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Post-Event Review in Older and Younger Adults: Improving Memory Accessibility of Complex Everyday Events

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Recalling an event at 1 time often increases the likelihood that it will be remembered at a still later time. The authors examined the degree to which older and younger adults' memory for everyday events that they watched on a videotape was improved by later seeing photographs or reading brief verbal descriptions of those events. Both older and younger adults recalled more events, in greater detail, with than without review. Verbal descriptions enhanced later recall to the same degree as reviewing photographs. Younger adults generally gained more from review than older adults on measures of the absolute number of details recalled and when facilitation was assessed relative to a no-review control condition, but not when memory for reviewed events was expressed as a proportion of each individual's total recall. Post-event review has clear potential practical benefits for improving memory of older adults.

Memory for an event is not exclusively determined by what happens at the time of the event itself. Although how we initially attend to and process an event is a crucial factor in determining what one later may be able to remember concerning it, cognitive processing that occurs after the event also plays an important role. Retrieving, rehearsing, or otherwise reactivating memories of an earlier experienced event[1] may alter both the likelihood that the event will subsequently be remembered (Bjork, 1988; Landauer & Bjork, 1978; Linton, 1975, 1978) and what will be remembered about it (Hashtroudi, Johnson, Vnek, & Ferguson, 1994; Suengas & Johnson, 1988). Beneficial effects of post-event retrieval on later recollection have been demonstrated in a variety of contexts, including explorations of the effects of repeated testing of recently learned information (e.g., Allen, Mahler, & Estes, 1969; Carrier & Pashler, 1992; Darley & Murdock, 1971; Landauer & Bjork, 1978; Modigliani, 1976), long-term studies of autobiographical memory (Linton, 1975, 1978), and the acquisition, retention, and accessibility of semantic knowledge (Herrmann, Buschke, & Gall, 1987; Rea & Modigliani, 1985). Powerful effects of the reinstatement or reactivation of memory have also been demonstrated with infants and children (Bauer, Hertsgaard, & Wewerka, 1995; Hitchcock & Rovee-Collier, 1996; Howe, Courage, & Bryant-Brown, 1993, see also Edwards & Middleton, 1988; Hudson, 1990; Hudson & Fivush, 1991; Tessler & Nelson, 1994).

Despite possessing clear practical and theoretical implications for older individuals, the effects of post-event review on the memory of older adults have received surprisingly little attention. The potential practical benefits of post-event retrieval in older adults are readily apparent. Older adults often report experiencing memory problems in their everyday lives, and objective measures of their memory performance, using a variety of tasks and stimuli, reveal that their memory is typically impaired relative to younger adults (for review, see Burke & Light, 1981; Craik, Anderson, Kerr, & Li, 1995; Light, 1991). Such impairments are often especially pronounced in tasks requiring recall

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[1] Various terms have been used to refer to post-event retrieval processing, including *reactivation* (e.g., Rovee-Collier, Enright, Lucas, Fagen, & Gekoski, 1981), *reinstatement* (e.g., Howe, Courage, & Bryant-Brown, 1993), *reminding* (e.g., Bauer, Hertsgaard, & Wewerka, 1995), and *retrieval practice* (e.g., Anderson, Bjork, & Bjork, 1994; Shaw, Bjork, & Handal, 1995). For an attempt to distinguish between various types of post-event processing (specifically reinstatement, refreshing, rehearsing, reactivating, and retrieving), see Johnson (1992) and Johnson and Chalfonte (1994). Although in other contexts it may be useful to draw distinctions between these types of post-event retrieval processing, the particular procedure that we adopted in our study involves a combination of several of these subtypes (e.g., *reinstatement,* in that the photographs we used to prompt review provide a form of physical reinstatement of spatiotemporal information, but also *retrieving* in that participants were specifically encouraged during the photograph review phase to try to think of their own memory of the scenes). We therefore do not attempt to differentiate between these different terms and refer to the overall procedure as post-event review or retrieval.

rather than recognition (Craik & McDowd, 1987). Given that recalling past events or experiences can substantially increase the likelihood that younger adults will later prove able to recall those events, to what extent, and under what conditions, do older adults benefit from such practice?

Two ideas about why post-event retrieval might enhance subsequent memory have been suggested by Bjork (1988; Landauer & Bjork, 1978) and Johnson and colleagues (Chalfonte & Johnson, 1996; Johnson & Chalfonte, 1994). Bjork (1988; Landauer & Bjork, 1978) has proposed that earlier recall facilitates later recall because the earlier retrieval is, indeed, a form of practice for the later retrieval attempt, with the amount of benefit observed depending on the extent to which the processes involved in the earlier and later retrieval overlap. According to this view, the act of retrieval does not simply strengthen an item's representation in memory but, rather, enhances some aspect of the retrieval process itself. More recently, Johnson and Chalfonte (1994; see also Johnson, 1992) have proposed that the reactivation or reinstatement of an earlier experienced event may enhance memory by increasing the activation level of different attributes of the original experience, such as spatiotemporal information (where and when it occurred), sensory and perceptual features (e.g., the color and size of objects), and other forms of information concerning one's thoughts and feelings in relation to the event. This co-activation of the different components of an event is postulated to increase both the likelihood that different features will become interassociated and the strength of already-existing associations between features, enhancing the degree to which they are "bound" with one another to form an integrated episodic trace (cf. Damasio, 1989; Teyler & DiScenna, 1986).

Both of these accounts would suggest that older adults should benefit from post-event review. Older adults appear to benefit as much as younger adults from practice on other forms of tasks (Salthouse & Somberg, 1982; for review, see Craik & Rabinowitz, 1985), and deficits in binding the different attributes of events have been postulated to underlie specific memory difficulties shown by older adults, such as disproportionately impaired memory for contextual features associated with an event (Johnson & Chalfonte, 1994). However, depending on the particular circumstances, whether older and younger adults should derive equivalent benefits from retrieval practice is unclear. For example, to the extent that a given instance of post-event retrieval provides a means of compensating for deficits in the binding of disparate elements of an episode in memory—and establishing such an integrated trace generally presents greater difficulties for older than younger adults—it could be expected that older adults would gain from such practice. Yet, depending on the complexity of the episode and the conditions present during the initial encounter, the memory of younger adults might also be considerably strengthened because of the conjunctive reactivation of the various components of the episode. Moreover, given the more efficient nature of the processes subserving such binding in younger than older adults, they might well gain as much, or even more, than older adults.

Few studies have explored the consequences of post-event retrieval in older compared with younger adults, and the results of these have not been entirely consistent. Two studies reported equivalent benefits in older and younger adults. Rabinowitz and Craik (1986) examined the effects of an earlier recall test on older and younger adults' later recall of words. Although, on the immediate recall tests, older adults recalled fewer words overall than did younger participants, after taking this into account and considering only items that had been successfully retrieved, the degree to which older and younger adults benefitted from a previous test of the items did not differ. A similar result was obtained for recall of previously performed tasks (Kausler & Wiley, 1990). Both older and younger adults recalled more of several different types of tasks that they had performed (e.g., unscrambling words and tracing mazes) if they had earlier recalled those tasks than if they had not, and the degree of benefit was similar for the two age groups.

However, conflicting results have also been reported. Smith (1980) compared multi-trial free-recall learning under conditions in which individuals were given repeated recall opportunities of to-be-learned items, in the form of free-recall tests (one study opportunity followed by three tests, or STTT) versus repeated study opportunities (three study opportunities followed by a single test, or SSST). Although there were no age differences in the latter condition involving repeated study opportunities, there was an age-related deficit in the former condition involving only one study opportunity but repeated test opportunities. Another study by Kausler (Kausler & Phillips, 1988), involving self-performed activities, also found that interpolated retrieval opportunities yielded only modest benefits for older adults, and the gain achieved due to previous retrieval seemed to be more pronounced for younger than for older adults.

Smith (1980) concluded that older adults benefit less from retrieval practice than do younger adults. However, as Rabinowitz and Craik (1986) noted, there are two difficulties with this conclusion. First, if older adults less often successfully retrieved items during the three retrieval practice opportunities, then age-related differences in the amount of benefit derived from retrieval might simply reflect the fact that older and younger adults did not receive equivalent amounts of review. In view of general age-related deficits in retrieval—and their especially pronounced presence in free recall—this type of retrieval practice has the undesirable feature that it may maximize age-related differences in initial retrieval success. Although differences in initial retrieval can be taken into account by conditionalizing performance on initial recall success (cf. Kausler & Wiley, 1990; Rabinowitz & Craik, 1986), a preferable approach might be to minimize such differences in the first place. This might be accomplished by providing cues at the time of retrieval practice. An additional, and important, advantage of such an approach is that it will tend to reduce differences in how older versus younger adults retrieve items during review. If, as Rabinowitz and Craik (1986) suggested, retrieval and encoding operations bear close similarity to one another, then providing additional constraints at the time of review, through the use of specific cues rather than the simple instruction to freely recall items, should increase the likelihood that the processes and outcomes of review are similar for younger and older adults.

The experiments reported here adopted this specific cues approach. In addition, whereas earlier studies all involved recall of relatively simple activities or verbal materials, we sought to examine the effects of previous retrieval on older and younger adults' memory for relatively complex everyday events, entailing

multiple components that might be further interassociated with one another through post-event review. The cues we used to guide retrieval were a ubiquitous and highly specific, but also a seldom studied, impetus to post-event retrieval in everyday life: that of photographs. The experimental paradigm was similar to one we recently developed to study false memories and aging (Schacter, Koutstaal, Johnson, Gross, & Angell, 1997; see also Schacter, Koutstaal, & Norman, 1997). Older and younger adults first watched multi-event videotapes of an everyday series of events. Later, they were shown photographs of some of the events that they had watched. Finally, at a still later time, memory for all of the events from the videotape—those that had been reviewed through photographs as well as those that had not been reviewed—was probed.

The results from the Schacter, Koutstaal, Johnson, et al. (1997) experiments clearly suggested that older and younger adults derive substantial benefit from such post-event review. On a verbal recognition test probing memory for all of the events from the videotape, both older and younger participants were more likely to correctly recognize objects from events that had been reviewed with a photograph than events that had not thus been reviewed. Furthermore, the recognition performance of older and younger participants appeared to benefit to a similar degree as a consequence of photograph review. There were no interactions of age with photograph review, either when overall recognition performance was considered or when several more qualitative self-report measures of the nature of participants' recollective experience for the reviewed versus nonreviewed events were considered (e.g., whether participants indicated that they could remember the visual appearance of the objects involved in the events, or what actions were performed with them).

Our experiments extend these initial findings, addressing several specific issues raised by an attempt to assess their implications and generalizability. Experiment 1 examines two issues: (a) the nature of the retention test used to probe memory following post-event review. Do the previous findings, showing no difference in the degree to which older and younger adults gain from post-event review when final retention was tested with recognition (a test format involving considerable retrieval support) extend to a situation where retention is tested with free recall (involving much less support)? (b) the possibility that, in addition to beneficial consequences for the reviewed events, post-event review may have detrimental consequences for the nonreviewed events. Does the apparent mnemonic advantage of reviewed events derive only from facilitation of memory for those events, or is memory for the nonreviewed events also adversely affected? Each of these issues is developed more fully later. Experiment 2 further explores these two issues and, in addition, provides an assessment of the extent to which the outcomes observed when review is prompted through photographs are also observed if another form of impetus to post-event review—that of brief verbal accounts of the events—is used.

