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Aging and implicit memory: Examining the contribution of test awareness

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ABSTRACT

The study examined whether test awareness contributes to age effects in priming. Younger and older adults were given two priming tests (word-stem completion and category production). Awareness was assessed using both a standard post-test questionnaire and an on-line measure. Results from the on-line awareness condition showed that, relative to older adults, younger adults showed higher levels of priming and awareness, and a stronger relationship between the two, suggesting that awareness could account for age differences in priming. In contrast, in the post-test questionnaire condition, there was no age effect in word-stem completion or category production priming, despite the fact that awareness was greater in younger than older adults in the word-stem completion test and that category production priming was dependent on awareness in both age groups. These results suggest that awareness may mediate age effects in priming, but only under conditions of relatively high levels of awareness.

0. Introduction

There are clear effects of aging on memory performance when memory is measured explicitly by using tests that directly require people to recall the past, such as free recall tests (see Light (1996) for review). The picture is less clear when memory is tested implicitly or indirectly. Implicit memory tests require participants to perform a task that is predictably influenced by past experience although participants are presumably unaware of the past's influence on their behavior. The resultant change in behavior (often improvements in accuracy or speed) is called priming (Graf & Schacter, 1985; Tulving, Schacter, & Stark, 1982). Sometimes priming is influenced by aging, but other times priming appears to be entirely unaffected by aging (see Fleischman and Gabrieli (1998), LaVoie and Light (1994), Light, Prull, La Voie, and Healy (2000) for reviews).

Several test factors have been hypothesized to account for the mixed pattern of aging effects on implicit tests, yet no clear support has emerged for any of these explanations. For example, researchers have suggested that age effects occur on implicit tests that require participants to analyze the conceptual (or semantic) features of the stimulus, but not on tests that require participants to analyze the perceptual (e.g., physical word features) of the stimulus (Jelicic, 1995; Jelicic, Craik, & Moscovitch, 1996; Rybash, 1996). However, sometimes age effects do occur on perceptual tests, such as word-stem completion, in which participants are given the first few letters of a word at test and are required to complete the stem with the first word that comes to mind (Chiarello & Hoyer, 1988; Davis et al., 1990; Fleischman et al., 1999; Hultsch, Masson, & Small, 1991; Light & Singh, 1987; Winocur, Moscovitch, & Stuss, 1996). Conversely, sometimes age effects do not occur on conceptual tests such as category verification, in which participants are given categories and are asked to quickly indicate whether target items are members of the category (e.g., Light, Prull, & Kennison, 2000; Small, Hultsch, & Masson, 1995).

With this in mind, researchers have instead suggested that age effects occur on tests that require participants to produce a response, but not on tests that require participants to simply identify the correct response (Gabrieli et al., 1994, 1999; Vaidya

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et al., 1997). However, some research also shows that age effects do not occur on tests that require the production of a response when other factors are held constant (Geraci, 2006; Prull, 2004). Another interpretation is that age effects in priming occur on tests that entail response competition (i.e., where there are many possible correct responses) and not on those that entail little response competition (i.e., where there are very few, or sometimes only one, possible correct response; Gabrieli et al., 1999; Nyberg, Winocur, & Moscovitch, 1997; Vaidya et al., 1997; see also Light et al., 2000)). Yet, when responses competition is selectively manipulated, age effects do not always occur under conditions of high response competition (Geraci & Hamilton, 2009). Finally, several other factors in addition to test factors, including time of day (May, Hasher, & Foong, 2005) and individual differences in older adults' neurological status (Fleischman & Gabrieli, 1998) have been offered as explanations for age effects in priming, but again there are results that appear inconsistent with these views (e.g., Geraci, 2006; Yang, Hasher, & Wilson, 2007).

Yet another possibility is that age effects in priming depend on whether explicit memory processes inadvertently contribute to implicit memory performance (Habib, Jelicic, & Craik, 1996; Light, 1991; Mitchell, 1995; Mitchell & Bruss, 2003; Russo & Parkin, 1993). The idea is that a certain number of participants become aware of the connection between the studied and test items and then begin to use explicit or intentional memory processes to perform the ostensibly implicit task (see MacLeod (2008) for review). This phenomenon is sometimes referred to as "explicit contamination". The contribution of explicit memory to implicit test performance is particularly problematic for understanding age effects in priming because younger and older adults differ in their ability to use explicit memory strategies (see Light (1996) for review). If younger adults are more likely to become test aware and/or engage in explicit memory strategies, then it is possible that age effects (when they are obtained) are driven by younger adults' use of explicit memory strategies to augment performance on a supposedly implicit test. This possibility makes it difficult to interpret age differences in implicit test performance. Do they reflect true differences in priming or differences in explicit memory performance? Unfortunately, test awareness is not always assessed in age comparisons of priming.

