *explicit memory*, or the ability to consciously recall or recognize previously experienced information (Cabeza, Nyberg, & Park, 2005). In contrast, another type of memory, *priming*, remains relatively intact in healthy older adults (D. A. Fleischman, 2007; D.A. Fleischman & Gabrieli, 1998; Light, Prull, La Voie, & Healy, 2000). Priming is a type of implicit memory and refers to a change in performance (e.g., speed, accuracy, or bias) for a previously encountered stimulus compared to a new stimulus. Priming can occur in the absence of conscious memory for a stimulus and

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is thought to rely on different neural structures than explicit memory (reviewed in Henson, 2003).

Notably, one important theoretical question that has received very little attention in studies of priming is whether intact priming in older adults relies on the existence of pre-existing memory representations. Whereas priming for familiar stimuli is largely based on the reactivation of existing memory representations, priming for novel stimuli has been suggested to be mediated by newly acquired representations (Bowers, 1994, 1996; Henson, Shallice, & Dolan, 2000; Schacter, Cooper, & Delaney, 1990). Of the over 100 studies investigating the effects of aging on priming, we are aware of only six studies that used pre-experimentally unfamiliar stimuli (Keane, Wong, & Verfaellie, 2004; Light, Kennison, Prull, LaVoie, & Zuellig, 1996; Light, La Voie, & Kennison, 1995; Schacter, Cooper, & Valdiserri, 1992; Soldan, Gazes, Hilton, & Stern, 2008; Wiggs & Martin, 1994) and all but two them (Schacter et al., 1992; Soldan, Gazes et al., 2008) used verbal material, which may, arguably, draw upon pre-existing semantic, lexical, or sub-lexical representations.

Interestingly, the evidence to date from studies using verbal material suggests that when priming of pre-existing semantic, lexical, and sub-lexical representations is minimized by using illegal non-words (Keane et al., 2004), priming can be obtained for young but not older adults. In the case of pronounceable non-words, which may involve the re-activation of lexical or sub-lexical representations, the evidence is more mixed. One study using Turkish words in non-Turkish speaking subjects also found priming in young but not older adults (Wiggs & Martin, 1994). Another study, by comparison, did not find an effect of age on priming for pronounceable non-words, although the magnitude of priming in both experiments was numerically smaller for the older subjects and did not appear to differ from zero in one experiment (Light et al., 1996, Experiments 1 and 3). Additionally, Light et al. (1995) showed age invariance in item and associative priming for novel compound words (e.g., “wifetest“ or “legthing”), where priming likely draws upon existing semantic and conceptual representations.

In the non-verbal domain, the evidence concerning the effects of aging on priming for unfamiliar stimuli is also very scant. Although two studies reported comparable levels of priming for novel three-dimensional (3-D) objects in young and older subjects (Schacter et al., 1992; Soldan, Gazes et al., 2008), both studies have potentially important limitations. In the study by Schacter et al. (1992), the older group’s overall task performance was at chance, making their priming effects difficult to interpret. By comparison, Soldan et al. (2008) used a short-term priming paradigm with an interleaved series of stimulus presentations and only 2 to 6 items intervening between stimulus repetitions (which corresponds to 9 to 21 sec). It is unclear whether their results would generalize to a traditional block-based priming paradigm where different tasks are performed during the encoding and the test phases of the experiment and where many items intervene between repetitions. Therefore, the primary goal of the current study was to examine perceptual priming for unfamiliar visual objects in a large sample of healthy young and older individuals using traditional block-based priming paradigms. Note that within the context of this study, ‘short-term priming’ refers to effects that are measured in the order of milliseconds to seconds; ‘long-term priming’ refers to effects measured on the order of days; and ‘priming’ without any further specification refers to effects in the order of minutes to hours, as is the case with most traditional block-based priming paradigms.

Investigating whether priming for unfamiliar stimuli remains intact in older individuals is also of theoretical significance from a neuroscientific perspective because current evidence suggests that priming for familiar and unfamiliar stimuli may be based on different underlying neural processes and/or structures (e.g., Fiebach, Gruber, & Supp, 2005; Henson et al., 2000; Soldan, Zarahn, Hilton, & Stern, 2008). This means that current knowledge regarding the

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effects of aging on priming may not generalize from studies using familiar stimuli to studies using unfamiliar stimuli. Furthermore, if aging differentially affects priming of familiar and unfamiliar stimuli, it would suggest that the underlying neural processes and/or structures that mediate priming may be differentially sensitive to age-related deterioration.

A secondary goal of this study was to examine the persistence of priming for unfamiliar objects over time in young and older adults. Studies using familiar stimuli have demonstrated priming following extended encoding-to-test delays (e.g., 52 weeks, Beatty, English, & Winn, 1998; 5 years, Kennedy, Rodrigue, & Raz, 2007), but all studies using unfamiliar stimuli tested priming immediately after the encoding phase. Because newly formed memory representations may be less stable over time or more susceptible to interference than representations of familiar words and objects, it is possible that priming for pre-experimentally unfamiliar stimuli deteriorates and possibly disappears over time. This hypothesis was tested in the present study by assessing priming for unfamiliar objects at four different delays: subjects were tested for one set of items encoded immediately before the test phase and for a second set of items encoded either 20 min, 90 min, or 1 week before the test phase. In addition, the present study tested whether priming in older adults decreases more rapidly over time than in young adults, as has been suggested by some studies (Kennedy et al., 2007; Wiggs, Weisberg, & Martin, 2006; but see Mitchell, Brown, & Murphy, 1990 for a similar decrease in young and older subjects).

Like the two prior studies examining priming for unfamiliar objects (Schacter et al., 1992; Soldan, Gazes et al., 2008), Experiment 1 of this study used the possible/impossible object-decision test to measure priming. In this test, subjects are asked to decide whether previously presented and new figures represent structurally possible or impossible 3-D objects (see Figure 1 for examples). Priming in this test has consistently been demonstrated for possible but not impossible objects (e.g., Schacter et al., 1990). (For a discussion why priming is not typically seen for impossible objects under standard test conditions, see Ratcliff & McKoon, 1995; Schacter & Cooper, 1995; Williams & Tarr, 1997). Experiment 2 tested whether the main findings from Experiment 1 would generalize to a different perceptual priming task using unfamiliar objects in a symmetric/asymmetric object-decision test. Finally, Experiment 3 directly compared the effect of aging on priming for familiar and unfamiliar objects in a real/non-real object-decision test.

Experiment 1: Possible / impossible object-decision priming

Several lines of evidence suggest that the possible/impossible object-decision test is truly a test of implicit rather than explicit memory, making it suitable for exploring age differences in priming. In particular, single- and double- dissociations between P/I object-decision and old/new recognition have been observed by manipulating the encoding instructions (e.g., Schacter et al., 1990), manipulating attention at encoding (e.g., Soldan, Mangels, & Cooper, in press), or by transforming object properties between encoding and test (Cooper, Schacter, Ballesteros, & Moore, 1992). Priming for possible objects has also been observed in amnesic patients whose explicit memory is impaired (Schacter, Cooper, Tharan, & Rubens, 1991; Schacter, Cooper, & Treadwell, 1993). Furthermore, priming appears to rely on perceptual, rather than conceptual processes, as it is most robustly observed with structural encoding tasks that emphasize processing of the objects' global structure, but not with elaborative conceptual encoding instructions that do not encourage structural encoding (Schacter et al., 1990).

Method

Participants—There were 120 young and 80 older participants in this experiment. The young participants for Experiments 1, 2, and 3 (age range = 18 – 32 years) were drawn from the student population at Columbia University and received either $10 per hour or partial course credit for participation. Older participants for all experiments (age range = 61 – 87 years) were

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recruited from local Manhattan Senior Centers and through a local roster of prospective volunteers and received $15.00 per hour for their time.

Subjects in all experiments reported having normal or corrected-to-normal vision and being free of neurological and psychiatric diseases, as determined via questionnaire. All older subjects were classified as non-demented and without serious cognitive impairment, based on their performance on the Dementia Rating Scale-2 (i.e., score of 130 or higher). Subjects were also administered the Selective Reminding Test, a test of explicit verbal long-term memory; the North American Adult Reading Test (NART), a measure of verbal IQ; the Controlled Word Fluency Test (CFL); and the WAIS-III Letter-Number Sequencing test, a measure of working memory. See Table 1 for a list of participant characteristics.

Stimuli—The stimuli consisted of images of 48 three-dimensionally possible and 48 impossible line-drawn objects (Figure 1). In a pilot study, an additional group of 10 older participants viewed these stimuli at the experimental test exposure duration of 200 ms and was asked to classify them as possible or impossible. The resulting time-limited accuracies were then used to divide the 96 objects into eight different lists of 12 possible and 12 impossible objects, such that baseline accuracy for both possible and impossible objects was similar across the eight lists. These object lists were then rotated across the experimental conditions, across subjects, such that each object appeared equally often in each condition. Note that although construction of the object lists was based on responses of older participants only, the same lists and counterbalancing procedure were used for both young and older subjects during the experiment so that the experimental conditions would be identical for both age groups. The same approach of constructing stimulus lists was used for Experiments 2 and 3, except that in Experiment 3, stimuli remained on the screen until a decision was made and the lists were matched on the basis of RT rather than accuracy. An additional 10 stimuli were selected as buffer items used at the beginning of each encoding and test block. In all experiments, the objects fit completely within a circle that subtended 10 degrees of visual angle.