Experiment 1

The experiments by Schacter, Koutstaal, Johnson, et al. (1997) showed that older and younger adults derived equal facilitation from post-event review for complex events when memory was tested with a verbal recognition test. However, as noted previously, age differences in memory are often less evident in recognition than free recall, and these differences may be observed even when the level of difficulty for recall and recognition tests is held constant (Craik & McDowd, 1987). The extent to which older adults' memory for complex events would be enhanced by previous review of photographs under conditions of less retrieval support at the time of ultimate retention testing is not known (cf. Perlmutter & Mitchell, 1982). Furthermore, although the recognition test data of Schacter, Koutstaal, Johnson, et al. (1997) did not show age-related differences in the amount of gain derived from photograph review, the recognition test probes essentially provided only a yes–no measure of whether an episode or particular features of the episode were recollected. It is possible that a more sensitive measure of episodic recall, probing the extent of participants' detailed recollection, would point to differences.

To address this question, we tested participants in Experiment 1 by using a free-recall test, and both generic recall of the events and more detailed recollection were examined. Participants first watched two multi-event videotapes and then either reviewed some of the events from the videotapes by looking at photographs of those events (photograph review groups) or received no review (no review control group). Later, they were given a free-recall test in which they were asked to write everything they could remember about the videotapes, including as much detail as possible and writing about all of the events in the order in which they happened. We then examined the extent and specificity of their recall, first asking whether individuals were more likely to recall events that they had earlier reviewed (regardless of the amount or nature of the details concerning the event that they recalled), and then assessing recall of specific types of information, including sensory–perceptual details (e.g., information regarding the color and size of objects), recall of specific objects or actions, and recall of auditory information associated with the events (for further details, see *Free-Recall Scoring Criteria* section).

A second issue addressed by Experiment 1 concerns the possibility that enhanced memory performance for events or items receiving review does not exclusively derive from facilitation or strengthening of those events but may also arise from impairment of memory for the nonreviewed events. Although this possibility was not considered in previous retrieval practice studies with older adults (Kausler & Wiley, 1990; Rabinowitz & Craik, 1986; Schacter, Koutstaal, Johnson, et al., 1997), several sources of evidence from studies with younger adults suggest that impairment of memory for nonreviewed items may occur. Recent work using a verbal retrieval practice paradigm has shown that inhibition or impairment of nonrehearsed items may occur for verbal items: The act of retrieving some information may diminish the likelihood that other categorically similar but nonretrieved (nonpracticed) items will be retrieved at a later time (Anderson, Bjork, & Bjork, 1994; Anderson & Spellman, 1995). Using an eyewitness-memory paradigm, Shaw, Bjork, and Handal (1995) showed that repeated questioning may also produce such "retrieval-induced forgetting" (Anderson et al., 1994) for visually presented items (objects shown in color slides allegedly depicting a crime scene). Impaired recall of some recently

learned items as a consequence of strengthening other items has also been observed in *part–set cuing* paradigms (e.g., Mueller & Watkins, 1977; Nickerson, 1984), where presenting a subset of previously studied items at or near the time of recall testing may impede recall of other (nonpresented) items relative to when no items are provided. Taken together, these findings raise questions as to the extent to which either (a) retrieval-induced inhibition of the nonreviewed events or (b) any of several other forms of interference arising from the comparative dominance and accessibility of the reviewed items (cf. Anderson & Bjork, 1994) may also contribute to the observed outcomes of post-event review in our paradigm. Is the memory of older and younger adults for nonreviewed events actually impaired (blocked, inhibited, or otherwise impeded) as a consequence of reviewing other events? If so, then the apparently facilitatory effects of photograph review reported by Schacter, Koutstaal, Johnson, et al. (1997) may be largely or entirely a reflection of decreased memory for the nonreviewed events.

The degree to which selectively reviewing some events might lead to impaired memory for the nonreviewed events was addressed by the inclusion of a further comparison group. After watching the videotapes, some participants were given an opportunity to review half of the videotaped events through photographs, and others were not (the none condition). If the effects of photograph review on later memory performance arise entirely from the enhanced accessibility of the reviewed events, then participants' recall of nonreviewed events (given that other events were reviewed) should not differ from participants' average level of recall of nonreviewed events in a situation in which no review occurred at all. If, however, some portion of the difference in memory for reviewed and nonreviewed events arises from impaired memory for the nonreviewed events, then recall performance in the absence of any review should exceed that for nonreviewed events in the photograph review conditions.

Experiment 1 also included a manipulation of the number of times that the photographs were presented, with some participants shown photographs only once and others shown photographs three times. This manipulation provides data concerning the degree to which older versus younger participants benefit from repeated review of previous events through photographs. Including repetition as a factor in the design also increased the likelihood that, if inhibitory or retrieval blocking effects were induced by reviewing photographs, these could be detected, both by increasing the opportunities for such impairment to occur within subjects (for the three repetitions group) and by increasing the statistical power of the experimental design by increasing sample size (inclusion of both a review once and a review thrice group, and combining estimates of impairment from the two groups).

Method

Participants. Participants were 36 older (M age = 68.4 years, SD = 4.6, range = 60–78) and 36 young (M age = 19.5 years, SD = 1.6, range = 18–26) individuals. Older adults were initially recruited by various means, including newspaper advertisements, posted flyers, and word of mouth. Younger participants were recruited through sign-up sheets posted at Harvard University. All were native speakers of English and were paid for their involvement in the experiment.

Participants were individually interviewed so as to exclude those with any of the following conditions: a history of alcoholism or substance abuse; cerebrovascular accident; recent myocardial infarction; present or previous treatment for psychiatric illness; current treatment with psychoactive medication; metabolic or drug toxicity; primary degenerative brain disorders (e.g., Alzheimer's disease, Parkinson's disease, or Huntington's disease); and brain damage sustained earlier from a known cause (e.g., hypoxia). Also excluded were any persons (either old or young) who obtained a score of 11 or higher on the Geriatric Depression Scale (Yesavage et al., 1983).

Older participants had on average about 2 more years of formal education (M = 15.4, SD = 2.3, range = 12–20) than their younger counterparts (M = 13.2, SD = 1.2, range = 12–16, n = 31[2]), $F(1, 65)$ = 22.22, MSE = 3.51, $p < .0001$. There was a tendency for younger participants to achieve higher scores on the Information subtest of the Wechsler Adult Intelligence Scale—Revised (WAIS–R; Wechsler, 1981) than obtained by older participants (M for the young = 24.2, SD = 2.9, range = 18–28, n = 32; M for the old = 22.7, SD = 4.3, range = 13–29), $F(1, 66)$ = 2.80, MSE = 13.49, $p = .10$,[3] but the two groups did not differ in their Vocabulary subtest scores (M for the old = 59.0, SD = 6.3, range = 44–68; M for the young = 59.8, SD = 4.6, range = 48–66, n = 32; $F < 1$).

Design. The design included two between-subjects variables: age (old or young) and experimental condition (no photographs, photographs shown once, or photographs shown three times). In addition, because participants in the photograph review conditions reviewed only one half of the videotaped events and did not review the other events, for these conditions there was a further within-subjects variable of event review (reviewed or R+, and nonreviewed or R−).

Participants from each age group were randomly assigned to the three experimental conditions such that 12 older participants and 12 younger participants were assigned to the no photographs condition, the photographs reviewed once condition, and the photographs reviewed thrice condition. For the within-subject variable of event review, two sets of photographs, each depicting one half of the videotaped events (see later), were constructed. Presentation of these stimulus sets (Sets A and B) was then counterbalanced such that 6 of the older adults and 6 of the younger adults in each of the photograph review conditions (once and thrice) reviewed the events from Set A, and an equal number reviewed those from Set B. In addition, the order in which the two videotapes (office or park) was presented was counterbalanced across participants, with subsequent photograph review and testing for each participant mirroring the order in which the videotapes were originally presented.

Stimulus materials. Two scenarios were constructed, each comprising 12 independent events (plus four unscored filler events). The first scenario, denoted the office videotape, involved a female professor and a male colleague and was filmed in a university professor's office. The second scenario, denoted the park videotape, involved a male and a female student and was filmed outdoors in a small park area.

The scenarios were constructed so as to be a plausible but not highly predictable or schema-like series of events. For example, the office vid-

[2] Because of clerical error, information concerning participants' education and performance on the WAIS–R subscales in Experiment 1 was not available for all participants. Where information is missing, the number of individuals for whom information was available is indicated in the text.

[3] Examination of a subset of older adults (n = 31), for whom performance on the General Information WAIS–R subscale was equated to that of the young ($F < 1$), revealed a pattern of means for the dependent measures that was extremely similar to that reported for the entire sample.

eotape showed the female professor watering a plant in the corner of her office, consulting a large dictionary on the shelf behind her desk, and interacting with a male colleague who shows her a newspaper article about an art exhibit. The park videotape involved various activities, such as the woman locking her bicycle to a park bench and the man working on a problem set at a picnic table. Each videotape was approximately 7 min long.

The scenarios were filmed by using a Sony Hi8 video camcorder and then transferred to VHS videotape. The videotapes were presented on a 20-in. color television monitor, with the volume adjusted individually to a comfortable hearing level for each participant.

Twenty-four 3 in. × 4 in. color photographs (12 for each videotape) were made directly from the videotapes by using a Sharp GZP21 Video Printer. The photographs were selected so as to be highly characteristic of each of the critical events in the office and park videotapes.

Two sets (A and B) of 12 photographs each were created. Each set included two subsets comprising 6 office and 6 park photographs. Set A included photographs of the even-numbered critical events from the office tape and odd-numbered events of the park tape; the reverse was true of Set B.

The photographs from each videotape were placed in a pseudo-random order such that no photograph occurred in its proper temporal sequence relative to the other five photographs. The photos were then placed in the clear plastic protector sheets of four small photo albums (one for each subset). Each photograph was placed on a separate page, with a blank page intervening so that only one photograph could be viewed at a time. Also, each of the six photos in each subset was clearly numbered.

Procedure. The overall procedure involved three key phases: Participants (a) watched two videotapes, then (b) viewed photographs depicting one half of the studied events from each of the videotapes (photograph review conditions) or performed an unrelated task (none condition), and finally (c) were tested for their memory of the entire videotapes.

All participants were tested individually. Before viewing the videotapes, participants were instructed to pay careful attention because, after viewing the tape, they would be asked to rate how much they had enjoyed the tape, how well acted it was, and how clearly it was filmed. Participants then watched the videotapes, providing their ratings immediately after each videotape. Two days later they returned to the laboratory and, depending on the experimental condition to which they had been assigned, saw photographs of one half of the 12 critical office events and one half of the 12 critical park events (once condition) or saw these photographs three times in direct succession, with the photographs occurring in the same order each time (thrice condition). Alternatively, if participants had been assigned to the none condition, they were asked to copy line drawings of three-dimensionally "possible" novel objects (cf. Schacter, Cooper, & Delaney, 1990) during the time that participants in the photograph conditions were reviewing the photographs. (All participants in the none condition performed this control task for 5 min, or approximately the time required to review the photographs once.)

