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Mistaking the Recent Past for the Present: False Seeing by Older Adults

Larry L. Jacoby, Chad S. Rogers, Anthony J. Bishara, and Yujiro Shimizu
Washington University in St. Louis

Results of three experiments revealed that older, as compared to young, adults are more reliant on context when "seeing" a briefly flashed word that was preceded by a prime. In a congruent condition, the prime was the same word as flashed (e.g., DIRT dirt) whereas in an incongruent condition, the prime differed in a single letter from the word that was flashed (DART dirt). Following their attempt to identify the flashed word, participants were asked to report whether they had "seen" the flashed word or, instead, had responded on some other basis (knowing or guessing). Older adults showed dramatically higher false seeing by reporting the prime on incongruent trials and claiming to have seen it flashed. This was true even though a titration procedure was used to equate the performance of young and older adults on baseline trials which did not provide a biasing context. Results of Experiment 3 related age differences in false seeing to willingness to respond when given the option to withhold responses. Convergence of results with those showing higher false memory and false hearing are interpreted as evidence that older adults are less able to avoid misleading effects of context. That lessened ability may be associated with decline in frontal lobe functioning.

Keywords: metacognition, aging, vision, context effects, priming, subjective experience, perception, illusions

A basic tenet of the "New Look" movement in perception (e.g., Balcetis & Dunning, 2010; Bruner, 1957) is that the contents of perception do not depend on characteristics of the visual stimulus alone. Rather, expectations that reflect prior experience, needs, values, and other factors that influence the accessibility of an interpretation of a stimulus are as if not more important than are characteristics of the physical stimulus itself. To support this claim, it was demonstrated that incongruity between expectations and a presented stimulus can produce perceptual illusions in people's subjective reports of "seeing" (e.g., Bruner & Postman, 1949). Bartlett's (1932) classic work, which emphasized the power of schemata, also gave an important role to prior knowledge as a source of errors in perception. People sometimes fail to see what actually occurred and instead falsely "see" what was expected.

Illusions produced by expectations are not inevitable. Bruner and Postman (1949, p. 208) stated that "most people come to depend upon a certain constancy in their environment and, save special conditions, attempt to ward off variations from this state of affairs." As implied by the word "most" in the preceding quote, there were individual differences in the extent to which participants were misled by false expectations, suggesting that some rely more heavily on expectations than do others. In this article, we investigate the possibility that expectations produced by recent prior experience are more likely to result in false seeing by older, as compared to young, adults.

To count as an illusion, it is necessary that one have the mistaken subjective experience of "seeing" an expected stimulus. False identification of a stimulus as being an expected stimulus would not count as an illusion if accompanied by the subjective experience of "guessing." We define false seeing as erroneously claiming to have seen an expected but not presented visual stimulus. Older adults might be more prone to such false seeing than are young adults because of their increased reliance on context. Older adults are more reliant on context when reading than are young adults (e.g., Speranza, Daneman, & Schneider, 2000), which is likely to make them more prone to errors in the form of false seeing when context is misleading. Further, Rogers, Jacoby, and Sommers (in press . . .) provided evidence to show that misleading context is much more likely to produce false hearing for older adults than for young adults. Older adults are also more likely to falsely "remember" by mistaking an easily accessible recent memory as being memory for a more distant event (e.g., Jacoby, Bishara, Hessels, & Toth, 2005). As will be described in the General Discussion, there are potentially important parallels between vulnerability to false seeing and vulnerability to false remembering and false hearing. All reflect older adults' greater reliance on expectations as a basis for subjective experience.

The experiments reported here used a priming procedure to examine age differences in false seeing. Figure 1 illustrates the procedure for conditions used in Experiment 1 in which a prime word was presented prior to the brief presentation of the target word (e.g., dirt) with the target word being preceded and followed by a visual mask. For a congruent condition (Figure 1a), the prime

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Larry L. Jacoby, Chad S. Rogers, Anthony J. Bishara, and Yujiro Shimizu, Department of Psychology, Washington University in St. Louis.

Anthony J. Bishara is now at Department of Psychology, College of Charleston. Yujiro Shimizu is now at Department of Psychology, American River College. Chad S. Rogers is now at the Volen National Center for Complex Systems, Brandeis University.

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Correspondence concerning this article should be addressed to Larry L. Jacoby, Department of Psychology, Washington University, One Brookings Drive, St. Louis, MO 63130. E-mail: lljacoby@artsci.wustl.edu

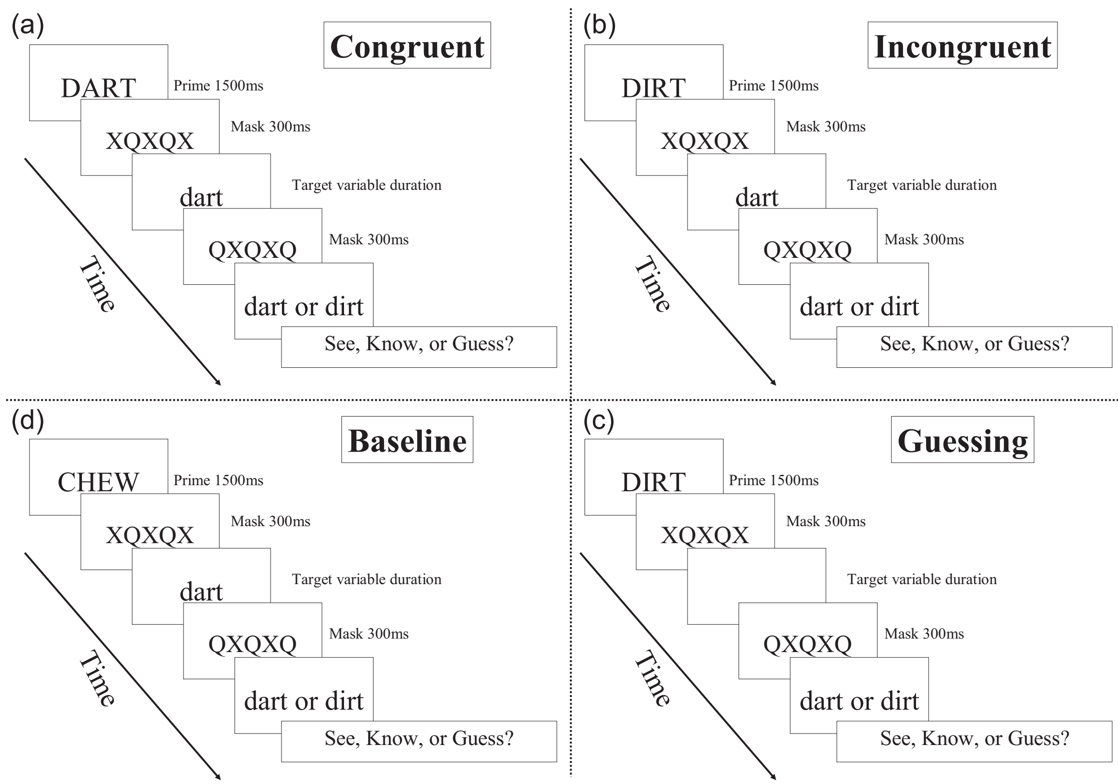

Figure 1. Procedure schematic of the four different trial types in Experiment 1. In the congruent (a) condition, the prime and target word were identical. In the incongruent (b) condition, the prime and target word differed by one interior letter. In the guessing (c) condition, no word was flashed during the target duration. In the baseline (d) condition, the prime and target words did not contain any of the same letters.