Procedure—The possible / impossible object-decision task consisted of two encoding blocks and a subsequent test block. Participants viewed distinct sets of objects (12 possible, 12 impossible) in each encoding session. Delay was manipulated by interposing a delay of 20 min, 90 min, or 1 week between the first and second encoding block. The test block immediately followed the second encoding block, such that all subjects viewed one set of objects immediately prior to the test block (the immediate condition, second encoding block) and a different set of objects at a delay (the delayed condition, first encoding block). In both Experiments 1 and 3, subjects were assigned to a delay condition (20 min, 90 min, or 1 week) primarily as a function of subject preference. While this manner of assignment is not ideal, we felt it was a compromise that we had to take in order to minimize the loss of participants over the 1-week delay period. Importantly, preliminary analysis indicated that there were no consistent differences in age, education, or any of the neuropsychological variables between subjects in the delay conditions in any of the three experiments, as determined via two-tailed t-tests.

In addition, for all experiments, preliminary analyses of variance (ANOVAs), separately for each age group, were conducted to test if the delay groups differed in object-decision performance for test items that were identical for the delay groups, i.e., items encoded in the block immediately preceding the test phase and new test items. These analyses did not reveal any significant main effects or interactions with delay group, indicating that the delay groups were indeed equivalent. Each delay group was composed of 40 subjects. Older subjects did not participate in the 1-week condition because priming was not obtained in the 20-min or 90-min delay conditions in older adults (see results).

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During each encoding block, the task was to indicate whether each object faced primarily towards the left or to the right. Although there is no objectively right or wrong answer to this question, these encoding instructions have been shown to elicit reliable priming of possible objects (e.g., Schacter et al., 1990). At test, all 48 encoded stimuli (12 immediate possible; 12 immediate impossible; 12 delayed possible; 12 delayed impossible) were intermixed with a new set of 24 possible and 24 impossible items. Subjects were instructed to indicate whether each object is three-dimensionally possible or impossible. Subjects were not informed of the possible/impossible test task in advance.

For subjects in the 90-min and 1 week delay groups, all neuropsychological testing could be completed in the time interval between the two encoding blocks. Subjects in the 20-min condition completed part of the neuropsychological assessment during this time window and the remainder following the test block of the object-decision test.

All encoding and test trials were participant-initiated by a press of the space bar. The encoding trials began with a fixation point ("+") shown at the center of the screen for 350 ms. Fifty ms after fixation offset, a single stimulus was presented for 4000 ms, and participants were directed to carefully examine each object for the entire duration it was on the screen to be able to make an accurate left/right judgment. Participants entered their left and right responses using their left and right index fingers, respectively. After responding, participants were prompted for the subsequent trial. Test trials followed the same general format as the encoding trials except that the fixation cue was shown for 150 ms, the stimulus was displayed for 200 ms (12 video refresh cycles) for the older participants, and 33 ms (2 refresh cycles) for the young participants. Shorter times were used with the young participants to avoid ceiling effects in performance. In the test block, participants were told to respond as quickly and accurately as possible, but there was no time limit. The experiment was run on Macintosh computers using Psyscope 1.2.5.

Data Analysis—An α-level of 0.05 was adopted for all analyses. The data were analyzed using ANOVAs and significant effects were followed up with appropriate post-hoc tests corrected for multiple comparisons using the Holm-Bonferroni correction. Analyses involving independent variables with more than 2 levels were corrected for violations of the sphericity assumption using the Greenhouse-Geisser corrected p-values. For interactions between age and other variables, the effect size statistic generalized eta squared (η^2_G) is reported, the recommended measure for repeated measures designs (Bakeman, 2005). The main dependent variable in this experiment was classification accuracy. Priming was measured as the difference in classification accuracy for previously encoded objects and new objects.

Results

Mean object-decision accuracy for young and older subjects as a function of delay is shown in Figure 2. In order to evaluate the persistence of priming over delays, separate ANOVAs were initially performed for young and older subjects, with object type (possible vs. impossible) and encoding status (encoded immediate vs. encoded delayed vs. new) as within subject factors and delay group (20 min vs. 90 min for the older adults and 20 min vs. 90 min vs. 1 week for the young adults) as a between subjects factor.

For the young subjects, there was a main effect of encoding status [$F(2, 234) = 11.88$, $p < 0.0001$] and an interaction between encoding status and object type [$F(2, 234 = 10.25$, $p < 0.0001$]. Separate ANOVAs for possible and impossible objects produced no reliable effects for impossible objects [all $p > 0.34$]. For possible objects, there was a main effect of encoding status [$F(2, 234) = 23.82$, $p < 0.0001$], but the effect of delay group did not reach significance [$F(2, 117] = 1.57$, $p = 0.21$]. Post-hoc helmert contrasts indicated that accuracy was significantly higher for encoded objects (immediate and delayed) than for new objects [$F(1, 117) = 50.85$, $p < 0.0001$] and that there was no difference in accuracy between the immediate

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and delayed encoding conditions [*F*(1, 117) = 0.46, $p = 0.50$]. By post-hoc *t*-test, collapsing across delay groups, priming was highly significant for possible objects encoded immediately before the test phase [*M* = 7.2%, *t*(119) = 6.83, $p < 0.0001$] and at a delay [*M* = 5.9%, *t*(119) = 5.51, $p < 0.0001$].

For the older participants, the only significant effect was an interaction between object type and encoding status [*F*(2, 156) = 6.02, $p = 0.004$]. Separate ANOVAs for possible and impossible objects revealed an effect of encoding status for possible objects [*F*(2, 156) = 5.92, $p = 0.004$], but not for impossible figures. Post-hoc helmert contrasts showed that encoded possible objects were classified more accurately than new possible objects [*F*(1, 78) = 11.14, $p = 0.001$] and that there was a trend for lower classification accuracies for possible objects encoded at a delay compared to possible objects encoded immediately before the test [*F*(1, 78) = 3.16, $p = 0.08$]. Post-hoc *t*-tests, collapsed across delay groups, indicated the presence of reliable priming for possible objects presented in the immediate encoding block [M = 6.7%, *t* (79) = 3.72, $p < 0.001$], but no priming for possible objects encoded at a delay [*M* = 2.7%, *t* (79) = 1.53, $p = 0.14$].

To confirm this interaction between age and delay on priming for possible objects, we conducted a follow-up ANOVA for possible objects with age group and encoding status as factors (collapsing across delay group). Only the 20-min and 90-min delay groups were included in this analysis, so that the same conditions were compared across age groups. Interestingly, the expected age by encoding status interaction did not reach significance [*F*(2, 396) = 1.69, $p = 0.19$, $\eta^2_G = 0.00133$].

This inability to detect an interaction between age and encoding status likely derived from the fact that the current analysis underestimated priming in young subjects because of ceiling effects in performance, which make it difficult to detect a difference in the magnitude of priming between the young and older groups. Therefore, we repeated the ANOVA for possible objects, excluding all subjects whose classification accuracy for new possible objects was 90% or higher (N = 28 young and 9 older subjects). This analysis revealed an interaction between age group and encoding status [*F*(2, 302) = 3.41, $p = 0.037$, $\eta^2_G = 0.0043$]. By post-hoc t-test, priming was significant for possible objects encoded immediately prior to the test block in young [*M* = 10.2%, *t*(51) = 5.72, $p < 0.0001$) and older [*M* = 8.04%, *t*(70) = 4.16, $p < 0.0001$] subjects, but only the young subjects demonstrated priming for possible objects encoded at a delay [*M* = 8.7%, *t*(51) = 5.92, $p < 0.0001$]. In the older participants priming was significantly reduced for objects encoded at a delay compared to objects encoded immediately prior to test [*t*(70) = 2.01, $p = 0.048$] and no longer significant [*M* = 3.1%, *t*(70) = 1.58, $p > 0.13$].

To further explore the apparent decrease of priming over the delay in the older participants, we examined whether this effect was dependent on subject's baseline performance for new objects. This analysis was motivated by the fact that although significantly longer stimulus presentation times during the test phase were used for the older than the younger participants, overall accuracy was still substantially lower for the group of older adults. Therefore, we split the older subjects into two groups, based on their classification accuracy for new objects (averaging across possible and impossible items). For the low-performing group (N=43), classification accuracy for new items was 54.6%; for the high-performing group (N=37), accuracy for new items was 75.7%. For all of the high-performing subjects, classification accuracy for new items was significantly higher than chance at $p < 0.05$ (i.e., 65% or higher, with chance being 50%), whereas none of the low-performing subjects differed from chance at this threshold. By post-hoc t-test, accuracy for new possible and impossible objects was significantly lower for the low-performing older subjects than for the high-performing older individuals and than for young subjects [all $p < 0.0001$]. There was no difference between the

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high performing older subjects and young subjects for possible [$t(115) = 0.85$, $p > 0.3$] or impossible [$t(115) = 1.56$, $p = 0.12$] objects.

Surprisingly, for the high-performing group, an ANOVA with object type, encoding status, and delay group as factors showed no significant effects or interactions (all $p > 0.12$), indicating that these subjects, although well capable of performing the possible/impossible object discrimination, did not benefit from prior exposure to the objects. This lack of priming was not due to ceiling effects for new objects, as exclusion of subjects whose classification accuracy for new possible items was 90% or higher (N=7) did not affect the pattern of results.