For test awareness to mediate age effects in priming, awareness would need to lead to more priming in general. In addition, either awareness would need to be greater in younger adults than it is in older adults or, when awareness occurs, it would have to increase priming more for younger adults than older adults. There is some evidence for the first idea that awareness increases priming. For example, when younger adults are given a post-test questionnaire to assess their awareness of the connection between studied and test items, younger adults who are classified as "test aware" on the basis of their responses to the questionnaire show more priming than "test unaware" participants (e.g., Barnhardt, 2004; Barnhardt & Geraci, 2008). In addition, some memory effects that are typically obtained on explicit tasks, such as free recall, are obtained for test aware participants, but not test unaware participants (e.g., Geraci & Rajaram, 2002). Together, these two types of evidence (i.e., showing that awareness leads to increases in priming and that awareness leads to differential priming effects) suggest that awareness can influence priming, at least in younger adults.

There is less research examining awareness in older adults, but some studies show that older adults are less likely to report test awareness than younger adults. In a recent study examining the effects of aging and frontal lobe functioning on priming, over half of the younger adults reported test awareness on a post-test questionnaire, while only three (all with relatively high frontal functioning) of the 56 older adults reported test awareness (Geraci, 2006). Because there were so few test aware older adults, the effect of awareness on priming for this group could not be statistically examined. However, awareness did appear to change the level of priming for younger adults, although the difference was not significant. Other studies have also found relatively high levels of awareness in younger adults and low levels of awareness in older adults using post-test questionnaires (Geraci & Hamilton, 2009). Older adults may report less test awareness than younger adults because older adults actually experience less test awareness than younger adults or because older adults are less able to accurately recall their mental state than younger adults when the awareness questionnaire is administered sometime later. We return to this second possibility shortly.

The final possibility—that awareness in younger adults leads to increases in priming whereas awareness in older adults does not—is difficult to test because so few older adults report awareness using the post-test questionnaire method of assessment. A handful of studies have compared age effects in priming by awareness using post-test questionnaires, but the data are mixed (e.g., Light & Albertson, 1989; Mitchell & Bruss, 2003; Park & Shaw, 1992). And again, lower reports of awareness from older adults may indicate less test awareness or poor awareness recall.

One way to circumvent the potential problem of recalling one's state of awareness from the past is to assess awareness at the time of testing, rather than waiting until some time later. In the current study, younger and older adults were given both an on-line awareness measure and a standard post-test questionnaire. For the on-line measure, participants were given standard implicit memory instructions to complete the task with the first word that comes to mind. They were also asked to note immediately after producing a word whether they thought the response they wrote might have been presented in the earlier study list (see Richardson-Klavehn and Gardiner (1996), for a similar paradigm used to assess involuntary awareness). If older adults' relatively low frequency of awareness is not attributable to older adults forgetting their past mental state, then we would expect greater levels of awareness in younger than in older adults in the on-line condition.

Further, using the on-line measure allowed us to examine age effects in priming under conditions in which participants are, by definition, test aware. Participants in the on-line condition can be considered test aware because the on-line test instructions essentially inform participants that the implicit memory test can be completed with previously studied words. Thus, the use of both the on-line assessment and the post-test questionnaire allowed us to contrast the pattern of age effects in priming under conditions of relatively high awareness (in the on-line condition) and relatively low awareness (in the post-

test questionnaire condition). It may be that age effects in priming occur only under circumstances in which there is a relatively high degree of awareness – as in the on-line condition – and that a relatively high degree of awareness is a kind of precondition for the contribution of explicit memory to implicit memory performance.

We also used two different priming tasks, word-stem completion and category production. We used these two tasks because both tests are production tests (tests that require production of a single response where many possible responses are possible) and this type of test has been linked with age differences in priming (Gabrieli et al., 1999). We used two types of production tests: a word-stem completion task that is often classified as a perceptual test and a category production task that is classified as a conceptual test (see Roediger and McDermott (1993) for review). One might predict that awareness would be more likely to influence priming on conceptual tests, than on perceptual tests, because conceptual processes generally aid explicit memory performance (Craik & Lockhart, 1972).

1. Method

1.1. Design

The experiment used a $2 \times 2 \times 2$ mixed factorial design in which age (younger and older) served as the between-subjects factor and test type (word-stem completion and category production) and awareness measure (post-test questionnaire and online) served as the within-subjects variables. The order of the implicit memory tests was counterbalanced across participants, but the post-test questionnaire measure was always administered after the first test and the on-line probe was always administered during the second test. For example, when the stem completion test was first and the category production test was second, the stem completion test was followed by the awareness questionnaire and the category production test was accompanied by the on-line awareness procedure. Participants always received the post-test questionnaire condition first as an attempt to keep that implicit test as pure as possible. Because the participants in the on-line awareness condition were, by design, aware of a potential connection between study and test, it was assumed that having already received a post-test questionnaire for the previous test would have little influence on subsequent on-line performance.