Before viewing the photographs, participants in the photograph review conditions were given the following instructions:

> Sometimes when we look at photographs, the photos are just like our memories of the event or scene. Sometimes they seem different. You will be looking at photographs taken from the videotapes that you watched earlier. I would like you to look carefully at each photograph. At the same time, please think about *your own memory* of that event or scene. Then rate how well the photo matches your memory on a 5-point scale, where 1 indicates that the photo does not at all match your memory and 5 indicates the photo exactly matches your memory.

Participants were told that they would have 20 s to look at each photograph and to provide their ratings. An audiotape on which the experimenter told the participants when to turn the page to the next photograph and when to make their ratings was then played. This photograph viewing phase (or in the case of the none group, the object copying phase) was followed by a 10-min unstructured break, after which a free-recall test for all of the items from the videotapes was administered.

In the free-recall test, participants were asked to write everything they could remember about the videotapes that they had watched earlier. They were asked to include as much detail as possible and to write about events in the order in which they happened. Participants were given 15 min to recall each videotape, with the experimenter indicating when they should proceed to recall the second videotape. Finally, participants were debriefed.

Free-Recall Scoring Criteria

The free-recall protocols were first scored for whether or not each of the 24 critical events were recalled. A value of one was assigned if there was a clear and unambiguous (although possibly quite general) reference to a given critical event; a zero was assigned if there was no unambiguous mention of the critical event. For each critical event, two or more highly characteristic actions, objects, or other details were compiled, and reference to any one of these details was sufficient for the participant to earn credit for remembering that event. For example, participants were given credit for recalling the event in which the female professor offered some cookies to the male professor if they mentioned either cookies or baked goods or noted that she offered him something to eat.

A second scoring method attempted to separately quantify more specific qualitative aspects of participants' recall and focused on four dimensions involving: (a) references to sensory or perceptual details such as color, size, texture, shape, and so on, and designated as the sensory criterion; (b) references to particular concrete objects portrayed in the videotapes (objects criterion); (c) references to mental or physical actions undertaken by the actors (e.g., she thought or he said) or physical actions undergone by objects in the videotapes (e.g., the stick fell), designated as the actions criterion; and (d) thoughts, feelings, evaluations, or other commentary supplied by the participant with reference to the videotaped events, designated as the subjective criterion. Under this second scoring method, participants were given one point each time they mentioned sensory–perceptual details, objects, actions, and so on (cf. Hashtroudi, Johnson, & Chrosniak, 1990; Hashtroudi, Johnson, Vnek, & Ferguson, 1994; Johnson, Foley, Suengas, & Raye, 1988), regarding the critical events, with credit assigned to the specific critical event to which it applied.

Also included was a measure of recall of auditory information, defined as a set of specific remarks made by the actors, during the critical events, that participants could not readily infer from visual information alone (e.g., that the female professor spoke with someone named Mary on the telephone, or that the art exhibit was closing on Tuesday). This measure was included as a test of the degree to which individuals were remembering the original videotaped episodes (access to which would allow recall of these auditory details) as opposed to only the photographs themselves (which did not directly represent auditory details).

Further measures included tallies of the number of times parti-

cipants mistakenly recalled details concerning the critical events (errors) or recalled critical events out of order relative to the order in which they occurred in the videotapes (sequence errors). An event was counted as out of sequence if there was a back-tracking in the order in which participants recalled the events such that an event that occurred earlier in the videotape was recalled after an event that occurred later in the videotape. The simple omission of an event, but that maintained the ordinal ordering of the events, was not sufficient to count as a sequence error. In addition, because the frequency of errors might be expected to covary with the number of opportunities for error (i.e., fewer errors might occur in some conditions simply because fewer events were recalled), these measures are also reported as conditional values. Conditional errors were defined as *number of errors/number of critical events that were recalled*; conditional sequence errors were defined as *number of sequence errors/number of events recalled −1*. (The latter term served as the denominator for the conditional sequence errors measure because, given our definition of sequence errors, a sequence error was only possible if more than one critical event was recalled.)

Results

The free-recall protocols were scored independently by two raters who were blind to participants' condition and age. For the six primary criteria (number of events recalled, sensory–perceptual details, objects, actions, subjective commentary, and auditory details), the interrater correlations were generally quite high, with an average correlation of .93 (range = .85–.98). The interrater correlation for the sequence errors measure was also quite high (.81) but was less strong for content errors (.63). Analyses were performed on the average of two raters' scores.

The means for the free-recall measures are shown in Table 1. The first two numerical columns show the number of events that were recalled when the events were earlier reviewed with a photograph (R+) or were not reviewed (R−) (maximum per reviewed or nonreviewed condition of 12, including 6 events from each of the two videotapes). The results are shown separately for older and younger adults and as a function of the number of times events were reviewed with photographs (once or thrice). Also shown is the level of recall observed for participants who did not review any events (none condition); the values shown for this condition were obtained by dividing participants' *total* recall for all 24 events by 2, thereby placing the level of recall for all three conditions (None, R+, and R−) on a similar 12-event scale. Subsequent columns show the number of qualitative details recalled for reviewed and nonreviewed events, including sensory–perceptual details, references to objects and actions, subjective commentary, and the amount of auditory information recalled.

Table 1
Free-Recall Results (Experiment 1)

	Scoring criterion											
	No. of events		Sensory		Objects		Actions		Subjective		Auditory	
Group	R+	R−	R+	R−	R+	R−	R+	R−	R+	R−	R+	R−
Older												
None	3.73		1.83		9.23		12.15		0.90		0.96	
SD	1.88		2.12		6.04		6.28		0.77		0.83	
Once	4.88	2.67	1.63	0.92	9.71	4.75	13.46	7.04	1.67	1.71	0.92	0.71
SD	2.11	1.92	1.60	2.18	5.87	4.19	6.56	4.73	3.78	2.50	1.17	1.29
Thrice	7.25	2.92	3.46	1.13	15.29	5.75	19.58	8.46	1.58	1.00	1.21	0.58
SD	2.11	2.58	1.89	1.85	8.11	4.95	8.06	7.50	1.77	1.23	1.08	1.00
M[a]	6.06	2.79	2.54	1.02	12.50	5.25	16.52	7.75	1.63	1.35	1.06	0.65
SD	2.39	2.23	1.95	1.98	7.49	4.51	7.84	6.17	2.89	1.96	1.11	1.13
Younger												
None	5.35		1.54		11.00		20.00		1.50		2.44	
SD	1.24		1.38		4.35		6.16		1.17		0.73	
Once	9.33	5.21	6.50	1.67	21.21	9.46	34.46	21.42	3.00	2.08	3.17	1.96
SD	1.98	2.07	5.56	3.08	7.39	5.50	5.38	7.80	2.60	2.01	0.91	1.45
Thrice	9.79	4.33	4.58	1.79	20.92	7.75	35.75	17.08	3.21	1.13	3.38	1.67
SD	1.47	1.64	2.16	1.48	6.73	4.75	12.47	8.80	4.09	0.93	1.68	1.14
M[a]	9.56	4.77	5.54	1.73	21.06	8.60	35.10	19.25	3.10	1.60	3.27	1.81
SD	1.72	1.88	4.24	2.36	6.91	5.10	9.42	8.43	3.35	1.61	1.33	1.28

Note. R+ designates events for which participants received photo review; R− designates events for which no photo review occurred, given that other events were reviewed; None designates recall in the control group where no events were reviewed.
[a] Column means are based only on the once and thrice groups.

The facilitatory effects of photograph review were examined first. Facilitation was examined by comparing recall scores for the reviewed events in the photograph review groups with one half of the average level of recall in the none group. Thereafter, the presence of possible decrements or impairment in recall due to nonreview was examined by comparing recall scores for the nonreviewed events in the photograph review groups against one half of the average level of recall in the none group. Last, because older and younger adults differed in their overall levels of recall, we also consider two alternate measures that assess facilitation relative to initial levels of recall.

Facilitation Comparisons

We first considered the number of events that participants recalled, regardless of the nature or number of the details they recollected. A 2 (age: old, young) × 3 (review condition: none, once, thrice) analysis of variance (ANOVA) on this measure revealed main effects of age, $F(1, 66) = 44.59$, $MSE = 3.34$, $p < .0001$, and review status, $F(2, 66) = 29.26$, $MSE = 3.34$, $p < .0001$, as well as an interaction of age with review status, $F(2, 66) = 3.76$, $MSE = 3.34$, $p = .03$. Overall, younger adults recalled more of the critical events ($M = 8.16$) than did older adults ($M = 5.29$), and recall of events was greater for the reviewed conditions (Ms = 7.10 and 8.52 for once and thrice, respectively) than in the none condition ($M = 4.54$). Pairwise comparisons (Fisher's PLSD) revealed that all three review conditions differed significantly from one another (thrice > once > none, ps < .01). As noted, however, these effects were also modified by a significant interaction of age with review status. To examine this interaction, we conducted two further ANOVAs contrasting the recall of old and young against the none comparison group for the once versus thrice review conditions separately. These analyses showed that there was a significant interaction of age with review status when events were reviewed only once, $F(1, 44) = 7.17$, $MSE = 3.36$, $p = .01$, with older adults under these conditions gaining less as a function of review (average increase of 1.15 events) than younger adults (average increase of 3.98) but not when events were reviewed three times ($F < 1$; average gain of 3.52 and 4.44 for old and young, respectively).

Next we considered recall as indexed by the various qualitative measures. Separate 2 (age) × 3 (review condition) ANOVAs on each of these measures revealed consistent overall effects of age. Older adults less often provided sensory or perceptual details of events, $F(1, 66) = 8.14$, $MSE = 8.01$, $p = .006$, and made fewer references to objects, $F(1, 66) = 16.77$, $MSE = 42.59$, $p = .0001$, and actions, $F(1, 66) = 65.76$, $MSE = 61.64$, $p < .0001$, than did younger adults. These recall measures also revealed consistent facilitatory effects of photograph review, with recall in each case greater for reviewed events than for the none comparison condition; this beneficial effect was observed for both the once and thrice review conditions: for sensory details, $F(2, 66) = 5.54$, $MSE = 8.01$, $p = .006$, pairwise comparisons: thrice = once > none; for objects, $F(2, 66) = 9.33$, $MSE = 42.59$, $p = .0003$, pairwise comparisons: thrice = once > none; and for actions, $F(2, 66) = 13.65$, $MSE = 61.64$, $p < .0001$, pairwise comparisons: thrice = once > none.

Each of these qualitative measures also showed interactions of age with review status: sensory details, $F(2, 66) = 5.34$, $MSE = 8.01$, $p = .007$; objects, $F(2, 66) = 3.38$, $MSE = 42.59$, $p = .04$; and actions, $F(2, 66) = 4.30$, $MSE = 61.64$, $p = .02$. Subsequent analyses performed on the once and thrice photograph review conditions separately, contrasting older and younger adults' recall gains against the none comparison group, indicated that, for each of these three measures, older participants shown photographs once gained less than did younger participants, $F(1, 44) = 8.05$, $MSE = 9.95$, $p = .007$; $F(1, 44) = 7.86$, $MSE = 36.15$, $p = .008$; and $F(1, 44) = 13.88$, $MSE = 37.35$, $p = .0006$, respectively; in contrast, similar comparisons for the thrice condition showed no significant Age × Review interactions, although there was a trend toward an interaction for one of the measures: actions, $F(1, 44) = 2.78$, $MSE = 74.47$, $p = .10$.