In comparison, for the low-performing older group, there was a main effect of encoding status [$F(2, 82) = 4.44$, $p = 0.018$] and an interaction between encoding status and object type [$F(2, 82) = 5.88$, $p = 0.005$]. An ANOVA on impossible objects did not reveal any significant effects [all $p > 0.28$], whereas an ANOVA on possible objects demonstrated an effect of encoding status [$F(2, 82) = 11.22$, $p < 0.0001$]. Post-hoc *t*-tests demonstrated priming for possible objects in the immediate [$M = 11.8\%$, $t(42) = 5.2$, $p < 0.0001$], but not in the delayed encoding condition [$M = 4.3\%$, $t(42) = 1.65$, $p = 0.15$]. Furthermore, the decrease in priming in the delayed relative to the immediate encoding condition was significant [$t(42) = 2.83$, $p = 0.01$]. See Figure 3 for a comparison of priming effects for possible objects between the high and low performing older subjects. The same pattern of results was found when a median split was performed based on subjects' overall classification accuracy (averaging across all conditions). Almost all young subjects performed significantly better than chance at baseline and exclusion of low performing young subjects did not affect the results. By post-hoc t-test (uncorrected), the only difference between the low and high performing older subjects was that the low performing group had slightly lower DRS-scores than the high performing group ($M = 138.0$ vs. $M = 139.8$, $t(78) = 2.05$, $p = 0.044$; all other $p > 0.12$)[1].

Discussion

The results from Experiment 1 demonstrate for the first time that perceptual priming for pre-experimentally unfamiliar 3D objects remains stable for at least 1 week in young adults. In healthy older adults, by comparison, priming for novel 3D objects was present only for objects that were encoded immediately prior to the test phase, but not for objects encoded 20 min or more before the test. Moreover, priming in the older group appeared to be limited to subjects whose accuracy in the task was near chance levels. Older individuals who performed the task at above chance levels did not show priming at any of the encoding-to-test delays. Taken together, these results provide evidence for an apparently profound age-related deficit in perceptual priming for novel 3D objects.

The present results are consistent with those reported by Schacter et al. (1992) who also reported normal priming for possible objects in older adults whose baseline classification accuracy was near chance levels when there was no encoding-to-test delay. As pointed out by Schacter et al. (1992), the presence of chance-level performance at baseline raises the possibility that the low-performing older subject may have performed the object decision task differently than the young subjects and the high performing older individuals. The current results provide support for this notion because the high performing older subjects evidenced a differential pattern of priming than the low performing older participants.

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[1] We also analyzed the data in terms of the signal detection theory measures of bias (C_L) and sensitivity (d_L), which are conflated in an accuracy analysis. Both d_L and C_L are based on logistic distributions and are functionally equivalent to d' and β (Snodgrass & Corwin, 1988). For the high performing older subjects, there were no effects of encoding status on either bias or sensitivity [all $p > 0.13$]. By comparison, for the low performing older group, both bias and sensitivity were greater for objects encoded immediately before the test than for new objects [both $p < 0.005$], and there was no difference between objects in the delayed encoding condition relative to new objects [both $p > 0.07$].

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One possibility that was also discussed by Schacter et al. (1992) is that the low performing older individuals responded on the basis of stimulus familiarity rather than on the basis of the structural information they were able to gather from test objects. Specifically, being unable to differentiate between the two types of objects, subjects may have judged objects as being possible when they were familiar (due to the prior exposure) because in the real world, all familiar objects are structurally possible. The reason why a similar increase in possible responses was not observed for previously presented impossible objects could be due to the fact that stimulus familiarity (as measured by old/new recognition memory) tends to be lower for impossible than possible figures (Schacter et al., 1990; Schacter et al., 1992). Thus, the level of familiarity for previously encountered impossible objects may have been too low to elicit a ‘possible’ response. This speculative explanation would also imply that the reason why priming for possible objects in the low performing older group decreased over time is that familiarity for these objects declined over time to a level that was too low to influence subjects’ responses.

The lack of priming in the high performing older participants suggests that these subjects have a deficit in the ability to form or maintain new implicit perceptual representations of previously unfamiliar 3-D objects. If so, this deficit would be expected to generalize to other perceptual priming tasks using similar stimuli. The aim of Experiment 2 was to test this prediction.

Experiment 2: symmetric/asymmetric object-decision priming

The design of Experiment 2 was identical to that used in Experiment 1, except that the test task was changed from one requiring a possible/impossible judgment to one requiring a symmetric/asymmetric judgment. In addition, the 1-week delay condition was eliminated. The stimuli consisted of depth-cued structurally possible objects (See Figure 4 for examples). Depth-cued rather than line drawn figures were used because the 3-D structure of these stimuli might be perceived more fluidly by the older subjects. Particular care was taken in pilot studies to choose stimuli that would produce similar above-chance performance in both age groups.

Using line-drawn 3-D objects, Liu and Cooper (2001) previously showed that priming in the symmetric/asymmetric object-decision test only occur for symmetric objects, even though both symmetric and asymmetric possible objects show priming in the possible/impossible object-decision task (for an explanation, see Liu & Cooper, 2001). Therefore, we predicted that priming would only occur for symmetric objects in Experiment 2. The following two hypotheses were tested: First, priming in young subjects is invariant with respect to the effects of delay. Second, older subjects do not show priming at any of the encoding-to-test delays.

Method

Participants—Sixty-four young and 64 older adults participated in this experiment (Table 2). Half of them were randomly assigned to the 20-min delay condition, half to the 90-min delay condition. An additional 8 older subjects and 2 young subjects were excluded from data analysis because both their baseline test performance for new items and overall performance across all test items did not differ from chance (<60% correct).

Stimuli and Procedure—A total 48 symmetric and 48 asymmetric objects were used in this experiment. All of these depth-cued objects were based on the type of line-drawn possible objects used in Experiment 1. The symmetric objects were symmetric about one or more planes, whereas the asymmetric objects did not have any planes of symmetry. The procedure was identical to that used in Experiment 1, except that subjects performed the symmetric/asymmetric decision at test.

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Results

Figure 5 shows the mean object-decision accuracy for young and older subjects. A preliminary ANOVA on new items was conducted to test if baseline performance differed across age and delay groups, with object type, age group and delay group (20 min vs. 90 min) as between subject factors. There was a significant interaction between object type and age group [$F(1, 124) = 5.55$, $p = 0.02$], indicating that performance for asymmetric objects was slightly higher in the young than in the older subjects [M (young) = 83.6; M (old) = 78.3; $t(126) = 2.46$, $p = 0.015$], whereas performance for symmetric objects did not differ across age groups [M (young) = 66.2; M (old) = 69.7; $t(126) = 1.51$, $p = 0.13$]. However, this age difference for new asymmetric objects is not problematic because neither young nor older subjects showed priming for these stimuli, as expected (see below). There were no effects involving delay group on baseline accuracy [all $p > 0.14$].

For young subjects, classification accuracy was higher for asymmetric than symmetric objects [$F(1, 62) = 19.35$, $p < 0.0001$]. There was also an effect of encoding status [$F(2, 124) = 6.88$, $p = 0.0017$], an interaction between encoding status and object type [$F(2, 124) = 13.13$, $p < 0.0001$], and an interaction between encoding status, object type, and delay condition [$F(2, 124) = 4.57$, $p = 0.014$). Separate ANOVAs for symmetric and asymmetric objects revealed no reliable effects or interactions for asymmetric objects [all $p > 0.13$]. For symmetric objects, there was an effect of encoding status [$F(2, 124) = 17.22$, $p < 0.0001$] and an interaction between encoding status and delay condition [$F(2, 124) = 3.09$, $p = 0.049$]. Post-hoc contrasts showed that symmetric objects presented in the immediate [$F(1, 62) = 25.32$, $p < 0.0001$] or delayed [$F(1, 62) = 25.83$, $p < 0.0001$] encoding condition were classified more accurately than new symmetric objects. However, for items in the immediate encoding phase, there was also an interaction with delay condition [$F(1, 62) = 5.30$, $p = 0.025$], reflecting more priming for subjects in the 90 min than in the 20 min delay group. There was no interaction with delay group for items in the delayed encoding condition [$F < 1$]. Significant priming occurred for previously presented symmetric objects in all conditions, as assessed via post-hoc t-test [all $p < 0.005$, except for items in the immediate condition of the 20-min delay group where $t(31) = 1.99$, $p = 0.056$].

The older adults also classified asymmetric objects more accurately than symmetric objects [$F(1, 62) = 4.53$, $p = 0.037$]. None of the other effects or interactions were significant, indicating the absence of priming in this group [all $p > 0.14$]. To confirm the effect of age on priming for symmetric objects, we performed an ANOVA on classification accuracies for symmetric objects, with age group, delay group, and encoding status as factors. There was an effect of encoding status that was qualified by an interaction with age [$F(2, 250) = 4.42$, $p = 0.01$, $\eta^2_G = 0.013$]. Post-hoc contrasts provided evidence for an interaction between encoding status and age group for items in both the immediate [$F(1, 125) = 7.29$, $p = 0.008$, $\eta^2_G = 0.055$] and the delayed [$F(1, 125) = 6.13$, $p = 0.015$, $\eta^2_G = 0.047$] encoding condition[2]. Unlike in Experiment 1, the dependence of priming on baseline performance was not examined further because classification accuracy for new objects was significantly higher than chance (at $p < 0.05$, M = 65%) for almost all subjects (only 4 old and 6 young subjects scored between 60% and 64% correct).

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[2] As in Experiment 1, there were no effects or interactions involving encoding status on bias or sensitivity scores in the older group [all $p > 0.18$], providing further evidence that priming did not occur in these subjects. In the young adults, by comparison, there was an effect of encoding status on both sensitivity [$F(2, 124) = 5.53$, $p = 0.005$] and bias [$F(2, 124) = 7.84$, $p = 0.0008$]. Post-hoc contrasts indicated increases in sensitivity and bias for items in the immediate and delayed conditions relative to new items [all $p < 0.02$].