word was identical to the target except for the letter case (DIRT dirt), whereas for an incongruent condition (Figure 1b), the incongruent prime differed from the target in a single letter (DART dirt). For a baseline condition, the prime word was unrelated to the target word (e.g., CHEW dirt). A "Guess" condition was the same as the other three conditions except a blank interval replaced the presentation of the target word. That is, a target word was not presented. These conditions were manipulated within-participants such that participants were unable to predict the relation between the prime and target or whether a target would be flashed. Instructions warned participants that the prime word would sometimes be misleading and other times would be unrelated to the flashed word. A forced-choice test included the target word along with the word that served as the prime in the incongruent-prime condition (e.g., dart dirt) for each of the conditions. Participants were instructed to choose the word that was flashed and then report on their subjective experience. They were to say "saw" if they were certain that they saw the selected word when flashed. If they believed the word they selected had been flashed but did not clearly see it, they were to say "know." Finally, if their selection of a word was a guess, they were to say "guess." False seeing was defined as choosing the prime in the incongruent condition or the guess condition and claiming to have seen it flashed.

Older adults might generally rely more heavily on expectations than do young adults because of poorer vision. To show that differences in vision are not the sole basis for age differences in false seeing, a titration procedure was used to equate young and older adults' performance in the baseline conditions. Use of that procedure resulted in flash durations that were generally longer for older than for young adults. For both young and older adults, words were flashed for either the duration determined by the titration procedure (short duration) or for a longer duration (14 ms longer for young adults and 28 ms longer for older adults) to further ensure the presence of comparisons for which young and older adults did not differ in their baseline performance. Only the short duration was used for guess trials because the longer duration made it obvious that nothing was flashed. Given equal performance on baseline items or an advantage for older adults, it can be concluded that any age differences in effects of congruent and incongruent primes on seeing cannot be fully because of differences in vision but, rather, reflect age-related differences in reliance on expectations produced by the prime. A finding of greater false seeing by older adults on guess trials, for which nothing was flashed, would also provide evidence of age-related differences in reliance on expectations that could not be owed to differences in visual processing of the target word. Another potential concern is that older adults might be slower than are young adults to finish their processing of the prime prior to presentation of the flashed word. To guard against effects of such slowing, presentation parameters allowed ample time for processing the prime.

Our primary interest was in age differences in false seeing. Because of their greater reliance on expectations, older adults were expected to more often report actually seeing the word that was expected (the prime) in the incongruent condition than were young adults, and they were to also be more likely to falsely see the prime in the guess condition. Such age differences in false seeing would be important for purposes of theory as well as being potentially important for applied purposes. As an example of the latter, false seeing that results from misleading expectations when driving can have deadly consequences. One's subjective experience of seeing can be important as a guide for action.

In contrast to our emphasis on subjective experience, tests of vision typically focus on accuracy of responding without questioning subjective experience. However, in other domains, differences in reports of subjective experience have been found in the absence of differences in accuracy, and even when differences in accuracy were in the opposite direction of those of subjective experience (e.g., Jacoby, Bishara, et al., 2005; Koriat & Goldsmith, 1996; Rogers et al., submitted). Consequently, we expected to find age differences in false seeing even when there were no age differences in accuracy. To conclude that such age differences result from older adults who rely more heavily on expectations produced by the prime than do young adults, it must be shown that older adults are not just generally more willing to claim to "see" than are young adults. The baseline condition, with its absence of overlap in letters between the prime and flashed word, was expected to discourage reliance on expectations produced by the prime and, therefore, produce equally little false seeing by older and young adults. That is, we expected age differences in "seeing" to be selective rather than general across conditions as it would be if older adults were just generally more willing to say "see."

The procedure for Experiment 2 was the same as described for Experiment 1 except that the test was changed. Rather than using a forced-choice test, as done in Experiment 1, a fragment-completion test was used. This change was made to ensure that age-related differences in false seeing were not restricted to the forced-choice procedure. Experiment 3 did not require subjective reports but, rather, examined age differences in responding when participants were given the option to withhold responses (cf., Koriat & Goldsmith, 1996). Comparing age differences in the probability of withholding responses in that experiment with results from the earlier experiments provides support for the suggestion that subjective experience guides action.

Experiment 1

Method

Participants. Twenty-eight young adults, ranging in age from 18 to 25 years ($M = 19.54$, $SD = 1.40$), from the Washington University in St. Louis undergraduate pool volunteered to participate for course credit or \$10. Twenty-eight older adults were recruited through the Washington University older adult subject pool. They ranged in age from 65 to 86 years ($M = 75.04$, $SD = 6.00$) and were paid \$10 for participating in the experiment. The mean score on the Vocabulary subtest of the Shipley Institute of Living Scale (Shipley, 1967) was lower for young participants ($M = 33.64$, $SD = 2.18$) than for older participants ($M = 35.25$, $SD = 2.50$), $t(54) = 2.57$, $p < .05$. Age groups had similar years of education (young $M = 13.11$, older $M = 13.32$), $t < 1$, *ns*. All were tested individually.

Materials and design. Materials comprised a pool of 140 pairs of similar words (e.g., dart dirt). The words in each pair differed by only one letter. Each pair was matched to a word with the same number of letters but mostly dissimilar shape (e.g., dart dirt, chew) for use in the baseline condition. Baseline words did not contain the critical letters that differentiated the corresponding word pairs ("a" and "i" in the above example). Further, baseline words did not share a letter in the same position with words in their corresponding pair and shared no more than one letter in a different position. These stimuli were divided into seven sets of 20 triplets each, which were rotated through the test conditions. All response words occurred equally often as the target response. This setup resulted in 14 different formats for a full rotation of the material through conditions (2 solutions $\times$ 7 combinations of duration and item type). Targets and alternatives within each cell were equated for word frequency and balanced for word length ($M = 4.8$ letters). Eight additional triplets were used for practice.