We also looked separately at recall of auditory information (shown in the last two columns of Table 1) because this type of information could be recalled only from the videotapes, rather than from the photographs alone. A 2 (age) × 3 (review condition) ANOVA on this measure showed a main effect of age, $F(1, 66) = 56.39$, $MSE = 1.23$, $p < .0001$, reflecting greater overall recall of auditory details by younger ($M = 2.99$) than older ($M = 1.03$) adults. Although there did not appear to be any overall differences between conditions on this measure, overall $F(2, 66) < 2$, pairwise comparisons: thrice marginally > none, $p = .07$, and no interaction of condition with age ($F < 1$), a consideration of the means (see Table 1) suggests that younger but not older adults tended to benefit from photograph review on this measure. Consistent with this, a more focused analysis including only the auditory information recall scores of younger adults, and comparing the combined photograph review groups (once and thrice) against the none condition, revealed a significant effect of review, $F(1, 34) = 4.07$, $MSE = 1.36$, $p = .05$.

Inhibition or Impairment Comparisons

Inhibition or impairment would be present if participants who did not review any of the videotaped events (the none group) recalled more events or details than participants in the photograph review groups for the nonreviewed (i.e., R−) events. To examine whether there was a significant decrement in the recall of nonreviewed events, we first performed separate 2 (age) × 3 (review condition) ANOVAs on each of the recall measures, now including the R− recall scores as the dependent measure for the photograph review conditions and contrasting these with the recall scores of the none condition.

These analyses revealed quite consistent effects of age, with younger adults recalling more details than older adults on all measures except the sensory details measure and the subjective commentary measure (Fs > 5.6 for events recalled, objects, actions, and auditory details). However, with only one exception, there were no significant effects of review condition; the exception was the objects measure, where a significant overall effect of condition was observed, $F(2, 66) = 3.28$, $MSE = 25.05$, $p = .04$ (all other Fs < 2.0). There were also no interactions of age with review condition (all Fs < 1.6).

To further characterize the effect of review condition on the

objects measure, we combined the two photograph review groups into a single review group and contrasted the average level of recall of objects for the R− events against that in the none control group. A 2 (age) × 2 (review condition: saw photos or none) ANOVA showed a reliable decrement in the recall of objects associated with nonreviewed events (R− average of 6.93) relative to the level of recall observed for the none group (average of 10.12), $F(1, 68) = 6.59$, $MSE = 24.66$, $p = .01$.

Although this analysis yielded evidence of impairment of nonreviewed events on only one of the several recall measures we used, examination of the means in Table 1 suggests that numerical trends toward impairment were present on several further measures. Thus, it is possible that stronger evidence of decreased recall of nonreviewed events would be observed on these measures with a more focused test contrasting the combined once and thrice groups against the none group. However, although analyses performed on the combined groups indicated that there were slight trends toward impairment on the number of events recalled measure, $F(1, 68) = 2.50$, $MSE = 3.70$, $p = .12$, the actions measure, $F(1, 68) = 2.14$, $MSE = 49.43$, $p = .15$, and the auditory details measure, $F(1, 68) = 2.97$, $MSE = 1.19$, $p = .09$, none of these further differences was reliable.

Consideration of the means in Table 1 also suggests that repetition may have had a different overall effect on the nonreviewed items for older versus younger adults. Whereas for most of the measures older participants showed slightly greater recall of the nonreviewed items given three photograph reviews rather than a single review, the reverse was generally true for younger participants. Younger adults tended to show a stronger decrease in recall of the nonreviewed items with three compared to one review, with this decrement (reflecting increased impairment) numerically apparent on the number of events recalled criterion, the objects and actions measures, and the auditory information criterion. Comparing the performance of younger adults for the nonreviewed items in the thrice condition alone against that of younger adults in the none condition for these measures revealed trends toward impairment on the number of events recalled criterion, $F(1, 22) = 2.96$, $MSE = 2.11$, $p = .10$, the objects measure, $F(1, 22) = 3.05$, $MSE = 20.76$, $p = .09$, and the auditory information criterion, $F(1, 22) = 3.91$, $MSE = .91$, $p = .06$. These findings suggest that, for younger adults, reliable impairment of nonreviewed events might be observed across a broader range of measures, at least under conditions involving (a) multiple review opportunities and (b) a sufficiently large sample size to detect what may be somewhat modest decrements in recall.

Facilitation Relative to Initial Levels of Recall

For some, although notably not all, of the facilitation comparisons, there were interactions of age with review status. These interactions were observed under conditions in which participants reviewed photographs once and indicated that, in absolute terms, younger adults gained more as a function of photograph review than did older adults. However, because younger adults generally recalled more events and details than did older adults, we also asked whether—after taking into account their absolute level of recall—the older adults still gained less from previous retrieval practice than did younger adults. This question was addressed in two ways. First, we calculated a *proportion of recall benefit* score for each participant, found by dividing each participant's recall score for the reviewed items (e.g., the number of events recalled for the R+ items) by their total recall score for the reviewed and nonreviewed items (e.g., the total number of events they recalled, for both the R+ and R− events). This measure allows a within-subject assessment of relative facilitation and is, in one respect, readily interpreted: If reviewed events had no recall advantage over nonreviewed events, then this proportion should, on average, be .50; to the extent that reviewed events were differentially accessible relative to nonreviewed events, the proportion should, on average, be greater than .50. For example, for the number of events criterion, the third older participant in the once condition achieved a score of 4.5 for the R+ events and 1.0 for the R− events. Thus, this individual's within-subject proportion recall benefit score for the number of events criterion was $4.5/(4.5 + 1.0) = .818$.

However, this within-subject measure also has a disadvantage, inasmuch as it may reflect the combined effects of facilitation and impairment, because both facilitation (of R+ events) and impairment (of R− events) may be contributing to the total level of recall. To address this issue, we also used a between-subjects proportional measure of recall, where we considered recall of the reviewed events in the photograph group (R+) as a proportion of total recall in the no-photographs or none control group (R+/total recall in the none group).[4] For example, older adults in the none condition recalled, on average, 7.46 of the 24 critical events. (Note that because the values for the none condition shown in Table 1 were divided by 2 to place them on the same scale as the R+ and R− events, the total recall of the none group is twice that shown in the table; for the number of events measure for older adults, this is $2(3.73) = 7.46$.) Thus, the between-subjects proportion benefit score of the older individual above for the number of events criterion would be $4.50/7.46 = .603$.

Table 2 presents the means for these two proportional measures of facilitation as well as the simple difference between reviewed and nonreviewed events for each of the recall measures we used. Shown in the upper panel is the simple difference of reviewed minus nonreviewed events (e.g., for the example participant above, the difference for the number of events criterion would be $4.5 - 1.0 = 3.5$); the middle panel shows the within-subject proportional measure, and the lower panel shows the between-subjects proportional measure.

Using the first (within-subjects) approach, the proportion recall benefit scores for each recall measure were subjected to separate 2 × 2 ANOVAs, treating age (old or young) and repetition (once or thrice) as between-subjects factors. In each case, age differences were no longer apparent once differences in the level of overall recall by the two age groups were taken into account (all Fs < 1 for the main effect of age and the Age × Repetition interaction for event recall, sensory details, objects, actions, and auditory details). For example, the average proportion benefit scores for overall event recall for older and younger adults in the once condition were .66 and .65, respectively; for the thrice condition, they were .75 and .70, respectively.

[4] We thank an anonymous reviewer for suggesting this analysis.

Table 2
Free-Recall Results: Three Measures of Facilitation (Experiment 1)

Measure	Scoring criterion					
	No. of events	Sensory	Objects	Actions	Subjective	Auditory
			Difference			
Once						
Older	2.21	0.71	4.96	6.42	−0.04	0.21
SD	2.58	2.62	7.17	7.48	2.19	0.84
Younger	4.13	4.83	11.75	13.04	0.92	1.21
SD	2.05	3.74	6.96	6.91	2.51	1.44
Thrice						
Older	4.33	2.33	9.54	11.13	0.58	0.63
SD	3.13	2.79	9.58	10.42	1.86	1.28
Younger	5.46	2.79	13.17	18.67	2.08	1.71
SD	1.73	2.16	4.91	7.38	3.80	1.57
			Proportion recall (within subjects)			
Once						
Older	0.66	0.76 (8)	0.70	0.67	0.33 (8)	0.69 (7)
SD	0.21	0.34	0.25	0.21	0.40	0.33
Younger	0.65	0.84	0.70	0.63	0.57	0.66
SD	0.08	0.14	0.11	0.08	0.29	0.17
Thrice						
Older	0.75	0.72	0.74	0.73	0.64 (10)	0.66 (10)
SD	0.19	0.39	0.23	0.21	0.35	0.40
Younger	0.70	0.74	0.75	0.69	0.62 (11)	0.64
SD	0.08	0.21	0.09	0.07	0.25	0.25
			Proportion recall (between subjects)			
Once						
Older	0.65	0.44	0.53	0.55	0.93	0.48
SD	0.28	0.44	0.32	0.27	2.11	0.61
Younger	0.87	2.11	0.96	0.86	1.00	0.65
SD	0.19	1.80	0.34	0.14	0.87	0.19
Thrice						
Older	0.97	0.94	0.83	0.81	0.88	0.63
SD	0.28	0.52	0.44	0.33	0.99	0.56
Younger	0.91	1.49	0.95	0.89	1.07	0.69
SD	0.14	0.70	0.31	0.31	1.36	0.35

Note. The top panel shows the simple difference in recall for reviewed versus nonreviewed events [R+ minus R−]; the middle and lower panels show the proportion of recalled information that related to the reviewed events, with this proportion expressed on a within-subjects basis (middle panel: [R+/(R+ plus R−)]) or a between-subjects basis (bottom panel: [R+/Total recall in none group]). Numbers in parentheses indicate sample sizes, with missing observations arising when no details for a given measure were recalled; unless otherwise indicated, $n = 12$.

Using the second (between-subjects) approach, a 2 (age) × 2 (repetition) ANOVA performed on the proportion scores for the number of events recalled criterion revealed no overall effect of age (proportions for old and young of .81 and .89, respectively); however, there was a significant interaction of age with repetition. Whereas older and younger adults showed nearly equivalent proportionate event recall after three viewings of the photographs (.97 and .91 for older and younger, respectively), younger adults showed greater gains than older adults when photographs were reviewed only once (.87 and .65, respectively), $F(1, 44) = 4.28$, $MSE = .05$, $p = .04$. Similar analyses performed on the other qualitative measures (sensory–perceptual details, objects, and actions) revealed that, for each of these measures, age-related differences were still apparent after taking baseline differences in recall into account, $F(1, 44) = 13.95$, $MSE = 1.05$, $p = .0005$; $F(1, 44) = 7.52$, $MSE = .13$, $p = .009$; and $F(1, 44) = 6.28$, $MSE = .08$, $p = .02$. These age-related differences tended to be somewhat (but not significantly)

more pronounced when the photographs were reviewed only once rather than three times: the largest F for the interaction of age and repetition was for sensory characteristics, $F(1, 44) = 3.60$, $MSE = 1.05$, $p = .06$.