1.2. Participants

Sixty-four younger adults (M age = 19.19, SD = 1.14) and 64 older adults (M age = 74.25, SD = 5.74) participated in the experiment. The younger adults were recruited through the Psychology Department undergraduate participant pool and received credit toward the research participation component of their introductory psychology course. The older adults were mostly Texas A&M alumni recruited from the community. They received an honorarium of $10 in appreciation of their participation. Although 64 older adults were tested, it was later discovered that two of those participants had previously participated in the same experiment. These two participants were eliminated from the data analyses, leaving 64 younger adults and 62 older adults.

Younger and older adults were given the Shipley Vocabulary Test (Zachary, 1986) to assess word knowledge. As expected, older adults had significantly higher vocabulary scores (M = 35.09, SD = 3.44) than younger adults (M = 31.09, SD = 3.92), $F(1, 124) = 37.04$, MSE = 13.60. Education level was also significantly higher for older adults (M = 16.48, SD = 2.53) relative to younger adults (M = 13.69, SD = .73), $F(1, 124) = 72.15$, MSE = 3.41. Older adults were also given a Mini-Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975) to exclude from the analyses people with significant impairments in cognitive functioning. The average MMSE was 28.71 (SD = 1.11), and no one in the sample scored lower than 26 on this test.

1.3. Materials

Two study lists of 70 items each were constructed such that in each of the lists there were 30 items that would latter serve as studied solutions on the word-stem completion test and 40 category exemplars (eight items in each of five categories) that could be used during the category production test. When one list was used for study, the items from the other list served as the baseline. This yielded 60 stems (30 studied and 30 baseline) for the word-stem completion test and 10 category labels (five studied and five baseline) for the category production test. Following guidelines for limiting potential test awareness (see MacLeod, 2008; Roediger & Geraci, 2005), 30 filler items were included in the word-stem completion test: eight were presented at the beginning of the test and the other 22 were randomly interspersed amongst the critical studied and baseline stems. In the end, the word-stem completion test consisted of 90 items. For the category production test, five filler category labels were included: two were presented at the beginning of the test and the other three were randomly interspersed amongst the studied and baseline category labels. In the end, the category production test consisted of 15 category labels. Finally, four buffer items were included at the beginning and end of each study list to blunt primacy and recency effects. All stems were unique in the stimulus set, including those from the buffers, fillers, and category production exemplars. Special care was taken to ensure that none of the word-stem completion stimuli could serve as exemplars in the category production test. In addition, based on their use in previous experiments, we selected critical items for both tests that would yield similar baseline performance across younger and older adult participants. To anticipate our results, baseline performance was similar across age groups. Please note, that all stimuli are available to readers upon request.

1.4. Procedure

For the study task, participants were told that they would be presented with a list of words displayed one at a time on a computer screen and that their memory for these words would be tested later with a free recall test. After the study list was presented, participants were given a 5 min distracter task in which they were asked to mentally rotate objects to answer same-different judgments. Next, participants were given either the word-stem completion test or the category production test, depending on test order, and this test was disguised as yet another distracter task before the expected free recall test.

For the word-stem completion test, participants were told that the test was designed to measure word knowledge. They were told that they would be given a list of word stems containing only the first three letters of words and that they should try to complete the stem with the first word that came to mind. Participants were given a booklet containing the word stems and they were told to work on completing one stem at a time. They were informed that speeded responding was of utmost importance and that if they could not complete an item within approximately five seconds, they should proceed to the next stem. Lastly, they were told not to use any proper nouns or words with fewer than five letters to complete the stems. In total, this test took approximately 7 min to complete.

For the category production test, participants were told that this test was designed to measure their knowledge of categories. During the test, each category label (e.g., A Type of Bird) was presented on a separate page and participants were given 30 s to write down as many exemplars of the category as they could in that amount of time. At the end of the 30 s, participants heard a beep sounded by an audio cassette that prompted them to pull down the cover sheet and to proceed to the next category label. Participants were instructed to work on one test item at a time and not to go back or skip ahead in the booklet. This test took approximately 7 min.

After the first test, whether it was stem completion or category production, participants were given a post-test questionnaire that was originally introduced by Bowers and Schacter (1990) and has been shown to accurately measure test awareness in younger adults (Barnhardt, 2004; Barnhardt & Geraci, 2008). When the test was stem completion, the questionnaire consisted of the following five questions: (1) What do you think was the purpose of the word-stem completion task that you just finished? (2) What was your general strategy in completing the word stems? (3) While you were doing the word-stem completion task, did you notice any relation between the words that were presented on the screen at the beginning of the experiment and the words you wrote in your booklet? (4) While you were doing the word-stem completion task, did you notice whether some of the words you wrote were the same as the words that had been displayed on the screen? (5) If you noticed that you were writing words that had been displayed on the screen, did you simply continue to use the first word that came to your mind or did you try to complete the stems with the words that had been displayed on the screen? The fifth question was designed to determine whether test aware participants continued to use the first word that came to mind or whether they changed their retrieval strategy to one in which they were intentionally trying to respond with studied words (see also Barnhardt, 2004; Mace, 2003, 2005). These questions were adjusted to fit with the category production test. The questions were printed on both sides of a single piece of paper, with the first three questions on one side and the last two questions on the other side and participants were instructed to answer the questions in order. If participants answered question five in a way that indicated they were intentionally retrieving the studied words, they were classified as ‘‘intentional” regardless of their other responses. If a participant was not classified as intentional, they were classified as aware if they indicated that they were aware on any of the first four questions. They were classified as unaware if they did not indicate awareness on any of the first four questions (see Barnhardt and Geraci (2008), for discussion of this classification).