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Discussion

Experiment 2 showed that perceptual priming for novel objects in the symmetric/asymmetric object-decision test was stable over a 90-min period in young adults. These results extend the findings from Experiment 1 and suggest that a single exposure to an unfamiliar 3-D object is sufficient for young adults to be able to form relatively long-lasting perceptual representations of these stimuli. In stark contrast, the older adults did not show priming in this task at any of the encoding-to-test delays. Taken together with the results from Experiment 1, this indicates that perceptual priming for unfamiliar objects in block-based priming paradigms is impaired as a result of normal aging. The main goal of Experiment 3 was to further evaluate the idea that preserved priming of visual objects in older adulthood is dependent on pre-existing memory representations by directly compared priming for familiar and unfamiliar stimuli.

Experiment 3: Real/non-real object-decision priming

The design of Experiment 3 was identical to that of Experiment 1 with two exceptions. First, the test task required subjects to classify objects as either real or non-real. Second, the test stimuli were displayed until subjects made a response, allowing us to use RT as the primary dependent variable. The reason for this change in task administration was two-fold. With the same short display durations used in the previous experiments, accuracy in the young participants was too close to ceiling to observe further increases in accuracy (i.e., priming). Also, it allowed us to test if age differences in priming for unfamiliar stimuli can be observed with RT-paradigms in which age differences tend to be smaller (Light et al., 2000). Both young and older subjects were tested for stimuli they viewed immediately before the test phase and for stimuli that occurred at a 20-min, 90-min, or 1-week delay. We predicted that older subjects show similar levels of priming for the familiar stimuli as young adults at all encoding-to-test delays, but reduced priming for the unfamiliar stimuli.

Method

Participants—96 young and 120 older adults participated in this experiment (Table 3). One young and one older subject were excluded from analysis due to a procedural error. Thus, there were 39 old and 31 young subjects in the 20-min delay condition and 40 old and 32 young subjects each in the 90 and 1-week delay conditions.

Stimuli—The stimuli consisted of 48 real-world familiar objects from the Snodgrass and Vanderwart (1980) stimulus set and 48 non-real unfamiliar objects. The non-real objects were constructed from smoothly connected features of real Snodgrass and Vanderwart (1980) figures (Figure 6). None of the real objects shared any features with the non-real objects (i.e., there were two non-overlapping sets of objects). Non-real stimuli were used rather than line-drawn possible objects so that subjects could not use low-level visual features (such as the presence of curved lines) to differentiate between the familiar and unfamiliar items.

Procedure—The procedure was the same as in Experiment 1, except that the test task required a real/non-real object-decision. Test stimuli remained on the screen until subjects made a response.

Results

Mean classification accuracy [*M* (young) = 97.48; *M* (old) = 97.41] and baseline classification accuracy for both young and older subjects were at ceiling and did not differ between age groups [both $t < 1$]. Therefore, RT was used as the dependent variable. In order to control the effect of outliers on RT, upper and lower RT fences (Tukey, 1977) were computed as three times the value of the interquartile range (as set for each subject by condition cell). Values outside the fences (1.41% of the data) were recoded to the appropriate fence values. The

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resulting RT data was analyzed for correct trials only. Mean RTs for young and older subjects are shown in Figure 7.

For young subjects, a repeated-measures ANOVA with object type, encoding status, and delay group as factors showed faster RTs to real than to non-real objects [$F(1, 92) = 26.96$, $p < 0.0001$]. The effect of encoding status was also significant [$F(2, 184) = 16.23$, $p < 0.0001$], but there were no effects of delay group [all $p > 0.5$]. Post-hoc *t*-tests, collapsing across delay groups, indicated that RTs to previously presented real objects were significantly faster than to new real objects in both the immediate [$t(94) = 3.98$, $p < 0.0005$] and the delayed encoding conditions [$t(94) = 3.63$, $p < 0.001$], which did not differ from one another [$t < 1$]. For non-real objects, priming was significant in the immediate condition [$t(94) = 3.38$, $p < 0.005$] but only marginally significant in the delayed condition [$t(94) = 1.73$, $p = 0.087$ uncorrected]. The reduction in priming for non-real objects in the delayed relative to the immediate condition approached significance [$t(94) = 1.91$, $p = 0.06$ uncorrected].

The older subjects also classified real objects faster than non-real objects [$F(1,116) = 72.96$, $p < 0.0001$], showed a main effect of encoding status [$F(2, 234) = 5.05$, $p = 0.008$], and an interaction between encoding status and object type [$F(2, 234) = 4.24$, $p = 0.017$]. There were no effects involving delay group [all $p > 0.3$]. By post-hoc *t*-test, collapsing across delay groups, priming was significant for real objects in the immediate [$t(118) = 6.05$, $p < 0.0001$] and delayed [$t(118) = 5.82$, $p < 0.0001$] encoding conditions. There was no priming for non-real objects in either the immediate [$t(118) = 0.19$, $p = 0.85$] or delayed [$t(118) = 0.07$, $p = 0.94$] conditions.

To evaluate the effect of aging on priming, proportional priming scores (i.e., percentage decrease in RT for encoded relative to new objects) were computed because of the large difference in baseline RT between young and older subjects [*M* (young) = 763 ms; *M* (old) = 1346 ms; $p < 0.0001$]. An ANOVA (collapsing across delay groups) with age group, delay condition (immediate vs. delayed), and object type as factors revealed more proportional priming for real than non-real objects [$F(1,212) = 25.76$, $p < 0.0001$], and a marginal interaction between object type and age group [$F(1, 212) = 3.28$, $p = 0.07$, $\eta^2_G = 0.005$]. Follow-up ANOVAs showed that there were no effects of age or delay on proportional priming of real objects [all $p > 0.4$]. For non-real objects, however, there was a main effect of age group [$F(1, 212) = 5.03$, $p = 0.026$, $\eta^2_G = 0.0153$], indicating less priming in the older than the young subjects.

Discussion

As predicted and consistent with previous research, Experiment 3 showed that priming for familiar objects is age invariant, even at encoding-to-test delays of up to 1 week. However, as in Experiments 1 and 2, only the young participants demonstrated priming for the unfamiliar stimuli. These results extent the findings from Experiments 1 and 2 by showing that the age-related decrease in priming for unfamiliar visual objects generalizes to a third class of stimuli – globally unfamiliar objects with familiar parts – and to another task – real/non-real object-decision priming. They further indicate that the presence of familiar object parts is not sufficient to support priming in older adults. The results from Experiment 3 also indicate that the age-related reduction in priming is not specific to object-decision tasks that require a purely perceptual judgment on the objects, because the real/non-real task requires subjects to access pre-existing semantic representations to decide if an object is in fact real. Finally, Experiment 3 extends the finding of an age-related reduction in priming for unfamiliar visual objects from accuracy paradigms to a RT paradigm. This latter finding is of significance because it has been argued that age-related decreases in priming are more prevalent in accuracy than in RT paradigms (Light et al., 2000).

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An interesting and unexpected finding from Experiment 3 is that priming for the non-real objects decreased in the young adults when as little as 20 min intervened between the encoding and test phases of the experiments. This stands on contrast to the observed preservation of priming for unfamiliar objects over delays in the possible/impossible and symmetric/asymmetric tasks. A potential explanation for this finding is that priming for the non-real objects was at least partially mediated by parts-based structural, lexical, or semantic representations, which decay more quickly over time (Biederman & Cooper, 1991). Priming for the possible objects used in Experiments 1 and 2 was likely mediated by global structural representations (Schacter et al., 1990), which appear to be more resistant to the effects of decay or interference.

General Discussion

In a recent review article, Fleischman (2007) concluded in that “a mild reduction in priming is not part and parcel of healthy aging”, but may be an early indicator for neurological disease. While this may be true for tasks using familiar stimuli, the present findings indicate that at least some forms of priming of unfamiliar visual objects are reduced in healthy older adults. Across three different block-based tasks and stimulus sets, young but not older adults showed priming for unfamiliar visual objects. As such, the present results point to the significance of pre-existing representations in supporting priming in later adulthood.

At first sight, the finding of an age-related reduction in priming for unfamiliar stimuli appears to conflict with the results by Soldan et al. (2008) who reported normal short-term priming in older adults in a continuous version of the possible/impossible object-decision test. However, the implementation of the possible/impossible object-decision test used by Soldan et al. (2008) differed from the implementation used in the current study in a number of ways that are likely to account for the differential pattern of results.

First and foremost, the number of stimuli intervening between stimulus repetitions was significantly lower in the study by Soldan et al. (2008) (i.e., 2, 4, or 6 intervening items) compared to an average of 70 items (including buffer stimuli) in the present study for stimuli in the immediate condition. One possibility, therefore, is that older adults are able to form novel representations of unfamiliar objects to support priming over short delays (in the order of seconds), but that these representations degrade relatively quickly over time due to the effects of decay and/or interference and are too weak to support priming over longer delays (several minutes) and many intervening stimuli. Support for this possibility comes from preliminary data in our laboratory showing that in older adults, the magnitude of priming for possible objects in the short-term paradigm decreased as a function of the number of intervening items whereas in young subjects it remained constant (Hilton, Pavlicic, & Stern, unpublished manuscript).