Figure 1 depicts the procedure for the 140-item, forced-choice test, which entailed presentation of an uppercase prime, a briefly flashed target in lowercase, and then a lowercase word pair (the target word and its alternate) presented side by side. The trial types (congruent, incongruent, baseline, and guessing) refer to the relationship between the target and flashed word. The prime was the same as the flashed target (congruent condition), the alternate answer choice (incongruent condition), or a dissimilar word that was not offered as an answer choice (baseline condition). Finally, for a guessing condition, one of the answer choices was primed but a blank screen was flashed. There were two flash durations for all trial types except guessing trials. Guessing trials only occurred with a short flash duration, resulting in seven total combinations with 20 items in each. The test list was arranged such that the target word appeared equally often as the left-hand member and right-hand member of the answer choices.

An example and a seven-item practice test preceded the main phase of the experiment with there being one practice item for each of the test conditions. Order of presentation at test was random with the restriction that not more than three items that represent the same condition were presented in a row, and all conditions were presented evenly throughout the list. The same item order was used for all participants.

Procedure. Words were presented and responses were collected on an IBM compatible computer with a VGA color monitor, using micro experimental laboratory (MEL) software (Schneider, 1988). Words were in white letters (approximately 5×8 mm in size) on a black background in the center of the screen.

Participants were told that they would alternate between reading uppercase words aloud and identifying briefly flashed lowercase words. Each trial started with an uppercase prime that participants were to read aloud. Then a masked lowercase word appeared and then two answer choices. If participants could identify the briefly flashed word, they were to choose it from these two words. If not, they were to guess which word was briefly flashed. Trials consisted of the following sequence of events: (a) presentation of uppercase prime for 500 ms; (b) a blank screen presented for 1,000 ms; (c) a premask (XQXQXQXQX) for 300 ms; (d) a flashed lowercase word or blank screen presented for a short or long duration (durations were chosen using a titration procedure described below); (e) an interstimulus interval (ISI) of 14 ms of blank screen; (f) presentation of a postmask (*QXQXQXQXQ*) for 300 ms; (g) an ISI of 500 ms of blank screen; (h) presentation of the pair of words until the participant gave a response at which time the screen cleared and the next trial started; and (i) presentation of subjective report choices "saw, know, or guess." Participants gave responses aloud. The experimenter keyed in both the participants' responses (word and subjective report) as they were said. After an intertrial interval (ITI) of 750 ms, the next trial occurred.

An example of the procedure (using the pair dart–dirt) was presented with the lowercase word flashed at a fairly long rate (500 ms and 800 ms for younger and older adults, respectively) to allow the participant to see the flashed word before the word pair was presented. It was explained to participants that the uppercase word could be the same as the lowercase flashed word (congruent condition), a similar word (incongruent condition), or a dissimilar word (baseline condition). They were not informed of the guessing condition. Participants were instructed to say "saw" if they saw the whole lowercase word or if they saw a portion of the word that allowed them to be certain of their response. Using the dart–dirt example, they were told that if they saw that the lowercase word started with "da" and they gave "dart" as their response, they should say "saw." "Know" was to be used when participants felt they knew what the flashed word was even though they did not see it. For example, if the word "popped in their head" before the two choices came onto the screen, then they were told that they should say "know." "Guess" was to be used when they had absolutely no idea what the flashed word was and were purely guessing. After the example, seven practice trials were presented, one from each condition. Following the practice session, participants were asked to summarize all instructions to ensure that they understood.

A titration procedure preceded the perception task. It consisted of seven blocks with a variable flash duration. The first block consisted of six trials, the next two blocks consisted of five trials each, and the next four blocks consisted of 10 trials each for a total of 56 trials. The trials were the same as described above except that the prime was always a string of plus signs. The plus signs were described to participants as a warning signal. The durations were adjusted at the end of each block by the experimenter with the goal of finding the flash duration at which participants correctly responded on 60% of the trials. This duration was used as the short duration for the perception task. The long duration was 14 ms longer than the short duration for young adults and 28 ms longer for older adults. The average short duration used for young adults ($M = 17.50$, $SD = 6.17$) was shorter than for older participants ($M = 89.43$, $SD = 36.84$), $t(54) = 10.19$, $p < .001$.

Results and Discussion

The dependent measures of interest were correct identification of targets (hit rates), the joint probability of a hit combined with a subjective "saw" judgment (correct seeing), and the joint probability of a false alarm combined with a subjective "saw" judgment (false seeing). Our primary interest was in age differences in false seeing. Correct seeing could not be observed on guessing trials, as only a blank screen was flashed after the prime word. False seeing, however, could be observed on congruent, baseline, incongruent, and guessing trials. Because guessing trials only occurred at the short duration, they were analyzed separately from the other conditions.[1] We did not observe any age differences in hit rates on baseline trials at either the short or long durations, and therefore reporting of results in Experiment 1 is collapsed across short and long durations.[2] Unless otherwise specified, we report only effects that were found to be significant at $\alpha < .05$ significance level and that were not involved in a higher order interaction.

Hit rate. The hit rates, collapsed across duration, are shown in the leftmost columns of Table 1. Older adults were equally likely as young adults to correctly identify the briefly flashed word on baseline trials. This result serves as a manipulation check for the titration procedure, and it ensures that age group differences in reliance on the prime were not due to age-related changes in visual acuity. Older adults relied heavily on the prime, which led to facilitation on congruent trials and interference on incongruent trials relative to baseline. In contrast, rather than relying on the prime, young adults *reacted against* the prime, leading to lower performance on congruent trials relative to baseline trials along with a lack of difference between performance on incongruent and baseline trials.

The statistical reliability of these findings was confirmed by a 2 (age: young, old) × 3 (trial type: congruent, baseline, incongruent) mixed-model analysis of variance (ANOVA) on mean hit rates which revealed a significant Age × Trial Type interaction, $F(2, 108) = 30.80$, $MSE = 2.06$, $p < .001$, $\eta_p^2 = .37$. Post hoc F tests revealed that older adults had greater hits than young adults on congruent trials, $F(1, 54) = 50.68$, $p < .001$, $\eta_p^2 = .36$; fewer hits than young adults on incongruent trials, $F(1, 54) = 7.67$, $p < .01$, $\eta_p^2 = .12$; and equivalent hits to young adults on baseline trials, $F(1, 54) = 1.39$, $p < .25$, *ns*.

Correct seeing. We refer to the joint probability of a correct response and a subjective "saw" judgment as "correct seeing." The middle columns of Table 1 show that young adults had less correct seeing than older adults on congruent trials, indicating greater reliance on the prime by older adults for the subjective experience of seeing. Despite young adults' greater incongruent hit rate, younger adults reported less correct seeing in the incongruent condition than did older adults. Their doing so might have resulted from their reactance against the prime leading them to be more reluctant to provide a "saw" response. Notably, age group differences were largest on congruent trials, leading to a significant Age × Trial Type interaction, $F(2, 108) = 16.48$, $MSE = 1.14$, $p < .001$, $\eta_p^2 = .23$. The greater correct seeing by older adults on congruent trials reflects their greater reliance on the prime and might also, in part, reflect young adults' reactance against the prime. Age group differences on baseline trials only approached

[1] Congruent and incongruent priming effects were frequently not symmetrical around baseline trials. For most analyses involving trial type, the assumption of sphericity of the data was violated. When Mauchly's test of sphericity was significant, we compared p values to those using the Greenhouse–Geyser correction. Hypothesis testing yielded the same conclusion in all cases, and so we report the uncorrected statistics. The same was true when Levene's test for equality of variances was significant for t tests, and so we report the uncorrected degrees of freedom as well.