Errors

An initial comparison of recall errors suggested that errors were more frequent for reviewed (R+) events in the photograph review conditions than for the none condition (Ms = 1.96, 1.65, and 1.08 for thrice, once, and none, respectively), $F(2, 66) = 3.92$, $MSE = 1.17$, $p = .02$; pairwise comparisons: once > none, $p = .08$; thrice > none, $p = .007$. However, after conditionalizing on the number of opportunities for error, this pattern was numerically reversed (Ms = .23, .25, and .29, respectively), and there was no effect of condition ($F < 1$). There was no effect of review condition on errors, or conditionalized errors, for the nonreviewed (R−) events (Fs < 1.4).

Considering sequence errors, in absolute terms, younger adults made more sequence errors for reviewed (R+) events than did older adults (Ms = 1.51 and 1.05, respectively), $F(1, 66) = 4.97$, $MSE = .76$, $p = .03$; however, after taking opportunities for such errors into account, the age difference was reversed and nonsignificant (Ms = .21 and .25, respectively; $F <$ 1.2). In absolute terms, there was also a significant effect of review condition on sequence errors for reviewed events, with errors in the ordering of event recall more frequent in the thrice (1.96) and once (1.29) photo review conditions than in the none condition (.58), $F(2, 66) = 14.92$, $MSE = .76$, $p < .0001$, pairwise comparisons: thrice > once > none, ps < .01. This effect of condition on sequence errors for R+ events remained numerically apparent after conditionalizing on opportunities for error (conditionalized sequence errors of .26, .23, and .20 for the thrice, once, and none groups, respectively) but was not significant ($F < 1$). There was no effect of condition on sequence errors for the nonreviewed (R−) events (Fs < 1 for both the absolute and conditionalized measures).

Discussion

This experiment has provided a clear answer to the first of the two questions we posed at the outset. Both older and younger adults showed enhanced recall of events that they had earlier reviewed through photographs relative to the level of recall observed when no review occurred. Thus, previous review benefitted memory of older adults under circumstances in which—at the time of retention testing—retrieval support was minimal. However, the benefits of post-event review for younger adults generally exceeded those for older adults, particularly when photographs were reviewed only once. Considering the absolute differences in levels of recall, older adults benefitted significantly less from review than did younger adults when review occurred only once but not when review occurred three times; this pattern was observed both for overall event recall and the more detailed probes of sensory–perceptual details, objects, and actions. Considering recall as a proportion of each individual's overall recall, the two age groups appeared to gain equally from photograph review; however, using the between-subjects measure to assess relative gain, the pattern was closer to that found for the absolute differences, with older adults generally gaining less through review than younger adults (with the exception of the simple access to events measure for which, with three review opportunities, older and younger adults did not differ).

Taken together, these findings suggest that, for comparatively more complex events, and under conditions of minimal retrieval support at the time of attempted retrieval, the initial differences in memory processes that favor more efficient memory processing by younger than older adults during their first encounter with events may be largely maintained during a subsequent review opportunity. However, age-related differences may be increasingly mitigated with repeated review opportunities. Note that these findings did not arise because the recall of younger adults was at ceiling, without further room for improvement; the total number of qualitative details that might have been recalled regarding the episodes is not known, but the level of recall for the number of events recalled measure was only 78% and 82% for the once and thrice young groups, respectively.

This experiment has also provided a relatively clear answer to the question of whether the mnemonic advantage for events that were previously reviewed with photographs derives only from facilitation of the reviewed items, or if impaired or decreased recall for nonreviewed events is also a substantial contributing factor. Comparisons of participants' recall for events that were not reviewed (given that other events were reviewed) against the average level of recall in the none control group revealed only relatively weak trends toward impairment on some of the recall measures we used (number of events recalled, references to actions, and auditory details), with significant impairment found on only one of the measures (references to objects). For young participants, these decrements in the recall of nonreviewed events tended to be more pronounced following repeated viewing of the photographs rather than only a single viewing, with younger adults who had reviewed photographs three times showing trends toward impaired recall of R− events for the number of events criterion, the objects criterion, and the auditory details criterion. Nonetheless, none of these decreases in the recall of nonreviewed events was, in numerical terms, very large, particularly when placed alongside the extremely consistent and robust facilitatory effects that were observed. Possible factors that may have acted to reduce the degree to which recall of the nonreviewed events was impaired are outlined in the General Discussion.

Considering the various qualitative measures of recall, post-event review led to significant facilitation of memory for auditory details associated with the videotaped events only for younger adults but not for older adults. One possible interpretation of this finding is that—particularly for older adults—a considerable portion of what appears to be enhanced memory for the original experience of watching the videotaped events is actually memory for the review stimuli themselves (which provided direct reinforcement for visual information but not auditory details) rather than the original videotaped episode (cf. Johnson, Hashtroudi, & Lindsay, 1993; Schacter, Koutstaal, Johnson, et al., 1997; Schacter, Koutstaal, & Norman, 1997). The possibility that a later pictorial or verbal account of an event might surreptitiously usurp the place of one's original memory for that event has been raised in literary and biographical accounts (Barthes, 1981; Stendhal, 1890/1995, p. 453; see

also Usher & Neisser, 1993, p. 164) and, indeed, in our experiment, some contribution of this form cannot be conclusively ruled out.

Nonetheless, it is unlikely that source confusions of this form can account for all of the facilitation that we observed for two reasons. First, if individuals had often based their recall entirely on the photograph, then they would not have been able to recall events slightly before and following the depicted events, that is, the temporal microstructure surrounding the reviewed events. Yet the vast majority of the recall protocols, for both older and younger adults, included numerous such details. For example, many participants described the methodical manner in which the female professor (in the office videotape) retrieved and then removed a thermos from her briefcase: initially attempting to rest the briefcase on her lap, but then opting to rest it on another surface instead; pouring what was assumed to be coffee into a cup from the top of the thermos; replacing the thermos, without its outer cup, into the briefcase; and then returning the briefcase to its original place under her desk. Yet the photograph relating to this extensive series of events simply depicted the female professor with the thermos in one hand and the briefcase in front of her. Second, despite the fact that the photographs were presented in an entirely different (and random) order relative to the order of the events that they depicted in the original videotape, participants relatively rarely made sequence errors, most often recalling the events in the order in which they occurred. The average number of sequence errors for the reviewed events (i.e., the 12 R+ events) for older adults in the photograph review conditions was 1.31; that for younger adults was 1.94. Although, in both age groups, sequence errors were significantly more frequent when photographs were reviewed than when no review occurred (for older adults, mean for no review = .52; for younger adults, mean for no review = .65), and a numerical difference in this direction remained after conditionalizing on the number of opportunities to make such errors (mean conditional sequence errors for three, one, and no reviews of .26, .23, and .20, respectively), the number of temporal sequence errors is considerably lower than would be anticipated if participants were recalling only the (incorrectly ordered) photographs.

This suggests that individuals were most often recalling the original videotape and that some other factor is necessary to account for the enhanced retrieval of auditory information relating to the reviewed events for younger but not older adults. One possibility is that older adults simply encoded so little auditory information to begin with, that they could not gain anything from review (although note that in both the once and thrice review groups, recall of auditory details for reviewed events by older adults numerically exceeded that for nonreviewed events, and this difference was larger for those who reviewed photographs three times than for those who received only one review). Another interpretation is that review of photographs may facilitate recollection of nonportrayed but associated information only to the extent that the associated information is comparatively well-bound into an integrated trace. To the extent that the diverse episodic features associated with a particular event might be less tightly interassociated and bound with one another for older than younger adults (cf. Chalfonte & Johnson, 1996; Johnson & Chalfonte, 1994), reinstatement of some of the components of the trace (e.g., those relating to the visual appearance of the scene) might yield fewer benefits for such associated but not directly reinstated information for older than younger adults.

This last possibility emphasizes comparatively automatic processes or outcomes associated with reinstatement: Given an initially well-integrated trace, reinstating some salient aspect of the event may largely automatically increase the activation and accessibility of other aspects of the event. However, it is also possible that age-related differences arose because of differences in how older and younger adults deliberately or consciously used the photographs as reminders: Perhaps younger adults were more active in their review than older adults and attempted more extensive retrieval in response to the photographs than did older adults. This account might also apply to the difference in relative gains achieved by older and younger adults for one versus three review opportunities: Perhaps younger adults consistently engaged in more extensive retrieval effort than older adults (see Schacter, Savage, Alpert, Rauch, & Albert, 1996, for relevant data from a brain imaging study), and the effects of this difference were most pronounced following a single review opportunity. Researchers have sometimes appealed to the importance of retrieval effort to account for the results of previous rehearsal (Kausler & Wiley, 1990, p. 188) or attempted semantic retrieval (Gardiner, Craik, & Bleasdale, 1973) on later recall. For example, Whitten and Leonard (1980; cf. Bjork, 1988) found greater improvement on a free-recall test if participants had earlier been tested on a multiple-choice recognition test that required particular care in selecting the correct response (because of the presence of a larger number of alternatives or of semantically related alternatives). It is possible that, in this experiment, older adults were especially likely to simply "stay with" the information that the photograph provided, whereas younger adults more often tended to use the photographs as prompts for further (self-initiated) recollection of nonportrayed details. In Experiment 2, we examined the consequences of a single post-event review for older and younger adults when, as in Experiment 1, review was prompted by a photograph compared with a situation where review might have required more active reconstructive efforts by the participant—where individuals were provided only brief and relatively abstract verbal accounts of the events.

Experiment 2

The primary purpose of this experiment is to determine whether the mnemonic gains that accompanied review in Experiment 1 and in the two experiments reported in Schacter, Koutstaal, Johnson, et al. (1997) are specific to the photographic elements of the reminder cues—that is, the rich visual and perceptual reinstatement they provide—as opposed to their more abstract informational value, including the provision of quite general (not necessarily even perceptual) reminders of the videotaped events. Do older and younger adults show a similar pattern of facilitation as a consequence of post-event review if, rather than reviewing some of the previously experienced events through looking at photographs, they instead read a brief and comparatively abstract verbal account of those events?

Several possible factors may contribute to the degree to which different forms of post-event review yield later benefits for older and younger adults. Verbal descriptions may elicit greater or

more extensive efforts at reactivation or retrieval than do photographs, and this may offset or compensate for their relatively less strong perceptual and contextual reinstatement value. As noted earlier, researchers have sometimes appealed to the importance of retrieval effort to account for the results of previous rehearsal (Kausler & Wiley, 1990) as well as the effects of previous recognition testing on later recall (Whitten & Leonard, 1980). Review prompted by verbal descriptions may also involve a stronger generational component (Slamecka & Graf, 1978) than review prompted by photographs. Thus, the greater cognitive operations evoked by verbal descriptions may offset the greater pictorial vividness of photographs, resulting in equal (or possibly even greater) benefits following post-event review prompted by abstract verbal cues than following review in response to photographs.

To address this question, we generated brief verbal descriptions for each of the photographs that were used in Experiment 1, describing the same events as depicted in the photographs but omitting most sensory or perceptual details concerning the events or scenes. Participants then either reviewed one half of the events from the videotapes in exactly the same manner as in Experiment 1, through viewing photographs of the events, or, instead, read these brief verbal descriptions. For example, for the office videotape, some participants saw a photograph of the male professor showing the female professor a newspaper, whereas other participants read the following description: "The male professor is standing near the female professor's desk. He is beginning to open a newspaper while she, also standing near her desk, looks on." Likewise, for the park videotape, some participants saw a photograph of the female student locking her bicycle to a park bench, whereas others read a brief verbal description of that event. Both the photographs and verbal descriptions were reviewed once. We also included a no-review control group: As in Experiment 1, participants in this condition were asked to copy three-dimensional abstract figures during the time that participants in the photograph and description review groups engaged in post-event review. Thereafter, free recall of all of the events was assessed.

