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Improved Episodic Integration Through Enactment: Implications for Aging

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ABSTRACT. Enactment may improve memory for verb phrases by facilitating episodic integration of object–action components into a unitized whole. It is unclear, however, whether the influence of enactment on episodic integration is related to or independent of the strength of the preexisting semantic relationship between components. To address this issue, the authors examined the influence of enactment on memory for lists of semantically *related* object–action phrases ("Put money in the wallet") and semantically *unrelated* phrases created by repairing these objects and actions to make phrases that were unusual but still were possible to perform ("String a thread through the wallet," "Put money in the napkin"). As such, phrases in the related and unrelated lists were matched for familiarity of the individual components and differed only in the associative strength of the object–action relationship. Although verbatim recall of unrelated lists was poorer under standard verbal encoding conditions, enactment succeeded in bringing performance to the level of related lists, indicating that enactment's influence on episodic integration was independent of the semantic relatedness of the object and action components. Analysis of partial recall errors (accurate recall of only one component) suggested that enactment benefited recall in the unrelated lists by improving memory for the action and reducing fragmentation of the association, providing further support for the unitization view. This pattern of results was replicated in normal older adults, a population that exhibits particular difficulty with episodic memory for unrelated associations. The cognitive mechanisms by which enactment may improve episodic integration in both younger and older adults are discussed.

Key words: encoding, memory, semantic, SPT, verbal

AN IMPORTANT ASPECT OF EPISODIC MEMORY is its ability to support the rapid learning of associations between the various elements of an event (e.g., perceptual, conceptual, spatial, temporal). In numerous studies, researchers have shown that verbatim free recall of a particular type of episodic association—verb phrases, such as "break the toothpick"—is superior when participants physically enact the phrase (i.e., subject-performed tasks [SPTs]), compared with when they passively read the phrase, hear the phrase, or even watch the experimenter enact the phrase (for recent review, see Nyberg, Persson, & Nilsson, 2002). Various theorists of enactment or SPT effect have suggested that physical manipulation provides encoding support by incorporating a distinctive motor program into the memory trace (see Engelkamp, 1998), and when real objects are used, manipulation provides additional multimodal sensory information (Backman & Nilsson, 1985; Nilsson & Backman, 1991). Furthermore, Cohen (1981) originally argued that this elaboration takes place relatively automatically. Although in subsequent studies, researchers have shown that the means by which SPTs enhance memory is not entirely automatic (for discussion, see Engelkamp), SPTs do appear to engage deep, semantic processing of the object–action command in a relatively involuntary manner, as suggested by the fact that enacted phrases are less influenced by level-of-processing manipulations than are verbally encoded phrases (Cohen; Zimmer & Engelkamp, 1999). Thus, by virtue of properly planning and executing the movement described by the verb phrase, enactment appears to result in elaboration of an item-specific object–action association without the additional attentional effort required by many other types of mnemonic strategies (e.g., rehearsal, imagery).

Taken together, these explanations converge on the view that SPTs benefit memory because they provide "encoding support" for elaborative semantic, sensory, and motor encoding of the object and action. Although researchers increasingly attribute the enactment effect to enhancement of some type of "item-specific" information (e.g., Engelkamp, Zimmer, & Kurbjuweit, 1995; Zimmer, 2001; Zimmer & Engelkamp, 1999), whether it is memory for the separate object and action units or the association between these units is less clear. However, Kormi-Nouri and colleagues (1995; Kormi-Nouri & Nilsson, 1998) suggest a specific "episodic integration" account of the SPT superiority effect. This view argues that enactment results in unitization of the object–action association. That is, it helps to encode object and action components either as a single memory unit or as separate units with stronger interconnections. Yet, the findings upon which this interpretation is based are limited. Kormi-Nouri found that the SPT effect on free recall was larger for stronger, more specific associations ("read the book") than for weaker, more general associations ("lift the book"), whereas the opposite pattern was found in cued recall, regardless of

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whether object or action served as the cue. However, both of these patterns were difficult to interpret given the possibility of floor effects in free recall of weak associates following verbal encoding and ceiling effects in cued recall of strong associates (see also Engelkamp, 1998).

In addition to Kormi-Nouri (1995), other researchers have examined the boundary conditions of the SPT effect by manipulating the strength of pre-existing semantic relationship between the object and action (Engelkamp, Zimmer, & Biegelmann, 1993; Helstrup, 1993; Knopf & Neidhardt, 1989; Kormi-Nouri; Mohr, 1992). Many of these researchers have used highly unusual or bizarre object–action pairings with extremely low preexisting association strength. As is often found when bizarre sentences are presented in a blocked format rather than mixed with common sentences (e.g., McDaniel, DeLosh, & Merritt, 2000; McDaniel, Einstein, DeLosh, May, & Brady, 1995), these researchers found that under standard verbal encoding conditions, free and cued recall memory for the bizarre phrases was generally poorer than was for the common phases. The effects of enactment on memory for the bizarre and common phrases were less clear, however. In some studies, the relationship between enactment and semantic knowledge acted in an additive fashion, in that benefits of SPTs on free recall performance were greater for familiar verb phrases than for unusual or bizarre phrases (Knopf, 1991; Mohr, Engelkamp, & Zimmer, 1989). Yet other researchers found that enactment facilitated recall memory proportionally for common and bizarre phrases (Engelkamp et al.; Knopf & Neidhardt). To our knowledge, no researchers found that enactment facilitated free recall memory for bizarre phrases to a greater extent than for common ones.