[2] Hit rates were greater at the long duration than at the short duration, as a 2 (age: young, old) × 2 (duration: short, long) × 3 (trial type: congruent, baseline, incongruent) mixed-model analysis of variance on mean hit rates revealed a significant main effect of duration. However, no higher order interactions involving duration were found to be significant.

Table 1
Hit, Correct-Seeing, and False-Seeing Rates in Experiment 1, Collapsed Across Duration

	Hit rate		Correct seeing		False seeing	
Experiment 1	*M*	*SE*	*M*	*SE*	*M*	*SE*
Congruent						
Young	0.62	0.04	0.20	0.04	0.03	0.02
Older	0.90	0.02	0.63	0.05	0.02	0.01
Baseline						
Young	0.76	0.03	0.35	0.04	0.02	0.01
Older	0.80	0.03	0.47	0.06	0.02	0.01
Incongruent						
Young	0.73	0.03	0.28	0.04	0.04	0.01
Older	0.58	0.05	0.43	0.05	0.23	0.05
Guessing (Short duration only)						
Young	0.35[a]	0.03	—[b]	—[b]	0.00	0.00
Older	0.73[a]	0.05	—[b]	—[b]	0.20	0.06

[a] denotes probability of providing the primed response. [b] denotes correct seeing cannot occur on guessing trials.

significance, $F(1, 54) = 3.60$, $p < .07$, $\eta_p^2 = .06$, as revealed by a post hoc *F* test. That difference might reflect the slight, not significant, advantage in hit rates for older as compared to young adults.

False seeing. The rightmost columns of Table 1 show that false seeing in older adults occurred at a rate of 23%, over five times more often than in young adults (4%). This finding shows that older adults' reliance on expectations produced by the prime led to illusory visual perception. It is important that on baseline trials, as well as congruent trials, false seeing was low and near identical for older and young adults. Those results provide evidence that older adults were not just generally more willing to say they "saw" the flashed word but, rather, their greater false seeing was selective to misleading expectations produced by the incongruent prime. The Age × Trial Type interaction was significant, $F(2, 108) = 16.62$, $MSE = 0.36$, $p < .01$, $\eta_p^2 = .24$. Post hoc analyses revealed that age group differences were not significant on congruent or baseline trials, $F\text{s} < 1$, *ns*, but were significant on incongruent trials, $F(1, 54) = 16.13$, $p < .001$, $\eta_p^2 = .23$.

Guessing trials. Recall that participants were instructed to provide a "saw" response only if they saw the flashed word or any portion of the flashed word that allowed them to be certain that their identification of the word was correct. Even when incorrect in the incongruent condition, older adults may have seen portions of flashed words that overlapped with the target word and relied on sensory information underlying that partial identification as a basis for their false seeing on incongruent trials. In contrast, a word was not flashed on guessing trials and, so, a "saw" judgment could not be based on sensory processing of the target. Results from performance on guessing trials produced strong evidence of age differences in reliance on the prime. As shown in Table 1, older adults were much more reliant on expectations produced by the prime than were young adults, as revealed by the greater likelihood of their choosing the primed response on guess trials, $t(54) = 6.56$, $p < .001$. Again, young adults reacted against the prime, as evidenced by their choosing the primed word with a probability that was significantly below chance when tested by a one-sample *t* test against a value of .50, $t(27) = 4.39$, $p < .001$.

More striking, the older adults falsely reported that they saw the prime word flashed on 20% of the guess trials, whereas the young adults never did so, showing a large age difference in false seeing, $t(54) = 3.49$, $p < .01$. This result provides strong evidence that age differences in false seeing can reflect differences in reliance on expectations rather than resulting from age differences in visual acuity alone. Most commonly, young adults chose the word that was not primed and gave a guess response (young $M = .58$, older $M = .25$), $t(54) = 5.82$, $p < .001$.

Experiment 2

Results of Experiment 1 revealed that older adults relied more heavily on expectations originating from a prime than did young adults, as shown by effects on both the accuracy of responding and differences in false seeing. However, age differences in reliance on the prime might, in part, reflect young adults' being more likely to respond against the prime so as to avoid being deceived. The forced-choice procedure used in Experiment 1 encourages such reactivity by presenting an alternative that differs from the flashed word by only a single letter, making obvious the possibility of being misled by the prime and providing a readily accessible alternative response. In Experiment 2, we sought to generalize our findings from Experiment 1 by using a fragment-completion identification procedure. We hypothesized that young adults would be less inclined to react against the prime in that task because the primed word itself and its alternative would not be presented on the screen during the test of word identification. If the change in procedure greatly reduced the reactance of young adults, it should be found that young adults show the same pattern of hits across conditions as do older adults. For both, the ordering of conditions with regard to the probability of a hit should be: congruent trials, baseline trials, and incongruent trials.

Method

Participants. Participants were recruited from the same pools as in Experiment 1. Twenty-eight young adults ranged in age from

18 to 23 years ($M = 19.64$, $SD = 1.62$). The 28 older adults ranged in age from 65 to 87 years ($M = 75.68$, $SD = 5.38$). Shipley vocabulary scores (Shipley, 1967) were similar for young ($M = 33.36$, $SD = 2.50$) and older participants ($M = 34.46$, $SD = 2.70$), $t(54) = 1.58$, *ns*. Age groups had similar years of education (young $M = 13.71$, older $M = 13.25$), $t(54) = 1.05$, *ns*.

Materials, design, and procedure. The materials, design, and procedure used for Experiment 2 were the same as for Experiment 1, except that during the identification test and titration phase, a lowercase word fragment was presented with one letter missing. The fragment could be completed with either the target or its alternative, which was flashed as a prime in the incongruent condition (e.g., d–rt; dart, dirt). The durations that produced performance that was best matched for older and young adults on baseline trials were the short durations for young adults and longer durations for older adults (young $M = 26.14$ ms, older $M = 99.11$ ms).