Method

Participants. Participants included 36 older (M age = 67.5 years, SD = 4.2, range = 60–74) and 36 younger (M age = 20.1 years, SD = 3.2, range = 16–30) individuals, all of whom were screened for medical and neuropsychological conditions in the same manner as in Experiment 1. Older participants had more formal education (M = 15.4 years, SD = 2.7, range = 12–21) than younger participants (M = 13.9, SD = 1.7, range = 12–19), $F(1, 70) = 7.54$, $MSE = 5.08$, $p = .008$. Younger adults obtained higher scores on the WAIS–R Vocabulary subscale (M = 63.9, SD = 4.6, range = 50–70) than did older adults (M = 57.1, SD = 8.3, range = 38–68), $F(1, 70) = 19.09$, $MSE = 44.74$, $p < .0001$. Younger adults' performance on the General Information WAIS–R subscale (M = 24.7, SD = 2.9, range = 16–29) also exceeded that of the older adults' (M = 21.9, SD = 4.0, range = 14–27), $F(1, 70) = 11.72$, $MSE = 12.21$, $p = .001$.[5]

Design. The experimental design was a 2 × 3 factorial, with age (old or young) and condition (photographs, verbal descriptions, and none) as between-subjects variables. In addition, embedded within this factorial design, for the photographs and verbal descriptions, there was a within-subjects variable of review status (reviewed or not reviewed). Within each age group, participants were assigned to the photograph and verbal description conditions according to a predetermined random order, with stimulus sets (Set A or Set B) counterbalanced within each condition. Older and younger participants in the none control group were run at a later time than those in the two review groups; older adults in this control group were of similar age and education to those in the two review conditions (Fs < 1) as were younger adults (Fs < 1.5). Older adults in the none control group achieved higher vocabulary scores (M = 60.5) than those in the description condition (M = 52.8), $F(2, 33) = 3.06$, $MSE = 60.98$, $p = .06$, but did not differ from those in the photographs condition (M = 57.9); these three groups did not differ in performance on the General Information subtest ($F < 1$). Younger adults in the none control group achieved lower vocabulary scores (M = 60.2) than those in the description (M = 65.6) or photographs (M = 66.1) groups, $F(2, 33) = 8.75$, $MSE = 14.77$, $p = .0009$. Individuals in the none control condition and the photograph condition did not differ on the General Information subtest (Ms = 25.8 and 25.2, respectively), but scores in the none control condition exceeded those in the description condition, $F(2, 33) = 3.18$, $MSE = 7.59$, $p = .05$ (see Footnote 5).

Procedure. Except for the inclusion of an additional verbal description group, the experimental procedure closely paralleled that used in Experiment 1. Participants first watched the two videotapes, then 2 days later returned to the laboratory and viewed photographs or read verbal descriptions of one half of the events from the videotapes they had watched (all participants reviewed photographs or descriptions once). Finally, they were given a free-recall test for all of the events.

The instructions during the review phase for participants in the verbal description condition were highly similar to those used for the photograph review group in Experiment 1. Participants were told:

> Sometimes when we read a description of an event, the descriptions are just like our memories of the event or scene. Sometimes they seem different. You will be reading brief descriptions of events from the videotapes that you watched earlier. I would like you to carefully read each description. At the same time, please think about *your own memory* of that event or scene. Then rate how well the description matches your memory on a 5-point scale, where 1 indicates that the description does not at all match your memory and 5 indicates the description exactly matches your memory.

The order of viewing the two videotapes was counterbalanced, with an equal number of participants in each condition watching either the office videotape or the park videotape first, followed by the other tape. Participants received the free-recall test for the two videotapes in the same order as they had viewed the tapes.

Results

Table 3 shows the means for the free-recall measures, with performance shown separately by age (old or young), type of reminder (photographs or verbal descriptions), and review status (reviewed or not reviewed). The initial two columns show the number of events recalled; subsequent columns show qualitative responses, including the amount of auditory information recalled. In view of the high interrater reliabilities that were found in Experiment 1, all protocols were scored by one rater, using the same criteria as used in Experiment 1.

[5] Restricting analyses to a subset of older (n = 26) and younger (n = 26) participants, whose performance on the Vocabulary and General Information WAIS–R subtests was equated across age (Fs < 1.96) and condition (Fs < 1.2), yielded a pattern of means for the dependent measures that was very similar to that obtained for the entire sample.

Table 3
Free-Recall Results (Experiment 2)

	Scoring criterion											
	No. of events		Sensory		Objects		Actions		Subjective		Auditory	
Group	R+	R−	R+	R−	R+	R−	R+	R−	R+	R−	R+	R−
Older												
None	3.33		0.38		5.13		8.04		0.88		1.00	
SD	1.74		0.61		4.83		6.64		1.09		0.91	
Photo	5.58	3.25	1.08	0.42	9.92	5.25	12.00	9.00	1.75	1.08	0.92	0.75
SD	1.73	1.87	1.17	0.67	4.38	6.33	7.16	7.71	2.56	2.11	1.24	0.97
Descrip	6.25	3.00	1.08	0.50	11.83	5.50	13.33	7.33	1.00	0.67	1.25	0.42
SD	2.34	1.54	1.08	1.24	6.06	4.03	6.44	5.43	1.41	0.99	1.55	0.67
M[a]	5.92	3.13	1.08	0.46	10.88	5.38	12.67	8.17	1.38	0.88	1.08	0.58
SD	2.04	1.68	1.10	0.98	5.26	5.19	6.70	6.58	2.06	1.62	1.38	0.83
Younger												
None	4.46		0.71		7.54		12.21		1.04		2.38	
SD	1.20		0.87		2.27		4.73		1.14		1.37	
Photo	9.50	6.00	6.00	2.17	22.08	10.83	29.08	17.50	2.58	1.17	4.42	3.50
SD	1.73	2.30	3.67	1.90	8.62	5.75	8.19	7.39	4.06	0.94	1.93	1.83
Descrip	9.00	4.83	3.67	1.75	22.92	11.50	31.92	19.08	1.00	1.92	2.75	2.50
SD	2.05	1.40	3.45	1.71	10.98	5.14	13.53	9.18	1.13	2.15	2.01	1.83
M[a]	9.25	5.42	4.83	1.96	22.50	11.17	30.50	18.29	1.79	1.54	3.58	3.00
SD	1.87	1.95	3.68	1.78	9.66	5.35	11.03	8.19	3.02	1.67	2.10	1.87

Note. R+ designates events for which participants received review (through either photographs or descriptions); R− designates events for which no review occurred, given that other events were reviewed; None designates recall in the control group where no events were reviewed. Descrip = description group.
[a] Column means are based only on the photograph and description groups.

Facilitation Comparisons

We first examined the number of events recalled. A 2 × 3 ANOVA treating age (old or young) and reminder condition (photographs, descriptions, or none) as between-subjects variables showed that, overall, young adults recalled more events than did older adults, $F(1, 66) = 36.25$, $MSE = 3.35$, $p = <$ .0001. There was also a significant overall effect of reminder condition, $F(2, 66) = 32.40$, $MSE = 3.35$, $p < .0001$, and a significant interaction of age with reminder condition, $F(2, 66) = 3.52$, $MSE = 3.52$, $p = .04$. Pairwise comparisons showed that recall in the review conditions exceeded that in the none condition ($M = 3.90$), both when photographs ($M = 7.54$) and when verbal descriptions ($M = 7.63$) were reviewed, but there was no difference in the reminder value of photographs versus descriptions ($ps < .0001$ for descriptions vs. none and verbal descriptions vs. none).

The Age × Reminder Condition interaction was further explored by additional analyses performed on each of the reminder groups separately. These analyses revealed a significant interaction of age with review for the photographs condition, $F(1, 44) = 8.96$, $MSE = 2.61$, $p = .005$, but not for the description condition, $F(1, 44) = 2.25$, $MSE = 3.53$, $p = .14$. Compared with their respective none control groups, younger adults who reviewed photographs showed greater recall gains than did older adults (gains attributable to review of 5.04 vs. 2.25, respectively, or a difference in differences of 2.79); the corresponding age-related difference for individuals who reviewed events using descriptions was less marked (gains of 4.54 vs. 2.92, respectively, difference of 1.62).

We next considered the qualitative recall measures. These analyses showed consistent effects of age such that, overall, young adults recalled more sensory–perceptual details, $F(1, 66) = 25.41$, $MSE = 4.83$, $p < .0001$, more objects, $F(1, 66) = 28.31$, $MSE = 46.55$, $p < .0001$, and more actions, $F(1, 66) = 46.53$, $MSE = 68.20$, $p < .0001$, than did older adults. For each of these measures, there was also an overall effect of review condition, reflecting greater recall in the conditions with review than those with no review: sensory, $F(2, 66) = 11.36$, $MSE = 4.83$, $p < .0001$; objects, $F(2, 66) = 18.67$, $MSE = 46.55$, $p < .0001$; actions, $F(2, 66) = 15.78$, $MSE = 68.20$, $p < .0001$; pairwise comparisons for all three measures: photo = description > none. These effects were, in each case, modified by interactions with age: sensory, $F(2, 66) = 6.52$, $MSE = 4.83$, $p = .003$; objects, $F(2, 66) = 3.68$, $MSE = 46.55$, $p = .03$; and actions, $F(2, 66) = 5.53$, $MSE = 68.20$, $p = .006$. Further analyses considering recall scores for each reminder type separately revealed that younger adults gained more from review than did older adults on each of these measures, regardless of review type (all Fs for Age × Review interaction > 4.29).

As in Experiment 1, we also looked separately at recall of

auditory information (shown in the last two columns of Table 3) because this type of information could only be recalled from the videotapes rather than from the photographs or descriptions alone. A 2 (age) × 3 (reminder condition) ANOVA of the auditory scores revealed greater recall of auditory information by younger than older adults, $F(1, 66) = 33.98$, $MSE = 2.39$, $p < .0001$. There was also a trend toward an overall effect of reminder condition, $F(2, 66) = 2.51$, $MSE = 2.39$, $p = .09$; and a significant interaction of age and reminder condition, $F(2, 66) = 3.57$, $MSE = 2.39$, $p = .03$. Pairwise comparisons revealed that overall recall of auditory information was greater for individuals who had reviewed photographs than for the none comparison condition ($p < .03$); there was no corresponding difference for individuals who had reviewed verbal descriptions. However, consideration of the means (see Table 3) indicates that the effect in the photograph review condition was borne entirely by younger adults. An analysis contrasting performance in the R+ condition of the photograph review group against the none condition, and considering only younger adults, revealed a significant effect of condition, $F(1, 22) = 8.95$, $MSE = 2.80$, $p = .007$.