A second difference between the present study and that by Soldan et al. (2008) is that subjects performed the same task on repeated stimuli in the study by Soldan et al. (2008), whereas a different task was performed during the encoding and test phases of the present study. This difference is potentially important because different processes and brain regions may support priming in both cases. When the same task is performed on repeated stimuli, the resulting priming effects have been proposed to largely reflect the learning of highly specific stimulus-decision or stimulus-response associations (Dobbins, Schnyer, Verfaellie, & Schacter, 2004). This type of priming has been associated with activity reductions in prefrontal cortical regions in young adults, older adults, and patients with Alzheimer’s disease (e.g., Lustig & Buckner, 2004). Perceptual priming effects that are observed when different tasks are performed on repeated stimuli, in comparison, must be based on the learning of stimulus-specific information that exists independent of a specific response or decision. This type of priming may be more

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reliant on posterior cortical regions that represent the perceptual properties of the stimuli (Schacter, Wig, & Stevens, 2007). It is possible therefore that the age-related reduction in priming observed in this study not only reflects a reduced ability to maintain priming over time and intervening stimuli, but also a deficit in the learning of task-independent novel perceptual information, particularly the 3-D structure of visual objects.

This view is supported by studies showing that older adults are impaired at drawing 3-D cubes and in recognizing whether line drawings accurately depict 3D cubes, but show no impairment for 2-D patterns (Plude, Milberg, & Cerella, 1986). Aging has also been associated with somewhat poorer recognition of line drawings of 3-D objects from 2-D views, i.e., orthographic depictions (Salthouse, 1991) and a reduced ability to discriminate 3-D shape from motion parallax (Norman, Clayton, Shular, & Thompson, 2004) and from static and dynamic patterns of binocular disparity (Norman et al., 2006). These visual-spatial age-related deficits in 3-D perception may be related not only to the reduction in priming observed in the present study but also to older adults' overall greater difficulty in task performance, particularly in the possible/impossible object-decision test. In particular, it is possible that the system for perceiving and encoding 3-D form is so impaired in the low-performing subjects that it could not support adequate task performance and the measured priming effect did not reflect facilitation in 3-D structural processing, but a different kind of memory process. In the high-performing group, these perceptual processes might be intact enough to support relatively normal task performance, but too impaired to support priming.

A third difference between Experiment 1 of the current study and that by Soldan et al. (2008) is the type of dependent variable used to measure priming (accuracy vs. reaction time). This difference, however, is unlikely to account for the differential pattern of results across studies because the results from Experiment 3 indicated that the age related-deficit in priming for unfamiliar stimuli extended to RT paradigms.

Finally, the possibility of explicit memory contamination needs to be considered. To the extent that priming in the tasks used here is influenced by explicit memory, the age-related reduction in priming might reflect decreased explicit memory that accompanies normal aging, rather than an age-related reduction in implicit memory. Although this possibility cannot be ruled out, several findings argue against it. First, as described in the introduction, priming in the possible/impossible object-decision test can be dissociated from explicit memory in a number of ways. Second, if explicit memory influenced priming in the possible/impossible object-decision test, one would expect this influence to be the same or greater in the high performing older adults as in the low performing older subjects. This is turn should produce the same or more priming in the high than in the low performing older adults, which was not the case. For the symmetric/asymmetric task, the relation between priming and explicit memory has not been examined previously, which indicates caution in interpreting the results. However, the finding that priming in the young participants only occurred for symmetric objects again suggests that explicit memory is unlikely to have influenced performance. Even if explicit memory were significantly lower for asymmetric than symmetric objects, one would expect at least a small influence of explicit memory on task performance for asymmetric objects in the young subjects (i.e., a trend towards priming), which was not evident. Finally, for the real/non-real task, the finding that priming did not decrease over the 1-week period is also inconsistent with an influence of explicit memory on task performance because explicit memory is known to decrease over time. In addition, unless the young group reached asymptotic levels of reaction time, the magnitude of proportional priming for real objects would be expected to be greater in the young than the older participants, because of their greater level of explicit memory. The data, however, showed no age difference in proportional priming for real objects.

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In conclusion, the present results provide evidence for an age-related reduction in priming for unfamiliar visual objects in block-based tasks that require the maintenance of priming over many intervening stimuli and changes in task from encoding to test. This finding supports the view that when older adults cannot rely on pre-existing memory representations, age-related deficits in priming can emerge.

References

Bakeman R. Recommended effect size statistics for repeated measures designs. Behav Res Methods 2005;37(3):379–384. [PubMed: 16405133]

Beatty WW, English S, Winn P. Long-lived picture priming in normal elderly persons and demented patients. J Int Neuropsychol Soc 1998;4(4):336–341. [PubMed: 9656607]

Biederman I, Cooper EE. Priming contour-deleted images: evidence for intermediate representations in visual object recognition. Cognit Psychol 1991;23(3):393–419. [PubMed: 1884597]

Bowers JS. Does implicit memory extend to legal and illegal nonwords? J Exp Psychol Learn Mem Cogn 1994;20(3):534–549. [PubMed: 8207371]

Bowers JS. Different perceptual codes support priming for words and pseudowords: was Morton right all along? J Exp Psychol Learn Mem Cogn 1996;22(6):1336–1353. [PubMed: 8921601]

Cabeza, R.; Nyberg, L.; Park, DC. Cognitive neuroscience of aging. Oxford University Press; 2005.

Cooper LA, Schacter DL, Ballesteros S, Moore C. Priming and recognition of transformed three-dimensional objects: effects of size and reflection. J Exp Psychol Learn Mem Cogn 1992;18(1):43–57. [PubMed: 1532021]

Dobbins IG, Schnyer DM, Verfaellie M, Schacter DL. Cortical activity reductions during repetition priming can result from rapid response learning. Nature 2004;428(6980):316–319. [PubMed: 14990968]

Fiebach CJ, Gruber T, Supp GG. Neuronal mechanisms of repetition priming in occipitotemporal cortex: spatiotemporal evidence from functional magnetic resonance imaging and electroencephalography. J Neurosci 2005;25(13):3414–3422. [PubMed: 15800196]

Fleischman DA. Repetition priming in aging and Alzheimer's disease: an integrative review and future directions. Cortex 2007;43(7):889–897. [PubMed: 17941347]

Fleischman DA, Gabrieli JDE. Repetition priming in normal ageing and Alzheimer's disease: A review of findings and theories. Psychology and Ageing 1998;13:88–119.

Henson RN. Neuroimaging studies of priming. Prog Neurobiol 2003;70(1):53–81. [PubMed: 12927334]

Henson RN, Shallice T, Dolan R. Neuroimaging evidence for dissociable forms of repetition priming. Science 2000;287(5456):1269–1272. [PubMed: 10678834]

Keane MM, Wong BM, Verfaellie M. Do priming effects in perceptual identification and word judgment reflect different underlying mechanisms? Am J Psychol 2004;117(1):93–113. [PubMed: 15058859]

Kennedy KM, Rodrigue KM, Raz N. Fragmented pictures revisited: long-term changes in repetition priming, relation to skill learning, and the role of cognitive resources. Gerontology 2007;53(3):148–158. [PubMed: 17179724]

Light LL, Kennison R, Prull MW, LaVoie D, Zuellig A. One-trial associative priming of nonwords in young and older adults. Psychol Aging 1996;11(3):417–430. [PubMed: 8893311]

Light LL, La Voie D, Kennison R. Repetition priming of nonwords in young and older adults. J Exp Psychol Learn Mem Cogn 1995;21(2):327–346. [PubMed: 7738504]

Light, LL.; Prull, MW.; La Voie, DJ.; Healy, MR. Dual process theories of memory in old age. In: Perfect, TJ.; Maylor, EA., editors. Models of cognitive ageing. Oxford: Oxford University Press; 2000. p. 238-300.

Liu T, Cooper LA. The influence of task requirements on priming in object decision and matching. Mem Cognit 2001;29(6):874–882.

Lustig C, Buckner RL. Preserved neural correlates of priming in old age and dementia. Neuron 2004;42 (5):865–875. [PubMed: 15182724]

Norman JF, Clayton AM, Shular CF, Thompson SR. Aging and the perception of depth and 3-D shape from motion parallax. Psychol Aging 2004;19(3):506–514. [PubMed: 15383000]

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Norman JF, Crabtree CE, Herrmann M, Thompson SR, Shular CF, Clayton AM. Aging and the perception of 3-D shape from dynamic patterns of binocular disparity. Percept Psychophys 2006;68(1):94–101. [PubMed: 16617833]

Plude DJ, Milberg WP, Cerella J. Age differences in depicting and perceiving tridimensionality in simple line drawings. Exp Aging Res 1986;12(4):221–225. [PubMed: 3569399]

Ratcliff R, McKoon G. Bias in the priming of object decisions. J Exp Psychol Learn Mem Cogn 1995;21 (3):754–767. [PubMed: 7602269]

Salthouse TA. Age and experience effects on the interpretation of orthographic drawings of three-dimensional objects. Psychol Aging 1991;6(3):426–433. [PubMed: 1930759]

Schacter DL, Cooper LA. Bias in the priming of object decisions: logic, assumption, and data. J Exp Psychol Learn Mem Cogn 1995;21(3):768–776. [PubMed: 7602270]

Schacter DL, Cooper LA, Delaney SM. Implicit memory for unfamiliar objects depends on access to structural descriptions. J Exp Psychol Gen 1990;119(1):5–24. [PubMed: 2141064]

Schacter DL, Cooper LA, Tharan M, Rubens AB. Preserved priming of novel objects in patients with memory disorders. Journal of Cognitive Neuroscience 1991;3(2):117–130.

Schacter DL, Cooper LA, Treadwell J. Preserved priming of novel objects across size transformation in amnestic patients. Psychological Science 1993;4:331–335.