Results and Discussion

In Experiment 2, young adults had significantly higher baseline hit rates than older adults at both the short duration (young $M = 0.74$, older $M = 0.66$), $t(54) = 2.03$, $p < .05$, and long duration, (young $M = 0.86$, older $M = 0.77$), $t(54) = 2.93$, $p < .01$. Those results show that use of the titration procedure was not fully successful. However, baseline performance for young adults at the short duration nearly matched that of older adults at the long duration (young $M = 0.74$, older $M = 0.77$), $t < 1$, *ns*. Thus, to investigate age-group differences in correct and false seeing that were not attributable to age-group differences in visual acuity, we compared young adults' performance at the short duration with older adults' performance at the long duration. Results from the remaining conditions (young, long duration; older adults, short duration) did not provide additional information that is useful for current purposes and, therefore, will not be reported.

Hit rates. As expected, the change in testing procedures reduced the reactivity shown by younger adults. Young participants reacted against the primed response in Experiment 1 as shown by their probability of a hit being larger for incongruent trials than for congruent trials, whereas the opposite was true for older adults. In contrast, in Experiment 2, the probability of a hit was larger on congruent trials than on incongruent trials for both young and older adults. An advantage of older adults in hits on congruent trials remained, but that advantage was much smaller than observed in Experiment 1. For incongruent trials, the probability of a hit was slightly higher for older than for young adults, whereas in Experiment 1, the probability of a hit on incongruent trials was much higher for young than for older adults.

A 2 (age: young, old) × 3 (trial type: congruent, baseline, incongruent) mixed-model ANOVA revealed significant effects of trial type, $F(2, 108) = 86.68$, $MSE = 2.64$, $p < .001$, $\eta_p^2 = .62$, and age, $F(1, 54) = 4.32$, $MSE = 0.14$, $p < .05$, $\eta_p^2 = .07$. Though not qualified by a significant Age × Trial Type interaction, $F < 1$, *ns*, post hoc F tests revealed a significant effect of age on congruent trials, $F(1, 54) = 8.08$, $p < .01$. Age differences were not significant on baseline or incongruent trials, Fs < 1, *ns*.

Correct seeing. As shown in the middle column of Table 2, the probability of correct seeing was higher for older adults on both congruent and incongruent trials. A 2 (age: young, old) × 3 (trial type: congruent, baseline, incongruent) mixed-model ANOVA on rates of correct seeing revealed a significant Age × Trial Type interaction, $F(2, 108) = 6.63$, $MSE = 0.30$, $p < .01$, $\eta_p^2 = .11$, with post hoc tests showing significant age group differences on congruent, $F(1, 54) = 19.14$, $p < .001$, and incongruent trials, $F(1, 54) = 8.31$, $p < .01$, but not baseline trials $F(1, 54) = 1.52$, $p < .23$.

The advantage of older adults in correct seeing on incongruent trials remained despite the change in testing procedure. Had the reactivity of young adults been fully eliminated, one would expect no difference in correct seeing for older and young adults because correct seeing on incongruent trials necessarily depends on visual processing of the flashed word. The advantage of older adults in correct seeing suggests that young adults were less willing to respond "saw" to primed items because of the possibility of being

Table 2
Hit, Correct Seeing, and False-Seeing Rates in Experiment 2, With Age-Matched Durations (i.e., Young-Short vs. Old-Long)

Experiment 2	Hit rate		Correct seeing		False seeing	
	M	*SE*	*M*	*SE*	*M*	*SE*
Congruent						
Young	0.82	0.03	0.31	0.06	0.01	0.00
Older	0.93	0.02	0.67	0.06	0.01	0.01
Baseline						
Young	0.74	0.03	0.34	0.04	0.03	0.01
Older	0.77	0.03	0.43	0.06	0.02	0.01
Incongruent						
Young	0.43	0.04	0.19	0.03	0.13	0.04
Older	0.48	0.05	0.35	0.05	0.27	0.05
Guessing (Short duration only)						
Young	0.78[a]	0.04	—[b]	—[b]	0.02	0.02
Older	0.84[a]	0.03	—[b]	—[b]	0.25	0.07

[a] denotes probability of providing the primed response. [b] denotes correct seeing cannot occur on guessing trials.

misled by the prime. Results of Experiment 3 provide support for this possibility.

False seeing. Older adults exhibited greater false seeing than did young adults on incongruent trials (rightmost columns of Table 2). Rates of false seeing were very low and near identical for older and young adults in the baseline and congruent conditions. The Trial Type × Age interaction was significant, $F(2, 108) = 5.88$, $MSE = 0.95$, $p < .01$, $\eta_p^2 = .10$. Post hoc F tests revealed significant age group differences in the incongruent condition, $F(1, 54) = 5.42$, $p < .05$, $\eta_p^2 = .09$, but they did not reveal age differences in the other conditions. Replicating the results of Experiment 1, the lack of age differences in false seeing on baseline trials provides evidence that older adults were not just generally more willing to say they saw the flashed word but, rather, their greater false seeing was selective to misleading expectations produced by the incongruent prime.

Guessing trials. For guessing trials, reduced reactivity was evidenced by the finding that the probability of producing the primed word as a completion did not significantly differ for older and young adults (older $M = 0.84$, young $M = 0.78$), $t(54) = 1.20$, *ns*. In Experiment 1, that probability was much lower for young adults and significantly below chance. However, as in Experiment 1, older adults produced a much higher probability of false seeing than did young adults. Older adults showed false seeing on 25% of guessing trials, but young adults almost never did so (young $M = 0.02$), $t(54) = 3.39$, $p < .01$. Instead, young adults were more likely than older adults to report the primed word as a "guess" (young $M = 0.64$, older $M = 0.43$), $t(54) = 2.57$, $p < .05$.

Experiment 3

Results of Experiment 2 agreed with those from Experiment 1 in showing that older adults were more reliant on expectations gained from the prime than were young adults. In both experiments, the rate of false seeing was much higher for older than for young adults, both on incongruent trials and on guessing trials. Differences in results across the experiments provide evidence that the fragment-completion method of testing reduced the reactivity of young adults but, perhaps, did not eliminate the reluctance of young adults to report seeing the flashed word on primed (congruent and incongruent) trials.

In Experiment 3, we used the fragment-completion testing procedure and included the same conditions as did Experiment 2 but did not directly ask for reports of subjective experience. Instead, age differences in subjective experience were measured by examining participants' willingness to respond when given the option to withhold responses. For one block of trials (forced report), responding was forced in that participants were instructed to complete all fragments on test trials. They were told to complete each fragment with the flashed word if they saw it and, otherwise, to complete the fragment with their guess about the identity of the flashed word. For a second block of trials (free report), participants were instructed to give a completion only if they were certain that they saw the flashed word. Otherwise, they were instructed to say "pass." The manipulation of free versus forced report was expected to yield information about the effects of subjective experience on willingness to respond (cf., Koriat & Goldsmith, 1996).