Inhibition or Impairment Comparisons

Description and photograph review conditions combined. Because Experiment 1 showed only relatively weak impairment in the recall of nonreviewed events, with significant impairment observed on only one of the recall measures, to maximize the power of our comparisons we first examined whether recall of nonreviewed events was impaired relative to recall in the none control condition when combining the two review conditions (photographs and descriptions). There was no indication of impaired recall of nonreviewed events for any of the measures. Indeed, for several of the measures for older adults, and all of the measures for younger adults, recall related to the nonreviewed (R−) events exceeded that for the none control condition. Overall, combining across older and younger adults, recall of sensory–perceptual details associated with the nonreviewed (R−) events was significantly greater than that for the none control condition, $F(1, 68) = 4.51$, $MSE = 1.58$, $p = .04$, and a similar trend was apparent for the actions measure, $F(1, 68) = 3.21$, $MSE = 48.08$, $p = .08$. However, in both instances these differences tended to be carried more by younger than older adults (see means in Table 3): interaction of age with review for sensory details, $F(1, 68) = 3.45$, $MSE = 1.58$, $p = .07$; for actions, $F(1, 68) = 2.95$, $MSE = 48.08$, $p = .09$.

Description and photograph review conditions separately. Analyses performed on the description and photograph review conditions separately also revealed no evidence of impaired recall of the R− events. For the description versus none comparisons, there were nonsignificant trends for performance in the nonreviewed (R−) condition to exceed that in the none condition (largest $F = 3.16$ for objects), although these trends were primarily carried by younger adults (see Table 3). Similar patterns were observed for the photograph versus none comparisons except that, for the sensory details criterion, there was a significant effect of condition, $F(1, 44) = 5.22$, $MSE = 1.29$, $p = .03$, and an interaction of age with condition, $F(1, 44) = 4.66$, $MSE = 1.29$, $p = .04$. Combining across age, recall of sensory details was greater for the nonreviewed events than in the none control condition, but this difference was nearly entirely carried by younger adults.

Facilitation Relative to Initial Levels of Recall

As in the previous experiment, we also examined performance after taking the overall age differences in level of memory performance into account, with two different approaches: a within-subjects approach, in which recall for reviewed events was calculated as a proportion of each individual participant's own overall recall level, and a between-subjects approach, in which recall for reviewed events was expressed as a proportion of recall in the none control condition. The means for each of these measures, as well as for the simple difference for reviewed compared to nonreviewed events, are presented in Table 4 (upper panel: reviewed minus nonreviewed difference; middle panel: within-subjects proportional measure; lower panel: between-subjects proportional measure).

A 2 (age) × 2 (reminder type) ANOVA on the number of events recalled measure, when this was expressed as a proportion of each individual's own recall, showed no effect of age and no interaction of age with reminder type (Fs < 1); proportion recall scores for older versus younger adults for photographs = .65 and .62, respectively; for descriptions = .68 and .65, respectively. Similar analyses performed on the qualitative measures in which the scores achieved on these measures were also expressed as a proportion of the individual's overall recall likewise indicated no differential effects of review associated with age ($F < 1.9$ for sensory details, $F < 1.5$ for objects, and $F < 1$ for actions and auditory information).

Next, considering values as a proportion of the no-review comparison group, a 2 (age) × 2 (reminder type) ANOVA on these scores revealed a marginal effect of age, $F(1, 44) = 3.84$, $MSE = .07$, $p = .06$, reflecting the finding that younger adults were somewhat more likely to recall reviewed events ($M = 1.04$) than were older adults ($M = .89$) when recall of reviewed events was considered as a proportion of baseline performance in the no-review comparison condition. This difference was not affected by reminder type ($F < 1.1$ for the Age × Reminder Type interaction). Similar analyses performed on the qualitative measures revealed strong and consistent age differences on three of the objective measures, including sensory details, $F(1, 44) = 10.86$, $MSE = 4.28$, $p = .002$; objects, $F(1, 44) = 6.41$, $MSE = .35$, $p = .02$; and actions, $F(1, 44) = 13.15$, $MSE = .20$, $p = .0007$, but no difference for subjective commentary ($F < 1$) or for auditory details ($F < 1.7$), and no interactions with reminder type (Fs < 2.5).

Errors

An initial analysis suggested that errors were somewhat, although not significantly, more frequent for reviewed (R+) events in the photograph ($M = 1.25$) and description ($M = 1.29$) conditions than in the none condition ($M = .67$), $F(2, 66) = 2.72$, $MSE = 1.08$, $p = .07$; pairwise comparisons: descriptions > none, $p = .04$, photographs > none, $p = .06$. However, after conditionalizing on the number of opportunities for error, this pattern was no longer observed (Ms = .16, .16,

Table 4
Free-Recall Results: Three Measures of Facilitation (Experiment 2)

Measure	No. of events	Scoring criterion: Sensory	Objects	Actions	Subjective	Auditory
			Difference			
Photo						
Older	2.33	0.67	4.67	3.00	0.67	0.17
SD	2.61	1.16	5.48	6.00	2.74	0.94
Younger	3.50	3.83	11.25	11.58	1.42	0.92
SD	2.91	3.35	7.62	7.60	3.75	2.39
Descrip						
Older	3.25	0.58	6.33	6.00	0.33	0.83
SD	3.02	1.17	5.98	7.54	1.30	1.53
Younger	4.17	1.92	11.42	12.83	−0.92	0.25
SD	2.17	3.12	8.87	11.04	2.19	2.38
			Proportion recall (within subjects)			
Photo						
Older	0.65	0.77 (8)	0.75	0.63	0.72 (9)	0.53 (8)
SD	0.19	0.25	0.20	0.19	0.39	0.39
Younger	0.62	0.72	0.67	0.63	0.57 (11)	0.57
SD	0.11	0.27	0.14	0.12	0.34	0.20
Descrip						
Older	0.68	0.85 (7)	0.69	0.66	0.62 (8)	0.72 (8)
SD	0.13	0.27	0.14	0.15	0.38	0.36
Younger	0.65	0.66 (11)	0.66	0.62	0.35 (10)	0.52
SD	0.07	0.24	0.11	0.11	0.37	0.27
			Proportion recall (between subjects)			
Photo						
Older	0.84	1.44	0.97	0.75	1.00	0.46
SD	0.26	1.55	0.43	0.45	1.46	0.62
Younger	1.07	4.24	1.46	1.19	1.24	0.93
SD	0.19	2.59	0.57	0.34	1.95	0.41
Descrip						
Older	0.94	1.44	1.15	0.83	0.57	0.63
SD	0.35	1.45	0.59	0.40	0.81	0.77
Younger	1.01	2.59	1.52	1.31	0.48	0.58
SD	0.23	2.43	0.73	0.55	0.54	0.42

Note. The top panel shows the simple difference in recall for reviewed versus nonreviewed events [R+ minus R−]; the middle and lower panels show the proportion of recalled information that related to the reviewed events, with this proportion expressed on a within-subjects basis (middle panel: [R+/(R+ plus R−)]) or a between-subjects basis (bottom panel: [R+/total recall in none group]). Numbers in parentheses indicate sample sizes, with missing observations arising when no details for a given measure were recalled; unless otherwise indicated, $n = 12$. Descrip = description group.

and .18 for photos, descriptions, and none, respectively; $F < 1$). There was no effect of review condition on errors, or conditionalized errors, for the nonreviewed (R−) events (Fs < 1).

Errors in the order in which events were recalled (i.e., sequence errors) were, in absolute terms, modestly and nonsignificantly more common for reviewed (R+) events in the two review conditions than in the none condition (Ms = 1.38, 1.17, and .79 for photographs, descriptions, and none, respectively; $F < 1.8$). After taking into account the number of opportunities for this type of error, this trend was nonsignificantly reversed, with conditionalized sequence errors in the none condition (.34) tending to exceed those in the photographs (.29) and descriptions (.15) conditions, $F(2, 63) = 2.47$, $MSE = .095$, $p = .09$ (three cases omitted with missing values; pairwise comparisons: none > descriptions, $p = .04$). For the nonreviewed (R−) events, there was no effect of review condition on the absolute measure of sequence errors ($F < 1$). On the conditionalized measure, there was a tendency for more errors to occur in the

none condition (.34) than in the descriptions (.26) or photographs conditions, $F(2, 60) = 2.77$, $MSE = .08$, $p = .07$ (six cases omitted with missing values; pairwise comparisons: none > photos, $p = .02$). In absolute terms, younger adults tended to show somewhat more frequent sequence errors for nonreviewed events (.81) than did older adults (.50), $F(1, 66) = 3.29$, $MSE = .51$, $p = .07$. However, this pattern was no longer apparent and was slightly reversed (younger = .22, older = .27) after conditionalizing on error opportunities ($F < 1$).

General Discussion

These experiments have provided three specific findings regarding the degree to which post-event review of complex everyday events may affect the subsequent memory performance of older and younger adults. First, Experiments 1 and 2 clearly and unambiguously demonstrate that beneficial effects of post-event review of complex events are observed in older adults under conditions of minimal cuing at the time of their recollection of the reviewed events. Second, we have shown that the consequences of post-event review—at least under circumstances similar to those of our paradigm—are primarily attributable to facilitation of participants' memory for the reviewed events rather than impairment or decreases in memory for the nonreviewed events. Third, we found largely equivalent effects from reviewing earlier experienced events, regardless of whether the reminder cues were photographs that provided a strong perceptual reinstatement of the earlier events or were comparatively abstract verbal accounts in which exploiting the reminder value of the cue demanded considerable reconstructive effort by the participant. Each of these three findings will be discussed in turn.

Aging and Review

Both older and younger adults' recollection of earlier experienced events was substantially improved by later reviewing those events, either through looking at photographs or reading verbal descriptions, and the relative magnitude of this improvement—considered on a within-subjects basis—was similar in older and younger adults. These findings are consistent with earlier reports of equivalent benefits in older and younger adults due to retrieval practice using verbal materials (Rabinowitz & Craik, 1986) or simple self-performed activities (Kausler & Wiley, 1990) and with our own report that older and younger adults show equal benefits of post-event review with photographs when later tested by a verbal recognition test (Schacter, Koutstaal, Johnson, et al., 1997). Our results extend the demonstration of equal relative benefit of review, irrespective of age, to the free recall of complex events and provide evidence that post-event review enhances objectively determined recollection of event details as well as self-reports of recollection (Schacter, Koutstaal, Johnson, et al., 1997).

However, considered on a between-subjects basis, the relative facilitation of older adults due to previous review was less than that for younger adults and, in absolute terms, older adults generally gained less than younger adults. The age-related factors that lead to differences in the level of recall in the absence of any review opportunities may also generally be present during the review opportunities themselves, so that although older adults acquire clear memory gains from such review, they remain relatively less able to profit from the review than do their younger counterparts. The data from the repetition manipulation in Experiment 1, however, suggest that repeated review opportunities may allow older adults to begin to close this gap.

Impairment Versus Facilitation

In these experiments, post-event review produced relatively little (Experiment 1) or no (Experiment 2) impairment of recall for the nonreviewed events. This suggests that, at least under some conditions, considerable facilitation of event memory by post-event review can be achieved with only relatively minor attendant costs due to decreased recall of the nonreviewed events, whether arising directly, and involving an actual decrement in the activation or strength of the memory representations of the nonreviewed events (inhibition), or indirectly, and deriving from the excessive dominance or accessibility of the reviewed events (e.g., blocking, interference with individuals' subjective retrieval organization for the episode as a whole, premature curtailment of efforts to recall, and so on; for review and discussion, see Anderson & Bjork, 1994; Koutstaal & Schacter, 1997).