Schacter DL, Cooper LA, Valdiserri M. Implicit and explicit memory for novel visual objects in older and younger adults. Psychol Aging 1992;7(2):299–308. [PubMed: 1610519]

Schacter DL, Wig GS, Stevens WD. Reductions in cortical activity during priming. Curr Opin Neurobiol 2007;17(2):171–176. [PubMed: 17303410]

Soldan A, Gazes E, Hilton JH, Stern Y. Aging Does Not Affect Brain Patterns of Repetition Effects Associated with Perceptual Priming of Novel Objects. J Cogn Neurosci. 2008

Soldan A, Mangels JA, Cooper LA. Effects of dividing attention during encoding on perceptual priming of unfamiliar visual objects. Memory. in press

Soldan A, Zarahn E, Hilton HJ, Stern Y. Global familiarity of visual stimuli affects repetition-related neural plasticity but not repetition priming. Neuroimage 2008;39(1):515–526. [PubMed: 17913513]

Wiggs CL, Martin A. Aging and feature-specific priming of familiar and novel stimuli. Psychol Aging 1994;9(4):578–588. [PubMed: 7893429]

Wiggs CL, Weisberg J, Martin A. Repetition priming across the adult lifespan--the long and short of it. Neuropsychol Dev Cogn B Aging Neuropsychol Cogn 2006;13(3–4):308–325. [PubMed: 16887776]

Williams P, Tarr MJ. Structural processing and implicit memory for possible and impossible figures. J Exp Psychol Learn Mem Cogn 1997;23(6):1344–1361. [PubMed: 9372604]

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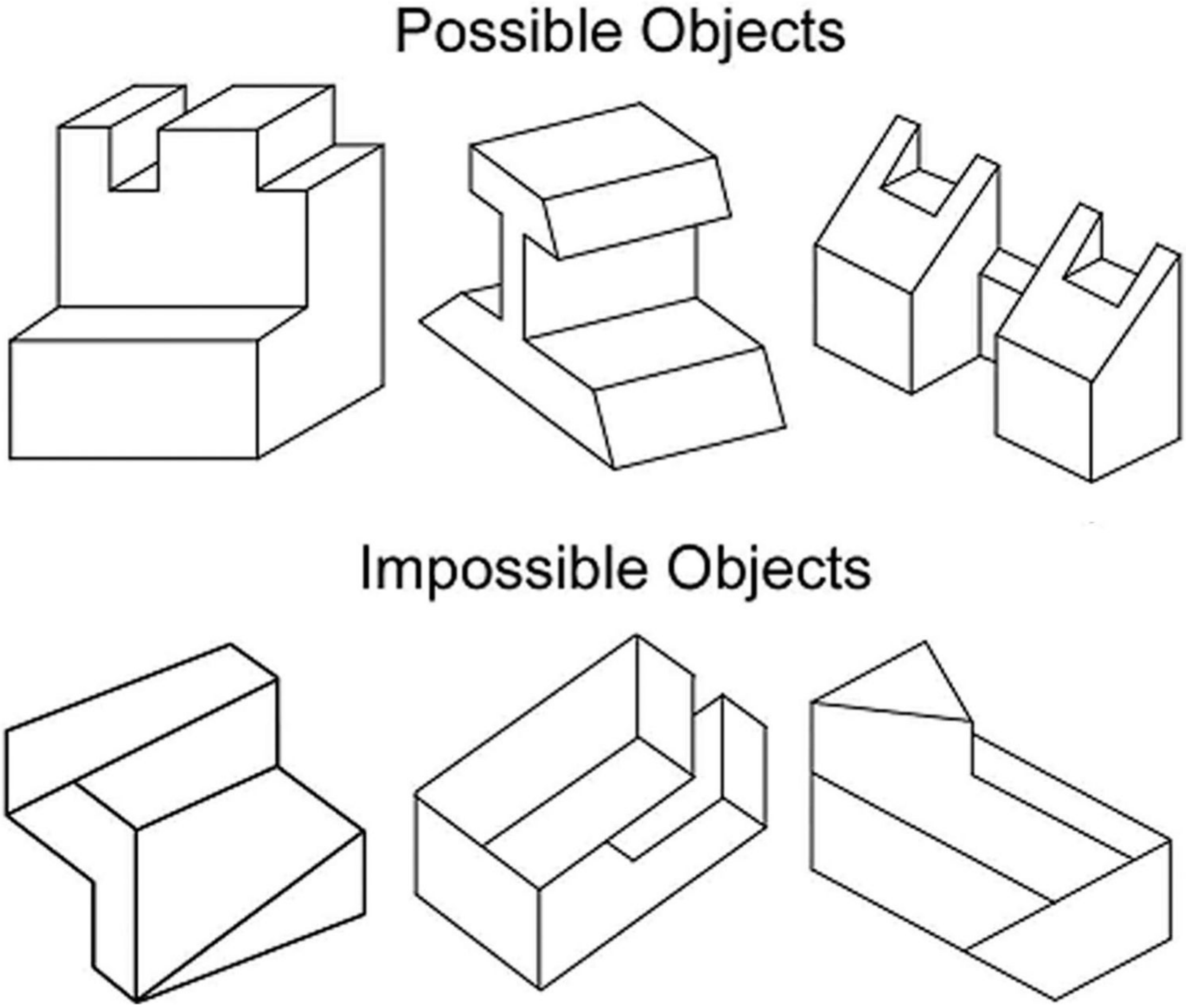

Figure 1.
Examples of structurally possible and impossible figures used in Experiment 1.

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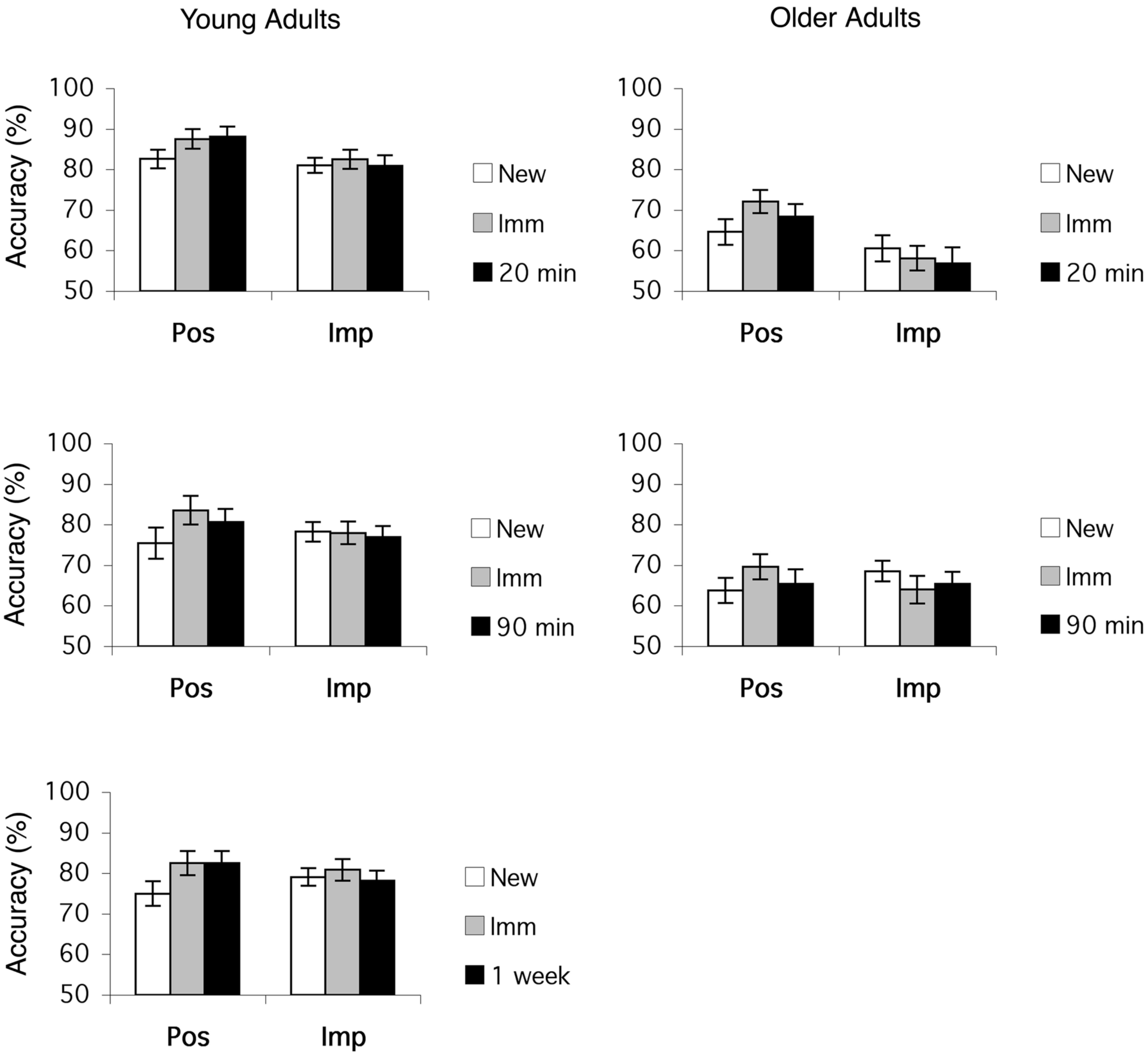

Figure 2.

Results from Experiment 1. Mean classification accuracy in the possible/impossible object-decision test for young (left panel) and older (right panel) adults for new objects (□ new), objects encoded immediately before the test phase (▨ Imm), and objects encoded at a delay (■ top panel: 20 min, middle panel: 90 min, bottom panel: 1 week). Error bars represent the standard error of the mean. Young subjects showed significant priming for possible objects at all encoding-to-test delays. In older subjects, priming was reliable in the immediate, but not in the delayed encoding condition.