After participants completed the post-test questionnaire, they were given the second implicit test (either word-stem completion or category production) with on-line awareness instructions. If the second test was category production, participants were given the standard implicit test instructions described earlier and were also told: ‘‘As you are writing the category examples, if you notice any words that were ones you saw earlier on the computer screen, please circle these words as you go. Otherwise, just focus on writing as many category examples as you can in the allotted time.” Instructions were similar for the word-stem completion test.

Finally, participants were given the expected free recall test in which they were told to write down all the words that they could remember from the study session. Younger adults were tested in groups of one to four and older adults were tested singly or in pairs. The entire procedure lasted approximately an hour and a half.

2. Results

The results for the on-line and post-test measures are reported separately, starting with the on-line measure. For each measure, we examined age differences in awareness, followed by age differences in priming, and then the relationship between priming and awareness for that measure. Then we examined the relationship between age and awareness across the awareness measures. Finally, we present the free recall data. The significance level for all statistical tests was set at $p < .05$.

2.1. On-line awareness

The number of participants who indicated awareness on at least one item in the on-line awareness condition is presented in Table 1. As can be seen, younger adults displayed more on-line awareness than older adults (91% of younger adults indi-

Table 1
Number of younger and older adults in each awareness category for both types of implicit tests in the on-line awareness condition.

	Younger		Older	
	WSC	CP	WSC	CP
Zero OLA	6	0	16	18
At least one OLA	26	32	14	14
All participants	32	32	30	32

Note: WSC = word-stem completion; CP = category production. OLA = on-line awareness. Standard deviations are in parentheses.

cated awareness on at least one item, whereas only 45% of older adults did so). Over half of the older adults failed to indicate awareness on any of the items in either the word-stem completion test or the category completion test. In contrast, only 19% of young adults did not indicate awareness on at least one stem completion response and all of the young adults indicated awareness on at least one category production response. Both of these age differences were significant, $\chi^2(1) = 8.09$ and $\chi^2(1) = 25.04$, respectively.

Next we examined the false alarm rates for the test aware participants in the two age groups. In the stem completion test, the mean false alarm rate for younger adults was .27 and for older adults was .14. In the category production test, this rate was .03 for the younger adults and .07 for the older adults. Neither difference approached significance, p's > .4.

2.2. Priming in the on-line awareness condition

Next we examined whether there was an age effect in priming in the on-line awareness condition. Priming was calculated by subtracting the proportion of correct responses to test items with nonstudied solutions from the proportion of correct responses to test items with studied solutions. We first examined priming without regard to awareness (see all participants section of Table 2). Priming was significantly different from zero in all cells except for the stem completion test for older adults. Younger adults had significantly greater priming ($M = .12$) than older adults ($M = .05$), $t(62) = 2.96$, $SE = .02$ on the category production test. Younger adults also showed numerically more priming ($M = .09$) than older adults ($M = .04$) on the word-stem completion test, but this difference did not reach significance, $p = .13$. Collapsing across test type (category production and word-stem completion), there was a significant age effect in priming in the on-line awareness condition, (younger = .10, older = .04, $t(124) = 2.98$, $SE = .02$).

2.3. The relationship between awareness and priming in the on-line awareness condition

To examine the relationship between awareness and priming, we calculated the correlation between the magnitude of priming and the proportion of studied responses on which awareness was indicated. Collapsing across test type, results showed that the correlation between priming and on-line awareness was significant in the younger adults ($r = .43$, $n = 63$), but not in the older adults ($r = .19$, $n = 62$, $p = .34$). The difference between these two correlations approached significance, Fisher's $z = 1.85$, two-tailed $p = .06$.

We have shown that a greater number of younger participants were aware, that younger participants displayed more priming, and that younger adults displayed a stronger positive relationship between the amount of awareness and the magnitude of priming. From this, we might expect that the percentage of studied responses circled as aware by younger adults would be greater than that for older adults. Interestingly, when the number of aware items was examined as a proportion of the number of studied responses in those participants that had circled at least one studied response, younger and older adults showed similar levels of awareness. In word-stem completion, younger adults were aware for 41% of items, older

Table 2
Priming for younger and older adults in each awareness category for both types of implicit tests in the on-line awareness condition.