However, stronger impairment of memory for nonreviewed events may emerge under other conditions, such as with more frequent review. The absence of impaired recall for the R− events in Experiment 2 might—at least for younger adults—partially be explained by this factor. Younger adults in the once condition of Experiment 1 (which, like that of Experiment 2, involved only a single review) also showed relatively little recall impairment for nonreviewed events and, indeed, for two of the objective measures (sensory details and actions), recall in the R− condition numerically exceeded that in the none condition (the pattern observed for all of the objective measures of Experiment 2). Greater impairment of nonreviewed events might also occur if the review occasions are more temporally distributed or spaced across time. Although the repeated viewings of the photographs in Experiment 1 were spaced inasmuch as each of the events from the two videotapes was reviewed once before the second or third reviews occurred, these reviews themselves occurred in massed fashion, with each review directly succeeding the former review. To the extent that distributed reviews might enhance recall of the reviewed events more than massed reviews (Cull, Shaughnessy, & Zechmeister, 1996; Landauer & Bjork, 1978), and impaired recall of the nonreviewed events derives from the relative dominance of the reviewed events, distributed reviews (which may more closely parallel how individuals review photographs in everyday life) may have more detrimental effects on the nonreviewed events.

It may also be important that, in these experiments, the events that were reviewed were drawn from two quite different spatiotemporal contexts (the office and park videotapes). Stronger impairment may have been observed from the same number of review cues if all of the reviewed events were drawn from one episode or context. For instance, greater decrements in the recall of noncued items have been observed in the part–set cuing paradigm with the provision of additional members from within a given studied category (Roediger, 1973; Rundus, 1973; cf.

Roediger & Neely, 1982). Indeed, recent work that we have conducted, using a somewhat modified photograph review paradigm (Koutstaal, Schacter, Johnson, & Galluccio, 1997), in which individuals themselves perform activities in the laboratory and then review some of these activities by looking at photographs, suggests that consistent and reliable impairment of nonreviewed events may be observed in both older and younger adults under some conditions. In this modified paradigm, we found that both older and younger adults showed impaired memory for nonreviewed events under conditions in which individuals were provided multiple review opportunities, all events occurred in a single spatiotemporal context, and memory was tested with free recall.

Although these experiments provided little evidence for impairment of nonreviewed events, when hints of such impairment were found, they were generally found for older as well as younger adults (e.g., for older adults, the numerical patterns in Experiment 1 were toward impairment of recall for the R− events in both the once and thrice review conditions and, for the once condition, were more consistent across the different measures than for younger adults). Whereas older adults often show less inhibition than younger adults in tasks requiring the active suppression of irrelevant or no longer relevant information (Hartman & Hasher, 1991; Hasher & Zacks, 1988; Zacks & Hasher, 1994; Zacks, Radvansky, & Hasher, 1996), inhibition of nonreviewed events in our post-event review procedure (to the degree that it is present at all) presumably occurs as an indirect consequence of reviewing other events. From this perspective, provided that the review cues are sufficiently specific to allow older adults to readily identify and focus on the to-be-reviewed events, older and younger adults might be expected to show similar amounts of inhibition (cf. Hartman, 1995). Other sources of impairment of nonreviewed events (e.g., output interference due to the heightened accessibility of the reviewed events or premature curtailment of the effort to retrieve the nonreviewed events due to the comparative ease of recalling the reviewed events) may also play a role, and might contribute to impairment in both older and younger adults. Nonetheless, the conclusions of our experiments concerning post-event review clearly and unambiguously point to the facilitatory consequences of such review. The results of these experiments suggest that, under the conditions we used, most of the mnemonic advantage observed for reviewed compared with nonreviewed events derived from facilitation of the former rather than inhibition or impairment of the latter.

Photographs Versus Descriptions

In general, there was very little evidence, for either older or younger adults, of differential gains in memory facilitation due to reminder type. One exception concerned auditory information, where recollection of auditory details was facilitated by photograph review for younger adults but not by verbal descriptions, and not by either type of review in older adults. Although caution is necessary in interpreting this finding, which may simply reflect poor sensitivity in our experiments (the numerical differences were in the direction of increased facilitation for both older and younger adults in all conditions), it may relate to the degree to which auditory information was automatically reactivated by the review stimuli. The verbal descriptions comprised comparatively abstract or generic pointers to the relevant events. Participants' attempts to recollect the events to which these descriptions referred would not necessarily focus on auditory information, as many features were involved in each event. In contrast, exposure to the photographs may have acted to initially and directly reinstate more perceptual information, which may then have allowed additional (probably largely automatic) reactivation of associated auditory information. Note that the pattern of significant facilitation in the recall of auditory information for younger but not older adults in the photograph review condition of Experiment 2 replicates the findings from Experiment 1 and is not inconsistent with this interpretation.

A further (slight) difference between the photograph and description conditions was that, for the comparatively coarse measure of access to events (Was an event recalled at all?), the absolute recall gains of younger adults due to review significantly exceeded those of older adults only for the photographs condition and not for the verbal description condition. However, for the more detailed measures, younger adults consistently gained more than older adults, regardless of reminder type.

One possible interpretation of the primarily parallel effects of photographs and verbal descriptions is that the beneficial mnemonic consequences achieved through post-event review are driven largely by an abstract component, such that—provided that some central aspect of an event is reactivated—substantial gains in the subsequent recall of the event will be attained regardless of how this reactivation of general event knowledge occurs (although subtle differences might be observed under some conditions). However, as noted earlier, it is also possible that the equivalence results from different task components and processes invoked by the two types of reminders: Verbal descriptions may elicit more extensive efforts at reactivation or retrieval than do photographs, and this may offset or compensate for their relatively less strong perceptual and contextual reinstatement value (cf. Bjork, 1988; Kausler & Wiley, 1990; Whitten & Leonard, 1980). Alternatively, descriptions may not invariably prove to be equivalent aids to later memory, but it may be something about the specific descriptions we used (or the photographs we used) that resulted in the observed equivalence. The particular way in which the verbal descriptions were written for this experiment may have encouraged a high degree of generation and especially visual imagery. The verbal descriptions were written to correspond to the photographs and thus may have invited re-picturing of the particular event or scene. Dewhurst and Conway (1994) showed that the usual picture-superiority effect could be reversed by instructions to imagine the pictorial representations of the verbal stimuli (cf. also Durso & Johnson, 1980). Thus, it is plausible that to the extent that participants did engage in imagery in response to the verbal descriptions, any uniquely pictorial reinstatement benefits of the photographs may have been counteracted.

These considerations suggest that, on a continuum of external to internal prompts to memory review (e.g., self-initiated attempts to remember, cuing by visual prompts such as a photograph or return to a particular environment, or verbal cuing), various factors may operate to make apparently quite different sources of reinstatement or reactivation equally effective. Whereas some external sources of cuing such as photographs

or actual physical return to a particular context may reinstantiate perceptual and spatial features that allow activation of a previous memory (cf. Hitchcock & Rovee-Collier, 1996), other forms of cuing that apparently provide less information may yet yield substantial benefits for later memory because they prompt greater or more concerted retrieval or reactivation processes.

Another possibility is that there was a greater match between the review cues and the test situation for verbal descriptions than for photographs and that this, again, compensated for or offset the greater perceptual cuing of photographs. In this paradigm, free recall required some translation of an original series of visual events into a verbal account, and the degree of overlap in processes involved during earlier review (through photographs vs. descriptions) and ultimate retrieval could affect the extent to which retrieval benefits will be observed (Bjork, 1988). How differences in the degree of match between the reinstatement stimuli and the format of the retention test may have contributed to the outcomes we observed is unknown. In any review situation, there are two forms of study-to-test match that may be important and that may (or may not) act to facilitate final retention: the congruence of processes and information encoded in the original situation with the processes and information required during review, and the congruence of the review processes with processes that are necessary during final retention testing.

The basic experimental paradigm that we used was intended to evaluate how memory of earlier experienced events is affected by later encountering photographs or verbal descriptions of some of those events. Given that consistent facilitatory effects were observed, exactly how did such review lead to enhanced recall for the reviewed events? Increased elaborative encoding of the reviewed events, and stronger associative binding or integration of the sundry components comprising an earlier experienced event, may occur when one looks at photographs of past events or, more generally, engages in retrieval of some events and not others (cf. Johnson & Chalfonte, 1994). Either or both of these factors may have contributed to the mnemonic advantage found for reviewed compared with nonreviewed events. Earlier retrieval may have enhanced later retrieval by strengthening the "retrieval pathway" to the reviewed events (cf. Landauer & Bjork, 1978) or by strengthening the binding of the event representation through activation of various components of the event, such as sensory and perceptual details, or thoughts and feelings concerning the event (Johnson & Chalfonte, 1994), which, in turn, later increased the likelihood of successful retrieval, even with minimal cues.

A further possible account of the enhanced memory performance for the reviewed relative to the nonreviewed events is that what appears to be enhanced memory for the original experience of watching the videotapes in fact derives, either in whole or in part, from memory for the review stimuli themselves (Johnson et al., 1993). Might greater memory for the reviewed than nonreviewed events have arisen from a form of faulty source monitoring such that what seems to be enhanced memory for the original events is, in fact, merely memory for the photographs or descriptions, masquerading as event memory (cf. Schacter, Koutstaal, Johnson, et al., 1997)? As noted previously, some writers have suggested that a later pictorial or verbal account of an event might supplant one's original memory for that event (Barthes, 1981; Stendhal, 1890/1995; Usher & Neisser, 1993) and, indeed, in our experiments, some contribution of this form cannot be conclusively ruled out. Nonetheless, as also noted previously, such source monitoring errors cannot provide a complete account of the findings. In the photograph review conditions, younger adults recalled greater auditory information regarding reviewed than nonreviewed events, and this specifically included information that could not have been derived from or inferred from the photographs alone (Experiments 1 & 2). Although similar significant facilitation was not observed among younger adults when review was prompted by verbal descriptions (Experiment 2) and was also not observed among older adults (Experiments 1 & 2), other aspects of the recall protocols also argued against a mistaken source account of the facilitatory effects that we observed. Both older and younger adults frequently recalled the detailed temporal structure of particular events that could not have been derived exclusively from the photographs. Moreover, they often correctly recalled the sequencing of the videotaped events, even though the ordering of the reminders was different from the original events and the original events themselves had little schematic structure.

The magnitude of the memory benefits derived from post-event retrieval among older adults in these experiments, and the multiple conditions under which such benefits were observed—with photographs or verbal descriptions as reminders, and with probes of general event memory as well as specific qualitative features of memory—strongly suggest that post-event review may provide an effective mnemonic technique for older adults (cf. Perlmutter & Mitchell, 1982; West, 1989). The practical importance of post-event processing among both older and younger adults is thus further underscored. Yet, our findings also suggest that there are multiple ways in which post-event processing may affect subsequent retrieval. The high degree of similarity between verbal and photographic reminders as facilitators of later uncued retrieval suggests that many attributes of both the reminder stimuli and the processes that they evoke must be taken into account if the exact manner in which a given act of retrieval modifies subsequent efforts at retrieval—and the likelihood of retrieval success—is to be understood. The amount and type of information that is given by the review stimulus itself is only one of the factors that must be considered. The information provided by the review cue cannot be considered in isolation from the search and other reconstructive processes that it provokes, or from the way in which both the review stimulus and the reconstructive processes it encourages match those necessary for successful retrieval at a still later time. Although how retrieval practice facilitates the later memory of older or younger adults remains unclear, that it does so is plain.

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