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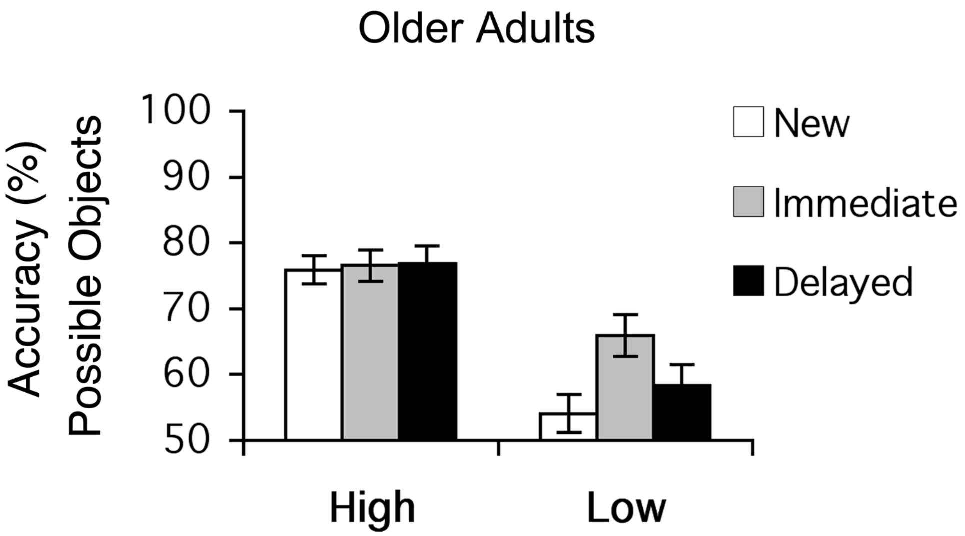

Figure 3.

Results from Experiment 1. Mean classification accuracy in high and low performing older subjects for new possible objects (☐), possible objects encoded immediately before the test phase (▨), and possible objects encoded at a delay (■ collapsing across the 20 min and 90 min groups). Error bars represent the standard error of the mean. The high performing older subjects did not show priming, whereas the low-performing older subjects showed priming in the immediate condition but not in the delayed condition. See text for more details.

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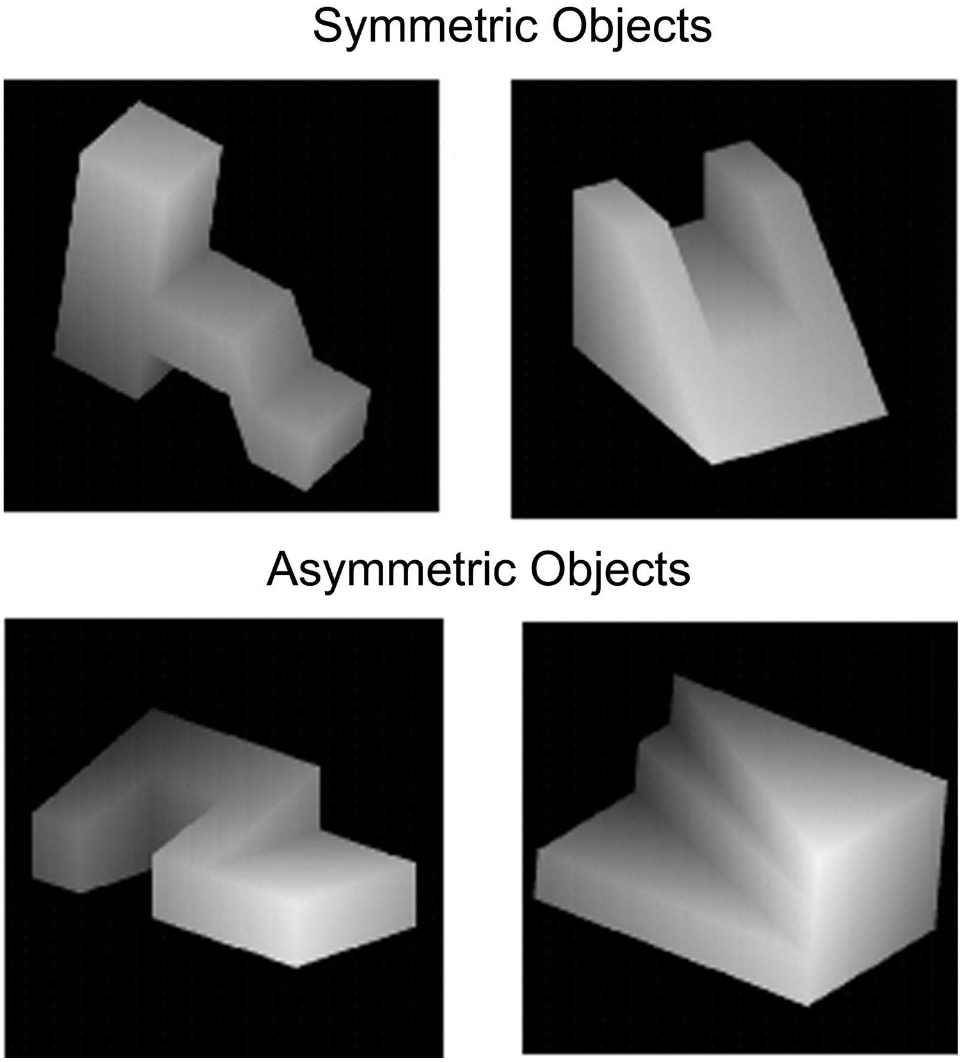

Symmetric Objects

Asymmetric Objects

Figure 4.
Examples of the depth-cued symmetric and asymmetric objects used in Experiment 2.

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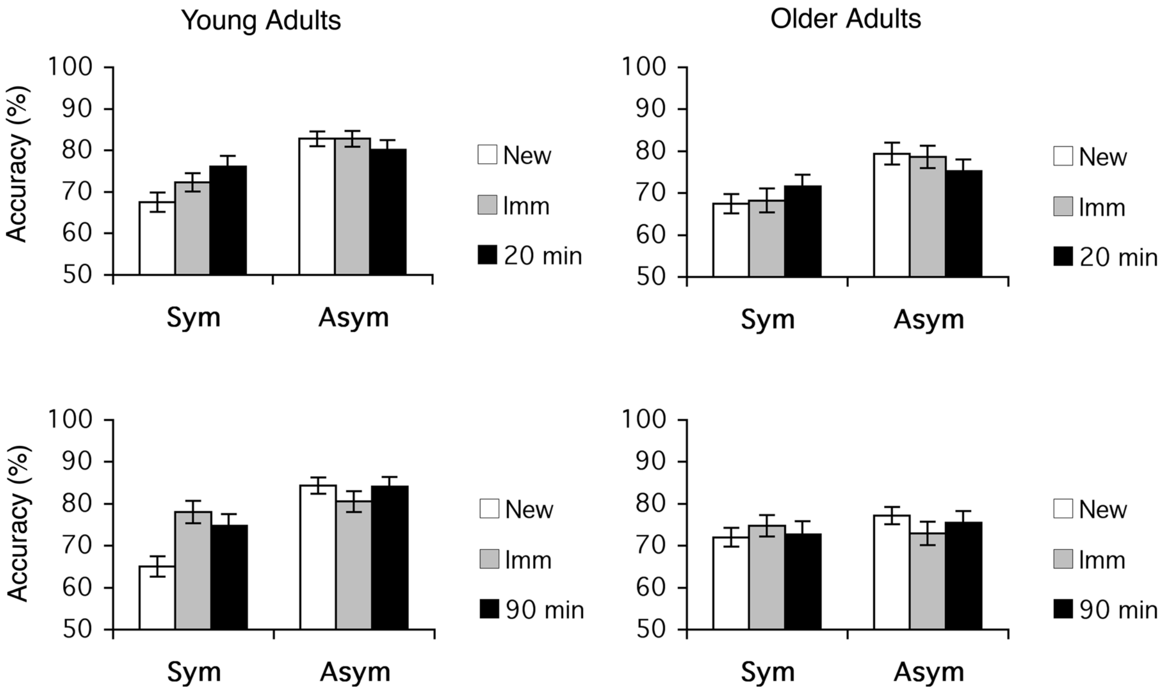

Figure 5.

Results from Experiment 2. Mean classification accuracy in the symmetric/asymmetric object-decision test for young (left panel) and older (right panel) adults for new objects (□ new), objects encoded immediately before the test phase (▨ Imm), and objects encoded at a delay (■ top panel: 20 min, bottom panel: 90 min). Error bars represent the standard error of the mean. Young subjects showed significant priming for symmetric objects at all encoding-to-test delays. In the older subjects, no significant priming was observed.