	Younger		Older	
	WSC	CP	WSC	CP
Zero OLA				
Priming	.03 (.19)	NA	.04 (.15)	.04 (.08)
Baseline	.16 (.11)	NA	.25 (.10)	.14 (.07)
At least one OLA				
Priming	.10 (.10)	.12 (.10)	.03 (.13)	.07 (.09)
Baseline	.21 (.08)	.19 (.06)	.25 (.10)	.18 (.08)
All participants				
Priming	.09 (.12)	.12 (.10)	.04 (.14)	.05 (.08)
Baseline	.20 (.09)	.19 (.06)	.25 (.10)	.16 (.07)

Note: WSC = word-stem completion; CP = category production. OLA = on-line awareness. Standard deviations are in parentheses.

adults were aware for 37% of items, and these means did not differ, $t < 1$. In category production, younger adults were aware for 65% of items, older adults were aware for 60% of items, and these means also did not differ, $t < 1$. Thus, it appears that, once the older adults recognized one item as having been studied, their level of awareness was very similar to that in younger adults.

In sum, the on-line awareness data show that, relative to older adults, younger adults showed higher levels of awareness, higher levels of priming, and a stronger relationship between the magnitude of priming and the magnitude of on-line awareness. Thus, it appears that awareness, as measured using this on-line method, could account for age differences in priming.

2.4. Post-test questionnaire awareness

First, we examined whether there were age or test differences in awareness using the post-test questionnaire. The number of participants in each awareness category, as a function of age and type of test, is displayed in the top half of Table 3. The most prominent feature of these data is that there was a difference between the stem completion and category production tests in the distribution of participants across the awareness categories. Participants were much less likely to be classified as intentionally retrieving following the stem completion test than after the category production test: only five participants were classified as intentional after stem completion, whereas 30 were so classified after category production. In complementary fashion, participants were much more likely to be classified as unaware following the stem completion test than after the category production test: 27 participants reported that they were unaware after stem completion, and only two reported that they were unaware after category production. Approximately the same number of participants reported that they were test aware after the two tests (32 vs. 30). A hierarchical log linear analysis of the three-way dependence of age, test type, and awareness classification verified a significant two-way dependence of test type and awareness, difference $G^2 = 45.49$. This analysis confirmed the fact that, on the word-stem completion test, participants were largely either test unaware or test aware, whereas on the category production test, participants were either test aware or intentionally retrieving. Almost no one was classified as test unaware on the category production test. The other prominent feature of these data is that it appeared that younger adults reported more test awareness than older adults. However this effect did not reach significance, $G^2 = 5.065$, $p = .079$.

Given the scaling differences in awareness type across the two tests (word-stem completion and category production), we attempted to "standardize" and simplify awareness classification across the two test conditions in order to better compare level of awareness across the two age populations. This approach consisted of defining the "median" amount of awareness in the perceptual test as the break between unaware and aware (collapsing across age, 27 participants had been classified as unaware and 32 as aware). In the conceptual test, the median amount of awareness was defined as the break between aware and intentional (collapsing across age, 30 participants had been classified as aware and 30 as intentional). Those below the median were classified as "less aware" and those above the median were classified as "more aware". The reclassification is presented at the bottom of Table 3. To instate this new classification in the word-stem completion condition, the awareness and intentional categories were collapsed into the "more aware" category. This resulted in five participants – 8% – originally classified as intentional being reclassified as "more aware". In the category production condition, the unaware and aware categories were collapsed into the "less aware category". This resulted in two participants – 3% – originally classified as unaware being reclassified as "less aware". This recategorization eliminated the problem that some of the cells in the full design had a very small number of participants (e.g., only one young participant and one old participant were classified as unaware in the category production condition).

Using this standardization and reclassification procedure, the clear pattern that emerges in Table 3 is that younger adults reported more awareness than older adults on the post-test questionnaire, thus replicating previous findings (e.g., Geraci, 2006). In word-stem completion, more of the younger adults were classified as more aware (23), while fewer of the younger adults were classified as less aware (9). However, the reverse was true for older adults (14 were classified as more aware and 18 as less aware). The pattern was similar, but much weaker, in the category production test condition: for the younger adults, 17 were classified as more aware and 15 as less aware, whereas 13 older adults were classified as more aware

Table 3
Number of participants in each awareness category as function of age and type of test for the post-test questionnaire condition.