We expected results for hits in the forced-report condition to be comparable to those found in Experiment 2 by showing a small advantage of older adults on congruent trials along with no age differences in performance on baseline trials. Further, we predicted that age differences in the probability of a "pass" response in the free-report condition would provide further evidence of older adults relying more heavily on the prime than did young adults. Older adults were expected to say "pass" less often on congruent and incongruent trials than did young adults. We also predicted that age differences in the probability of a hit in the free-report condition would be comparable to those in correct seeing in Experiment 2. Participants were instructed to produce a completion only when certain the flashed word was seen in Experiment 3. This was expected to have effects that were largely equivalent to the effects in Experiment 2 of instructions to produce the flashed word and say "saw" if the flashed word was seen. Finally, age differences in the probability of producing the primed word as a false alarm in the free-report condition were expected to parallel effects on false seeing found in Experiment 2. If participants followed instructions, the prime word should be given as a completion on incongruent and guess trials only if participants falsely saw the prime as having been flashed. We predicted that such false alarms would occur more often for older adults just as did false seeing in the earlier experiments.

Aside from the manipulation of free-versus-forced responding replacing subjective reports, the only other change between Experiments 2 and 3 was that flash duration was not varied within participants in Experiment 3, whereas it was in Experiment 2. Use of a single flash duration for each participant allowed a larger number of observations per condition. As in earlier experiments, a titration procedure was used to equate performance of older and young adults on baseline trials in the forced-report condition.

Comparing results across forced- versus free-responding conditions provides a further measure of the generality of the finding of greater false seeing by older adults across testing conditions. Also, comparisons of results from the free-responding condition in Experiment 3 with the subjective reports of seeing gained in Experiment 2 allows one to examine the relation between subjective reports of seeing and the action of responding on the basis of seeing.

Method

Participants. Sixteen young adults from the Washington University in St. Louis undergraduate pool volunteered to participate for course credit or $10. These young participants ranged in age from 18 to 22 years ($M = 19.50$, $SD = 1.26$). Sixteen older adults were recruited through the Washington University older adult subject pool. Older participants ranged in age from 65 to 83 years ($M = 76.00$, $SD = 4.65$), and were paid $10 for participating. The mean score on the Vocabulary subtest of the Shipley Institute of Living Scale (Shipley, 1967) for young participants ($M = 33.36$, $SD = 2.50$) was similar to that of older participants ($M = 34.46$, $SD = 2.70$), $t(30) < 1$, *ns*. All participants were tested individually.

Materials and design. The materials used in Experiment 3 were the same as those used in Experiments 1 and 2 except that the total list of items was expanded to 160 items so as to increase the number of observations per condition. These stimuli were divided into two sets of 80 triplets each, which were rotated through the two response options (forced vs. free). Each of these sets was further divided into four sets of 20 words each, which were rotated through the test conditions: congruent, incongruent, baseline, and guessing. All response words occurred equally often as the target response. This resulted in 16 different formats for a full rotation of the material through conditions (2 solutions $\times$ 2 free vs. forced block $\times$ 4 item types). Cells were balanced for word length (M = 4.9 letters). Eight additional triplets were used for practice.

Procedure. The procedure used in Experiment 3 was the same as that used in the fragment-completion procedure in Experiment 2 except for one critical change: each participant completed two blocks of the task (free report vs. forced report). During the forced report block, participants were instructed to complete the fragment with the lowercase word that they saw. If they did not see the flashed word, they were to complete the fragment by guessing its identity. During the free-report block, participants were instructed to give a completion only if they were certain they saw the briefly flashed lowercase word. Otherwise, they were instructed to say "pass." After an example, four practice trials were given at the beginning of each block, one for each of the four conditions. Following the practice trials, participants were asked to summarize all instructions to ensure that they understood them. Blocks were counterbalanced across participants with regard to whether the forced-report or the free-report block was presented first.

The titration procedure was the same as in Experiment 2, except that the goal was to find the presentation rate at which participants correctly completed 70% of the fragments whereas in Experiment 2 the goal was to find a duration that produced a correct completion rate of 60%. The obtained rate was used as the flash duration for the perception task. The average duration used for young adults (M = 16.69, SD = 7.84) was shorter than that used for older adults (M = 104.69, SD = 37.30), $t(16.32) = 9.13$, $p < .001$.

Results

Analyses of results revealed that the order of forced- versus free-report blocks did not produce a significant main effect nor any significant interactions and, therefore, reported results are collapsed across that factor. Results are presented in Table 3 with the layout of the table being meant to facilitate the comparison of results with those from Experiment 2 (see Table 2). Results in the first column (Forced-report hit rate) were expected to be comparable to those in the column labeled "Hit rate" in Table 2, and results in the second column (Free-report hit rate) were expected to be comparable to those in the second column of Table 2 (Correct seeing). Results in the third column (Free-report false-alarms) were expected to be comparable to those in the column labeled "False seeing" in Table 2. False alarms were defined as occurring when participants produced the primed word as a completion on incongruent trials or guessing trials in the free-responding condition. To follow instructions, if the flashed word was not seen, participants should respond "pass" and, therefore, only false seeing could contribute to completion with the prime in those conditions. The probability of responding "pass" was expected to reflect the extent to which participants relied on the prime as a basis for the subjective experience of seeing.

Forced report. Hit rates in the forced-report condition show that the titration procedure used in Experiment 3 was highly effective in producing age-group equivalence on baseline trials in the forced-report condition. Priming had a strong effect on both age groups' identification responses, as indicated by a significant main effect of trial type, $F(2, 56) = 81.82$, $MSE = 3.05$, $p < .001$, $\eta_p^2 = .73$. As in Experiment 2, the interaction between age and trial type did not approach significance, $F < 1$, *ns*, but the trend toward older adults having a higher rate of hits than young adults on congruent trials was significant by a t test, $t(30) = 2.62$, $p < .05$.

On guessing trials, older adults were more likely to produce the primed response than were young adults, $t(30) = 2.39$, $p < .05$. That result suggests that young adults continued to be reluctant to produce the prime as a response because of the possibility of being misled. Further evidence of differential reliance on the prime was produced by age differences in the free-report condition.

Free report.

Passing. Passing responses (see Figure 2) provide strong evidence of qualitative differences between older and young adults

Table 3
Hit Rates at Forced-Report and at Free-Report, and False-Alarm Rates at Free-Report in Experiment 3

	Forced-report hit rate		Free-report hit rate		Free-report false-alarm rate	
Experiment 3	*M*	*SE*	*M*	*SE*	*M*	*SE*
Congruent						
Young	0.87	0.03	0.57	0.05	0.04	0.02
Older	0.96	0.01	0.81	0.04	0.02	0.01
Baseline						
Young	0.69	0.03	0.66	0.05	0.07	0.02
Older	0.69	0.04	0.37	0.08	0.06	0.02
Incongruent						
Young	0.41	0.06	0.29	0.05	0.34	0.05
Older	0.38	0.07	0.22	0.07	0.51	0.07
Guessing						
Young[a]	0.83	0.04	—[b]	—[b]	0.08	0.05
Older[a]	0.94	0.02	—[b]	—[b]	0.34	0.08

[a] denotes probability of providing the primed response. [b] denotes hits cannot occur on guessing trials.