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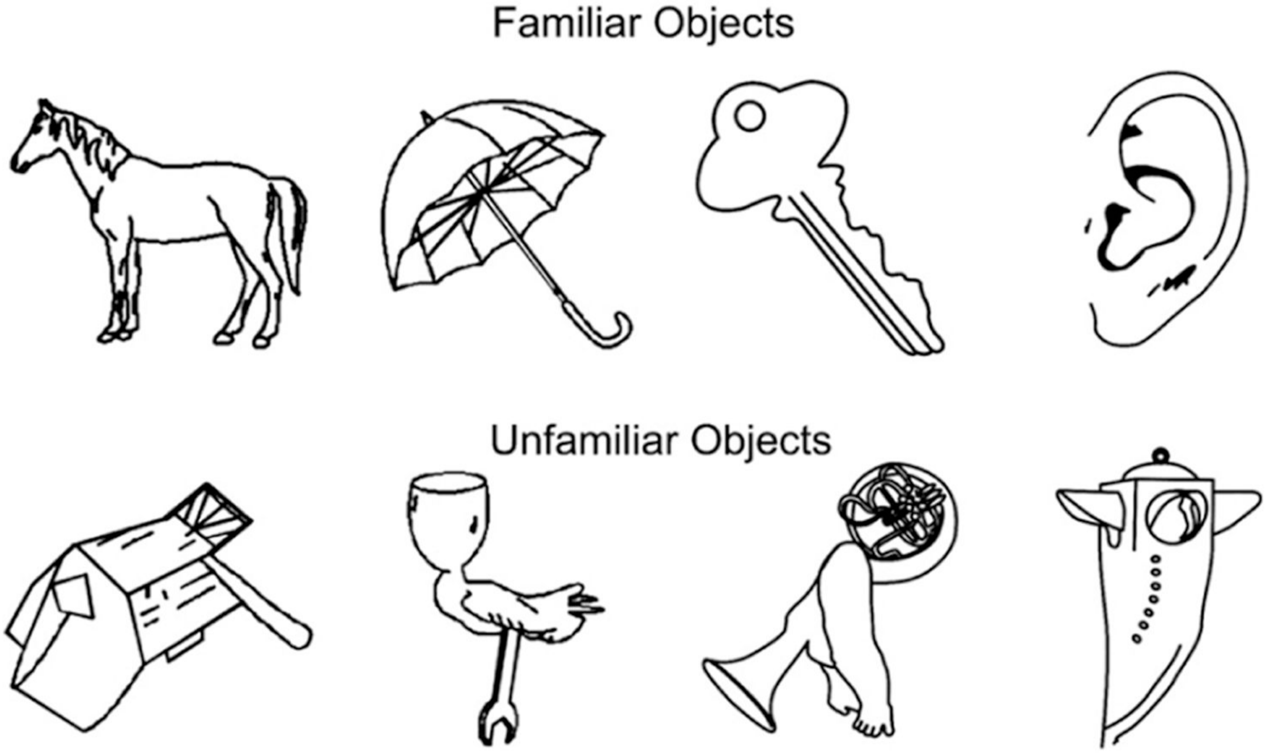

Figure 6.
Examples of the familiar, real objects and the unfamiliar, non-real objects used in Experiment 3.

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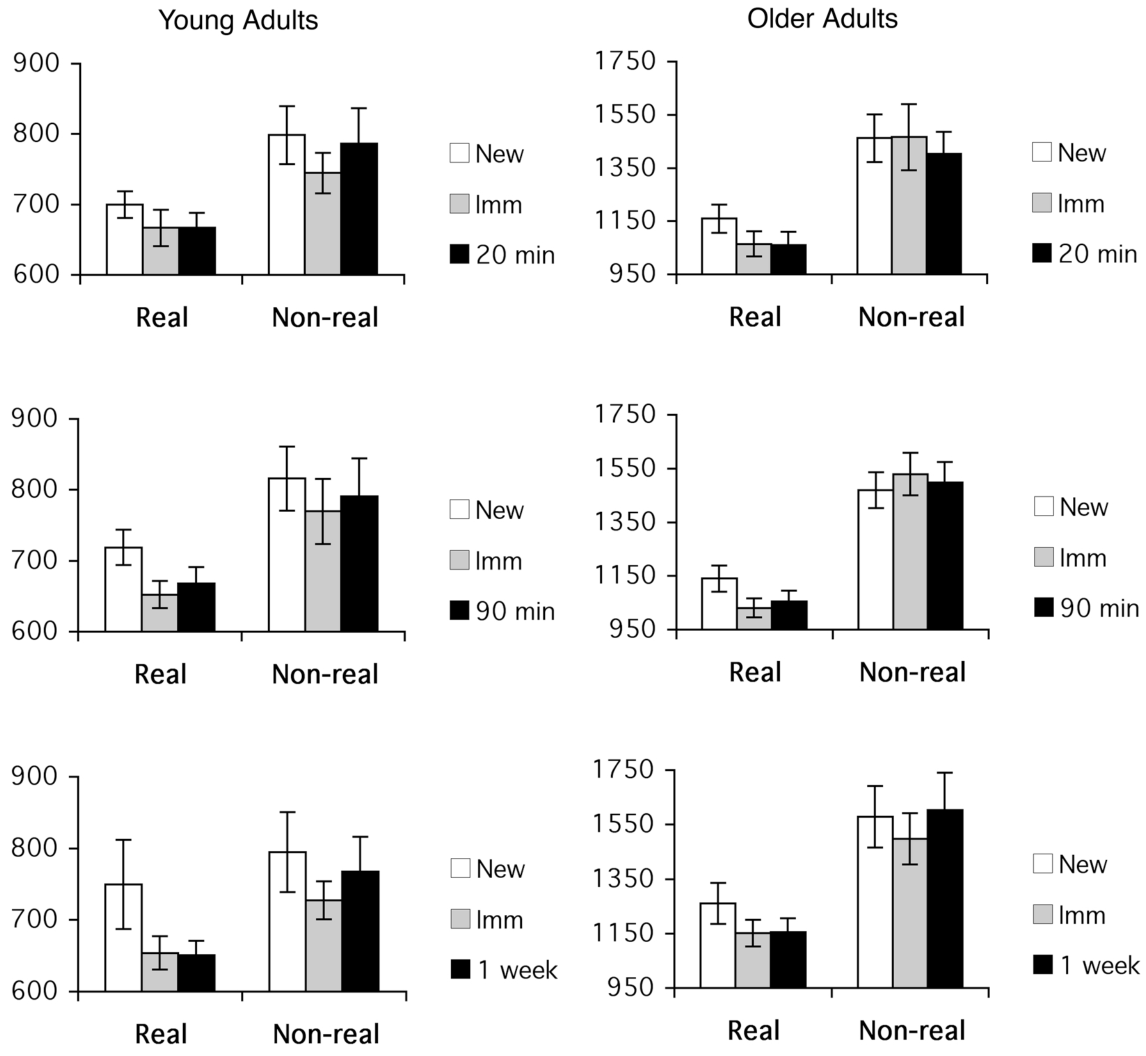

Figure 7.
Results from Experiment 3. Mean classification accuracy in the real/non-real object-decision test for young (left panel) and older (right panel) adults for new objects (☐ new), objects encoded immediately before the test phase (▨ Imm), and objects encoded at a delay (■ top panel: 20 min, middle panel: 90 min, and bottom panel: 1 week). Error bars represent the standard error of the mean. Young and older subjects showed priming for the familiar objects at all encoding-to-test delays. Only the young subjects demonstrated priming of the unfamiliar objects.

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Table 1

Demographic and neuropsychological variables for subjects in Experiment 1

	Young **(n = 120)**	**Old** **(n = 80)**
Female/Male	71/49	50/30
Age [*]	21.1 (3.4)	73.8 (6.1)
Education (yr)	14.3 (2.9)	14.3 (1.9)
DRS-2 [*]	141.4 (2.3)	138.8 (3.9)
NART-IQ[*]	115.2 (5.6)	119.7 (6.9)
SRT total recall[*]	59.8 (5.2)	44.1 (9.2)
WAIS letter-number sequencing [*]	13.3 (3.1)	9.6 (2.4)
Verbal fluency- CFL	48.2 (10.6)	46.6 (14.0)

Note: means and standard deviations (in parentheses) for demographic variables and neuropsychological test scores. DRS-2, Dementia Rating Scale-2; NART-IQ, North American Adult Reading Test estimated IQ; SRT, Selective Reminding Test; WAIS, Wechsler Adult Intelligence Scale.

[*] Significant difference between groups, $p < 0.001$.

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Table 2

Demographic and neuropsychological variables for subjects in Experiment 2

	Young (n = 64)	**Old (n = 64)**
Female/Male	41/23	41/23
Age [*]	21.0 (3.5)	71.6 (4.8)
Education (yr)	14.1 (2.2)	14.7 (2.9)
DRS-2 [*]	141.7 (2.0)	138.4 (3.1)
NART-IQ	117.6 (6.3)	115.0 (10.3)
SRT total recall[*]	61.8 (4.8)	46.7 (8.6)
WAIS letter-number sequencing [*]	13.5 (2.7)	9.0 (2.3)
Verbal fluency- CFL[*]	47.6 (10.3)	40.7 (13.3)

Note: means and standard deviations (in parentheses) for demographic variables and neuropsychological test scores. DRS-2, Dementia Rating Scale-2; NART-IQ, North American Adult Reading Test estimated IQ; SRT, Selective Reminding Test; WAIS, Wechsler Adult Intelligence Scale.

[*] Significant difference between groups, $p < 0.001$.

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Table 3

Demographic and neuropsychological variables for subjects in Experiment 3

	Young (n = 95)	**Old** (n = 119)
Female/Male	59/36	77/42
Age *	20.8 (2.8)	72.5 (5.5)
Education (yr)	14.0 (1.9)	14.4 (2.5)
DRS-2 *	141.0 (2.2)	139.5 (2.9)
NART-IQ	115.9 (5.8)	117.7 (7.2)
SRT total recall*	58.6 (6.3)	47.4 (8.6)
WAIS letter-number sequencing *	12.8 (2.5)	9.7 (2.4)
Verbal fluency- CFL*	48.9 (10.9)	43.5 (13.2)

Note: means and standard deviations (in parentheses) for demographic variables and neuropsychological test scores. DRS-2, Dementia Rating Scale-2; NART-IQ, North American Adult Reading Test estimated IQ; SRT, Selective Reminding Test; WAIS, Wechsler Adult Intelligence Scale.

*Significant difference between groups, $p < 0.001$.