	Younger		Older	
	WSC	CP	WSC	CP
Awareness category				
Unaware	9	1	18	1
Aware	20	14	12	16
Intentional	3	17	2	13
All participants	32	32	32	30
Reclassification				
Less aware	9	15	18	17
More aware	23	17	14	13
All participants	32	32	32	30

Note: WSC = word-stem completion; CP = category production. Standard deviations are in parentheses.

and 17 as less aware. A hierarchical log linear analysis of the three-way dependence of age, test type, and awareness classification yielded a significant two-way dependence of age and awareness, difference $G^2 = 4.57$, $p = .03$. Collapsing across type of test, 62.5% of younger adults were classified as more aware (37.5% as less aware), whereas only 43.5% of older adults were classified as more aware (56.5% as less aware). These results demonstrate that younger adults were more test aware than older adults, as measured by the post-test questionnaire. Although the three-way interaction was not statistically significant, the fact that younger adults were more test aware than older adults appeared to be especially true in the stem completion condition.

2.5. Post-test questionnaire priming

We also examined whether there was an age effect in priming in the post-test questionnaire condition. Results showed that there was no significant age effect in priming in the word-stem completion test (younger = .07, older = .04), $t(62) = 1.23$, $SE = .03$) or category production test (younger and older = .07), $t(62) < 1$). In addition, collapsing across test type showed no significant age difference in priming (younger = .07, older = .05), $t(124) < 1$. $p = .39$. Thus, we found a significant age effect in priming in the on-line awareness condition but not in the post-test questionnaire condition, despite the fact that there were age differences in awareness in both conditions.

We examined possible baseline performance differences between the young and older adults because such differences can sometimes undermine a straight-forward interpretation of age effects in priming. For example, on the word-stem completion test, older adults ($M = .24$) had significantly higher baselines than younger adults ($M = .19$), $t(124) = -3.07$, $SE = .02$, which could indicate that reduced priming for older adults was an artifact of older adults having higher baseline performance. However, this explanation could not account for the data from the category production test, where the younger adults ($M = .20$) had a significantly higher baseline performance than the older adults ($M = .16$), $t(124) = -3.01$, $SE = .01$, yet priming was equivalent across the two age groups. Thus, baseline differences between the younger and older adults did not appear to account for the priming results.

2.6. The relationship between awareness and priming in the post-test questionnaire condition

Next, we examined whether reports of awareness on the post-test questionnaire were related to priming levels for younger and older adults (see Table 4). Inspection of Table 4 shows that there was a clear relationship between priming and awareness classification for both younger and older adults in category production: priming was .10 for more aware younger adults, whereas it was .03 for less aware younger adults; priming was .10 for more aware older adults, whereas it was .04 for less aware older adults. A 2×2 (age $\times$ aware) ANOVA showed that there was a main effect of awareness on category production priming, $F(1, 58) = 7.07$, $MSE = .58$. This finding contrasted with the lack of an age effect in awareness and priming in category production, a point we return to in the general discussion.

Turning to stem completion priming, inspection of Table 4 shows that there was no relationship between priming and awareness classification for either the younger or the older adults: priming was .07 for both the less and more aware younger adults and was .04 for both the less and more aware older adults. Again, the fact that there was no relationship between stem completion priming and awareness contrasted with the fact that younger adults displayed a numerically greater amount of priming (although the advantage was not significant) and younger adults reported more awareness in the post-test questionnaire. Again, we return to this point in the general discussion.

2.7. Comparing on-line and post-test questionnaire awareness

To determine whether older adults experienced less awareness than younger adults at the time of test or whether they forgot their state of awareness while waiting for the questionnaire to be administered, we examined the number of younger

Table 4
Priming for younger and older adults as a function of level of awareness for both types of implicit test in the post-test questionnaire condition.

	Younger		Older	
	WSC	CP	WSC	CP
Less aware				
Priming	.07 (.09)	.03 (.11)	.04 (.11)	.04 (.11)
Baseline	.13 (.06)	.20 (.09)	.23 (.10)	.16 (.08)
More aware				
Priming	.07 (.08)	.10 (.11)	.04 (.13)	.10 (.07)
Baseline	.20 (.08)	.20 (.06)	.23 (.13)	.16 (.07)
All participants				
Priming	.07 (.08)	.07 (.11)	.04 (.12)	.07 (.10)
Baseline	.18 (.08)	.20 (.07)	.23 (.11)	.16 (.07)

Note: WSC = word-stem completion; CP = category production. Standard deviations are in parentheses.

and older adults reporting awareness on these two measures. Table 5 shows the awareness counts as a function of awareness measure, implicit test, age, and awareness classification. For purposes of this comparison, aware and intentional categories in the questionnaire condition were collapsed into a single aware category to parallel the nature of the classification in the on-line condition. Visual inspection of Table 5 revealed quite different patterns for the stem completion and category production conditions.

In the stem completion condition, as noted in the analyses above, younger adults were more aware than older adults. Most important, the nature of this age difference was remarkably similar across the on-line and questionnaire conditions, which is inconsistent with the notion that older adults report less awareness on standard post-test questionnaires than younger adults because they cannot recall their conscious states from the time of testing. Instead, this pattern of data indicated that older adults reported less awareness on standard post-test questionnaire than younger adults because they experienced less awareness at the time of testing.