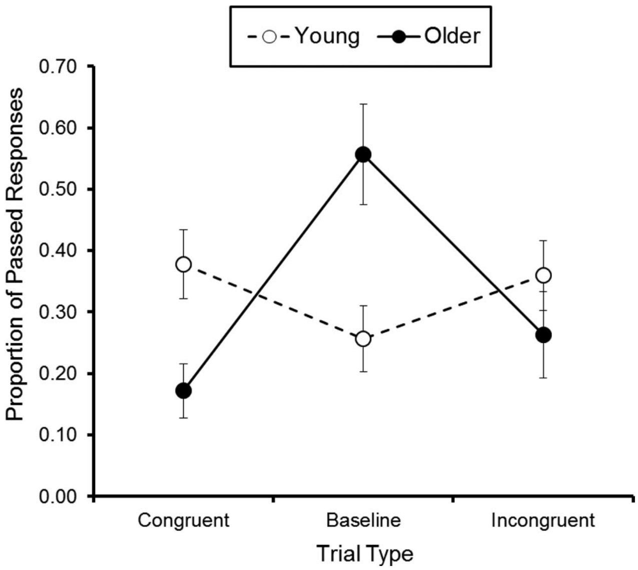

Figure 2. Passing rates in Experiment 3.

in the bases used for certainty of seeing the flashed word. Older adults relied much more heavily on the prime than did young adults. Older adults passed frequently on baseline trials and were less likely to pass on congruent and incongruent trials. In contrast, young adults passed at a relatively low rate on baseline trials, and were more likely to pass when priming was present (e.g., congruent and incongruent trials). Age-related differences in passing were largest on baseline trials. Older adults apparently found baseline trials to be difficult ones due to the lack of usable expectations and, therefore, often passed, whereas for young adults, baseline trials were treated as safe from potentially misleading effects of the prime and, therefore, they seldom passed. The crossover interaction in passing rates provides strong support for the claim that age differences in false seeing observed in earlier experiments was not simply because older adults were generally more willing to say they saw the flashed word. Rather, age differences in passing reflected differences in reliance on the prime.

A 3 (trial type: congruent, baseline, incongruent) × 2 (age: young, older) mixed-model ANOVA revealed a significant interaction of trial type and age, $F(2, 60) = 33.61$, $MSE = 0.57$, $p < .001$, $\eta_p^2 = .53$. Post hoc F tests revealed significant age group differences on congruent, $F(1, 30) = 8.88$, $p < .01$, $\eta_p^2 = .23$, and baseline trials, $F(1, 30) = 10.10$, $p < .01$, $\eta_p^2 = .25$, but not incongruent trials.

Age group differences in passing rates were also observed for guessing trials. Young adults were more likely to pass on guessing trials (.89) than were older adults (.64), $t(30) = 2.29$, $p < .05$, again showing older adults' greater reliance on the prime.

Free-report hit rate. A 3 (trial type: congruent, baseline, incongruent) × 2 (age: young, older) mixed-model ANOVA of free-report hit rates revealed a significant interaction of trial type and age, $F(2, 60) = 26.22$, $MSE = 0.58$, $p < .001$, $\eta_p^2 = .47$. Post hoc F tests revealed significant age group differences on congruent, $F(1, 30) = 12.90$, $p < .001$, $\eta_p^2 = .30$, and baseline trials, $F(1, 30) = 10.58$, $p < .01$, $\eta_p^2 = .26$, but not incongruent trials.

Returning to Table 3, hit rates in the free-report condition (second column) showed that older adults had greater hits than did young adults on congruent trials, just as older adults produced more correct "saw" responses than did young adults in Experiment 2. However, effects on the probability of a hit in the remaining conditions differ from effects on correct seeing in Experiment 2. The probability of a hit in the free-report, baseline condition was lower for older adults than for young adults in Experiment 3, whereas correct seeing in that condition in Experiment 2 was numerically but not significantly higher for older adults. That difference in results was due to young adults showing a hit rate in Experiment 3 that was much higher than their level of correct seeing in Experiment 2. The higher hit rate likely arose from young adults using a lower criterion for seeing as a prerequisite for outputting a completion in Experiment 3 than was used for a subjective report of "saw" in Experiment 2. A second difference in results across experiments is that age differences in free-response hits on incongruent trials were opposite in direction from differences in correct seeing in Experiment 2. For young adults, the difference across experiments can again be explained as reflecting their use of a more lenient criterion for outputting a completion in Experiment 3 than was used in Experiment 2 for saying that they "saw" a flashed word. For older adults, the reduced free-report hit rate in Experiment 3 as compared to correct seeing in Experiment 2 on incongruent trials (.22 vs. .35) might reflect the corresponding reduction in forced-report hit rate in Experiment 3 as compared to hit rate in Experiment 2 (.38 vs. .48).

We do not have an account for why young adults used a more lenient criterion for outputting a response as compared to saying they saw a flashed word whereas older adults did not do so. In combination with effects on passing, these results reveal both quantitative and qualitative differences between young and older adults in the criteria used for responding. Clearly, older adults relied more heavily on expectations as a basis for seeing than did young adults. This qualitative difference in criteria makes it difficult to interpret age differences in quantitative changes in criteria.

Free-report false-alarm rate. As shown in the final column of Table 3, older adults were more likely to produce the primed word as a completion on incongruent trials (false alarm) than were young adults—a result that is in agreement with the higher false seeing on incongruent trials shown by older adults in Experiment 2. On baseline and congruent trials, older and young adults did not differ in their probability of a false alarm which, again, is consistent with false-seeing results found in Experiment 2. Analysis of the results revealed a significant interaction of trial type and age, $F(2, 60) = 5.78$, $MSE = 0.10$, $p < .01$, $\eta_p^2 = .16$. Post hoc F tests showed that age group differences were significant only on incongruent trials, $F(1, 30) = 4.48$, $p < .05$, $\eta_p^2 = .13$.

False alarms on guessing trials also converged with findings of age differences in false seeing in Experiment 2. On guessing trials, older adults were much more likely than young adults to complete the fragment with the primed word, even though they were told to pass unless they were certain that they saw the flashed word, $t(30) = 2.75$, $p < .01$.

Results from Experiment 3 in combination with those from Experiment 2 show that people act on their subjective experience of seeing when allowed to withhold responding. Results from the two experiments agreed in showing that older adults relied more heavily on the prime than did young adults, a qualitative difference in the basis for judging that the flashed word was seen. However, to explain the full pattern of results, it is necessary to acknowledge that there were quantitative as well as qualitative differences. Younger adults were generally less willing to conclude that a word was seen on primed trials because of the possibility of being misled by the prime, and their criteria for seeing appears to have been more lenient for producing a completion (Experiment 3) than for a subjective report of seeing the flashed word (Experiment 2).

General Discussion

Our findings of older adults' greater reliance on expectations produced by a prime are in general accord with prior findings in the literature showing that older adults are more reliant on context than are young adults when reading (e.g., Speranza et al., 2000). However, prior experiments only examined age differences by comparing performance in a condition for which context was congruent with performance in a baseline condition, and have not included subjective reports of seeing. From results of those experiments, it might be concluded that older adults' greater reliance on context is generally advantageous in serving as a compensatory mechanism for age-related declines in visual acuity. By including a condition for which context was incongruent (presenting a misleading prime) and by querying the subjective experience of seeing, we show that greater reliance on context carries costs as well as benefits.

Older adults were more likely than young adults to report seeing the flashed word in the congruent-context condition. However, this advantage in correct seeing came at the cost of a large increase in false seeing. Older adults were much more likely to falsely see a word in the incongruent test condition than were young adults. Further, they were much more likely to falsely see even when a word was not actually flashed, as in the guessing condition. The results for the guessing conditions are important in showing that age difference in false seeing did not reflect differences in sensory processing alone. The differences remained even when sensory processing of a flashed word was impossible because a word was not flashed.

As further evidence against an account in terms of age differences in visual processing, performance of young and older adults was equated on baseline trials by means of a titration procedure. On those trials, young and older adults were equally able to identify a flashed word that differed from its alternative in only a single letter (e.g., DART, dirt). Also, age differences in false seeing in the incongruent-prime condition were found in Experiments 2 and 3 although young and older adults did not significantly differ in their probability of a hit (correct identification of the flashed word). Consequently, it seems certain that age differences in reliance on the prime were not solely because of differences in sensory processing.

Prior investigations of age differences have focused on quantitative differences in criteria for responding. For example, Botwinick (1966, 1969) suggested that older adults are more cautious, requiring greater evidence prior to responding than do young adults. However, qualitative differences in the basis for responding are potentially more important than are quantitative differences. A qualitative difference in criteria for responding is revealed by older adults' greater reliance on the prime. Rather than heavily relying on the prime, younger adults tended to react against the prime and rely more heavily on sensory processing so as to avoid being deceived. The greater willingness of older adults to "pass" on baseline trials in Experiment 3 is in line with the suggestion that older adults are more cautious than are young adults. However, when the prime provided a basis for expectations, older adults were strikingly less cautious than were young adults as shown by their being much less willing to "pass." Quantitative differences in criteria must be interpreted in the context of qualitative differences. Clearly, age differences in false seeing were selective to conditions rather than only reflecting an age difference in general willingness to conclude that they "saw" the flashed word.

It might be held that older adults' greater reliance on context results from a habit formed by their relying on context to compensate for age-related declines in vision. However, young adults also heavily rely on context in some situations. An alternative to an account in terms of differences in habit is that young adults are more sensitive to the demands of a current situation than are older adults, relying on context when its use is likely to be advantageous and avoiding its use when context is likely to be misleading. Rather than focus on habitual reliance on context by the older population, we find it more useful to propose that there are age differences in cognitive flexibility of the sort that are important for optimizing performance for a particular situation. Such flexibility in interpretation of visual stimuli is important for applied concerns. As an example, one should rely less on expectations when reading a legal document than when reading a novel.

Just as older adults are more prone to false seeing, they are also more prone to false hearing (Rogers et al., submitted). Older adults' greater false seeing is also akin to their greater false memory produced by being "captured" by a prime (Jacoby, Bishara, et al., 2005). Older adults' greater vulnerability to illusions in each of these types of situation can be interpreted as resulting from their being unwilling or unable to avoid misleading effects of accessibility resulting from influences of memory or other forms of context. Age differences in false hearing and in false memory were observed in the experiments referenced above although baseline performance was equated for young and older adults as was done in our false-seeing experiments. However, equating of baseline performance does not ensure that one has fully equated sensory processes or general memory. For example, age-related changes in visual cortex might produce differences in visual processing that are not eliminated by equating baseline performance and that are fully responsible for age differences in false seeing. Against possibilities of this sort, the convergence of age differences across domains provides support for the conclusion that observed differences in each of the domains were not solely due to lower level differences in sensory or memory processes. Rather, age differences in illusions of perception and memory seem better explained as, at least in part, being due to older adults reduced cognitive flexibility, which is likely related to age differences in frontal lobe function (e.g., McCabe, Roediger, McDaniel, & Balota, 2009; West, 1996). In that vein, older adults are also less willing or able to engage in source-constrained retrieval of the sort that is optimal for correct responding on memory tasks (e.g., Anderson, Jacoby, Thomas, & Balota, 2011; Jacoby, Shimizu, Velanova, & Rhodes, 2005).

The effects of context are typically beneficial for both memory and perception (e.g., Gigerenzer, Hoffrage, & Kleinbolting, 1991). By arranging situations such that recent memory or context is a source of errors (incongruent context), our experiments revealed the costs of older adults' greater reliance on context. If greater reliance on context reflects a general decrease in cognitive flexibility, the prediction would be that there should be a high correlation between vulnerability to illusions in different domains. It would be predicted that those who are most vulnerable to false seeing would also be most vulnerable to false hearing and false memory. Such findings would provide further evidence that for both perception and memory, age differences in accuracy and subjective experience do not solely reflect age-related declines that are specific to the different domains but, rather, they also reflect a more general decline in flexibility that might result from declining frontal lobe functions.

The possibility of a general decline in cognitive flexibility that holds across domains has potentially important applied implications for diagnosis and treatment of deficits in perception and memory. As an example, eyeglasses enhance visual sensory processing and hearing aids enhance auditory information. However, for older adults, neither will be effective as a means of eliminating age differences in false seeing and false hearing that reflect overreliance on context, nor will it help to encourage people to generally be more or less cautious. This is because context is sometimes an inappropriate basis for subjective experience. Perhaps measures of subjective experience should serve a larger role in diagnosis, and reeducation of subjective experience would be useful as a treatment for age-related deficits in perception and memory. Of course, this is not to deny that there are also age-related declines that are specific to different sensory modalities and to memory processes.

In sum, the results of our experiments have revealed age-related differences in the bases for the subjective experience of seeing. Older adults' greater reliance on context makes them more vulnerable to false seeing when faced with impoverished visual processing, as in the current experiments. Age differences in false seeing would likely be greatly reduced or even eliminated if the target word was presented for an unlimited amount of time rather than flashed. However, much of our visual life rests on a glance—limited visual processing. Age differences in the subjective experience of seeing are important for applied purposes as well as for purposes of theory. This is because people sometimes act on their subjective experience of seeing, even when that subjective experience reflects an illusion produced by expectations.

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