In the category production condition, there was once again a remarkable similarity in the amount of awareness reported by younger adults in the on-line and questionnaire conditions. However, this was not the case for older adults. Older adults reported more awareness in the post-test questionnaire condition than in the on-line condition. Thus, it appeared that older adults were willing to describe themselves as aware in a post-test questionnaire even though they were relatively unable to accurately identify – in the on-line condition – the studied items that they had produced. Possible reasons for this finding are discussed in the General Discussion section. Regardless of the exact reason for this pattern of data in the category production condition, overall, the results indicated that older adults were not under-reporting the extent of their test awareness on post-test questionnaires because they were forgetting that they had been aware at the time of the implicit test.

2.8. Free recall

Lastly, we examined age effects in explicit memory. Results showed that there was an age effect on recall of both word-stem completion and category production items. Younger adults recalled more word stem items ($M = .10$, $SD = .08$) than older adults ($M = .05$, $SD = .05$), $F(1, 124) = 24.03$, $MSE = .01$, and they recalled more category production items ($M = .22$, $SD = .12$) than older adults ($M = .15$, $SD = .13$), $F(1, 124) = 24.03$, $MSE = 10.59$. Thus, we obtained the expected age effect in explicit memory.

3. General discussion

This study examined the influence of test awareness on age effects in priming. We used two methods for assessing test awareness: an on-line assessment and a post-test questionnaire. Results showed that in the on-line assessment condition, overall, younger adults showed greater priming than older adults, greater awareness than older adults, and a stronger relationship between awareness and priming than older adults. These results suggested that greater priming in younger adults is associated with greater test awareness in younger adults. In contrast, results from the post-test questionnaire condition showed equivalent priming for younger and older adults in both the category production and stem completion tests. Awareness likely led to increased priming for younger adults in the on-line condition, but not the post-test questionnaire condition, because participants in the on-line condition were test-informed. That is, in the on-line awareness condition, participants were told that there could be some items from the study session on the test and to circle those items if they recognized any of their responses as studied. In addition, the on-line awareness condition always followed the post-test questionnaire and so participants already had had some experience with the nature of implicit tests, which may have facilitated their ability to identify studied responses. Further, the use of intentional study instructions may have facilitated better explicit memory in the younger adults. Previous research has shown that younger adults display better recall and recognition memory performance after intentional study compared to incidental study, while older adults do not show any benefit of intentional study (e.g., Mitchell & Perlmutter, 1986).

Thus, the fact that we obtained an age effect in priming in the on-line awareness condition, but not in the post-test questionnaire condition, may be due to the fact that awareness levels were relatively high in the on-line awareness condition. Further, it appears that younger adults in this condition took advantage of their test awareness in a way that older adults did not, possibly by using explicit retrieval strategies to boost their performance. Indeed, it appeared that the relatively small

Table 5
Number of younger and older adults in each awareness category for both types of implicit tests in both awareness assessment conditions.

	Online				Questionnaire			
	WSC		CP		WSC		CP	
	Young	Old	Young	Old	Young	Old	Young	Old
Unaware	6	16	0	18	9	18	1	1
Aware	26	14	32	14	23	14	31	29

Note: In the post-test questionnaire condition, aware and intentionally retrieving participants were collapsed into a single aware category.

number of older adults that identified at least one response as having been studied may have been attributable to the relative inability of the older adults to initiate some kind of recollective processing during the on-line task.

In contrast, in the post-test questionnaire condition, the opportunity for awareness was much lower, particularly given all of the additional standard procedures we used to limit awareness, including using a cover story and using additional non-studied, "filler" items at test. With these procedures in place, we hoped to mimic the standard "best case scenario" in which the influences of test awareness would presumably be relatively low. To be clear, when awareness categories were compared across the questionnaire and on-line conditions (see Table 5), the number of participants in each cell was very similar, except for older adults in the category production condition, where there were actually more aware older adults in the questionnaire condition than in the on-line condition. We believe this is an artifact of the assessment methods themselves. In order to be categorized as "aware" in the on-line condition, a participant must accurately identify at least one instance of having responded with a studied word, a relative strict criterion for being classified as aware. In contrast, in the questionnaire method, a participant can be described as aware without having to identify a specific instance of having said a studied word, a relatively liberal criterion for being classified as aware. In many instances, participants in the questionnaire condition were unable to specify an instance of awareness when asked. In the present experiment, the last question on the awareness questionnaire asked participants to identify one of the responses they had made that they thought was a studied word. For younger adults, only five of the 23 aware participants in the stem completion test and only 16 of the 31 aware participants in the category production test were able to do so For older adults, only two of the 14 aware participants in the stem completion test and only 15 of 29 in the category production test could report an aware item. Thus, despite the relatively equivalent numbers of aware participants across the questionnaire and on-line conditions for both the younger and older age groups, it still seems fair to say that awareness, in general, was greater in the on-line condition than in the questionnaire condition, and that the greater incidence/degree of awareness in the on-line condition set the stage for meeting the preconditions necessary for observing age differences in priming. Taken together then, the on-line and post-test questionnaire results indicated that test awareness may have been a factor leading to or associated with age effects in priming when the potential of awareness was relatively high, as in the on-line awareness condition. When test awareness was relatively low, as in the post-test questionnaire condition, priming differences across younger and older adults did not appear.

Despite the fact that there was no age difference in priming in the post-test questionnaire condition, both younger and older adults did report some test awareness and, at least in the stem completion test, this awareness was greater in younger adults. This finding is noteworthy for two reasons. First, this pattern of data (showing greater awareness in younger adults relative to older adults) was similar to the pattern obtained in the on-line awareness condition. Given the same age-associated pattern of awareness across the two tests, this finding suggests that post-test questionnaires are probably fairly accurate measures of the degree of awareness that was present during testing. Moreover, this finding is important for understanding age effects in awareness, because it suggests that the lower reports of awareness from older adults, relative to younger adults, is not due to problems with retrospective accounts of awareness that could be exacerbated for older adults (such as increased forgetting of awareness states). Instead, our results show that older adults are also less aware at the time of testing than are younger adults.

Second, the finding that awareness levels differed for younger and older adults in the post-test questionnaire data, at least in the stem completion condition, is interesting in light of the fact that this awareness did not lead to or result from an age difference in priming. We have suggested that this pattern of data occurred because the overall level of awareness was relatively low in this condition. In neither the stem completion nor the category production tests were both the hypothesized preconditions met. In the stem completion condition, younger adults were more aware than older adults (one of the preconditions), but increases in awareness were not associated with increases in priming (the other precondition). In the category production test, the problem was just the reverse: increases in awareness were associated with increases in category production priming (one of the postulated preconditions), but the younger adults were not more aware than the older adults (the other postulated precondition). The absence of an awareness advantage for younger adults in the category production condition may have been due to a ceiling effect (i.e., nearly 100% of older adults were classified as aware; as a result, it was difficult for *more* younger adults to be aware). Again, it was only in the on-line condition that both preconditions were met – greater awareness in younger adults than older adults and an association between awareness and priming (with said association also greater in younger adults) – and age effects in priming were observed.

With regard to the post-test questionnaire condition, the association between awareness and priming was greater in category production than in stem completion. This finding was not surprising given the different processing demands of the two tests. The category production test is typically classified as a conceptual test, meaning that priming on this test is influenced by processing the meaning of the studied items, while the word-stem completion test is typically classified as a perceptual test, meaning that priming on this test is influenced by processing the perceptual or surface features of the studied items (see Roediger, 1990). Previous research shows a much stronger relationship between test awareness and conceptual, or deep, processing than between test awareness and perceptual, or shallow processing (e.g., Barnhardt & Geraci, 2008; Graf, Mandler, & Haden, 1982; Mace, 2003, 2005; Richardson-Klavehn, Gardiner, & Java, 1994; Toth, Reingold, & Jacoby, 1994). Thus, it appears that awareness is probably more highly associated with priming under conditions of conceptual processing, than under conditions of perceptual processing.

Certainly we have very strong evidence that under conditions where younger adults show more priming than older adults (the on-line awareness condition in the current study), younger adults are also more test aware than older adults. This finding provides support for the idea that awareness may mediate age effects in priming when they are obtained. Most research-

ers assume that awareness leads to increased priming via the following processes. Participants notice the study-test connection, which should be more likely for younger adults who have better explicit memory than older adults. Once participants become aware of the fact that some test items can be completed with studied items they, in turn, begin to treat the implicit test as an explicit one. Because younger adults are also better able to engage in explicit strategies to boost performance than older adults, they are better able to complete the implicit task with studied items than are older adults.

However, an alternate possibility is that awareness is associated with priming because younger adults are more likely to use test items to complete stems or category cues, and so they have more opportunities to become test aware. By this view, part of the phenomenon of priming might simply include some level of awareness (which could be conceived of as involuntary aware memory; Kinoshita, 2001; Richardson-Klavehn & Gardiner, 1995, 1996). This does not mean that people attempt to recall the past, but simply that good memory performance is associated with more explicit memory features.

Finally, the idea that explicit memory contributes to age effects in priming can accommodate some specific patterns in the literature. For example, one possible explanation for the previously reported dissociation between older adults' performance on production and identification implicit tests could be that younger adults may be more likely to use explicit strategies to perform production tests than identification tests (see Geraci (2006) for this hypothesis). Production tests are often less speeded than identification tests, which may allow for a greater opportunity for awareness to influence priming. The influence of awareness on this and other test dissociations awaits future testing. For now, though, the current data suggest that under some conditions, awareness may contribute to age effects in priming, which may help explain why age effects in priming are only sometimes obtained.

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