In contrast to the mixed results of free and cued recall, most studies employing recognition tests have consistently found that for bizarre phrases, SPTs convey no additional benefit over the high levels of performance (relative to common sentences) observed when these bizarre object–action associations are encoded under standard verbal encoding conditions (Engelkamp et al., 1993; Heil et al., 1999; Knopf, 1991; Mohr et al., 1989). These results have been taken as evidence that bizarre associations, because they are already highly distinctive, cannot benefit further from the distinctiveness conveyed by enactment. Compared with recall tests, the differential effects of SPTs and bizarreness on memory when measured with recognition most likely occur because recognition performance benefits more from distinctive item-specific processing in general, whereas recall benefits more from interitem relational processing (Hunt & Einstein, 1981). However, it is worth noting that in recent recognition studies using mixed lists, despite individual object and action components being discriminated well, their association was remembered more poorly. Specifically, Worthen and Wood (2001a, 2001b) found higher rates of false alarms to distractors created by repairing components of bizarre phrases, than to distractors created by repairing components of common phrases.

Although this pattern was found even when phrases were encoded under SPT conditions, these studies contrasted self-performed actions with other-performed actions or with imagery, rather than with a standard verbal-encoding condition, so it is difficult to compare their results with previous recognition studies of enactment.

In summary, it is not yet clear whether the ability of SPTs to improve recall performance is proportional to or independent of the strength of the preexisting semantic association between object and action, an issue that is critical for evaluating the unitization hypothesis of enactment. Also, because previous studies using unusual or bizarre verb phrases tested recognition memory only with the whole object–action pair, it is unclear how enactment influences recognition of the object–action unit relative to the individual object and action components. Thus, a primary goal of the present study is to evaluate the unitization hypothesis and its relationship to semantic relatedness more directly.

First, we hypothesized that if enactment serves specifically to unitize episodic associations unique to the spatiotemporal context of the study phase, the strength of this effect would be revealed best in situations where the to-be-learned (episodic) associations were not only unsupported by semantic associations, but where episodic and semantic associations were placed in opposition. To this aim, the present study compared related, common object–action phrases (e.g., “Put money in the wallet”) with unrelated, “crossed” phrases (e.g., “Put money in the napkin”), created by breaking up the meaningful semantic associations and repairing the objects and actions to make unusual or bizarre commands (see Appendix). We hypothesized that the strong semantic relationships between objects and actions from different pairs might compete with the relatively weak episodic associations between the object and action of a given unrelated pair. Indeed, because they are unique to a particular event, episodic associations appear to be particularly vulnerable to disruption when they conflict with semantic associations that are present in the same general context (e.g., Crowder, 1976; Mangels, 1997; Nairne, 1990). As such, if we found that enactment conveyed a protective effect against such disruption, we would have relatively strong evidence that enactment serves to strengthen or unitize episodic object–action associations relative to verbal encoding.

Second, given that our primary motivation for this study was to evaluate the relationship between episodic unitization and semantic relatedness, we not only analyzed free recall for instances in which the entire verb phrase was correctly recalled (verbatim recall), but also for incidences of partial recall. Partial recall was defined as situations in which one component of the object–action phrase was successfully retrieved, but the complementary component was not, either because it was remembered incorrectly or omitted entirely. As such, partial recall might be viewed as direct evidence of instances in which components of the phrase could be retrieved but the association could not. To the extent that enactment improves unitization specifically, rather than simply benefiting memory for individual components of the association, we would expect fewer partial recall errors following enactment than following verbal encoding. Our recognition test also provided a more direct test of associative retrieval than previous studies (e.g., Engelkamp et al., 1993; Heil et al., 1999; Knopf, 1991; Mohr et al., 1989). We first assessed memory for the object with an old or new recognition test. Then, for correctly recognized old items (and false alarms), we gave participants a four-alternative, forced-choice recognition test for the action component. A unitization theory would predict that the probability of choosing the correct action given correct recognition of the object would be higher following enactment than verbal encoding, for both related and unrelated (bizarre) object–action phases.

Finally, because the potential of enactment to strengthen episodic associations has particular relevance to normal aging, we also tested a group of healthy older adults. Recently, an "associative-deficit hypothesis" of cognitive aging has been proposed, which suggests that difficulty in integrating the multiple, unrelated features of an episode triggers the decline in episodic memory commonly observed in older adults (Naveh-Benjamin, 2000; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003). Many researchers, employing a variety of different stimulus–stimulus pairings, have shown that older adults demonstrate relatively intact recognition for individual items in the presence of impaired recognition of the association between them (Castel & Craik, 2003; Naveh-Benjamin; Naveh-Benjamin, Guez, & Marom, 2003; Naveh-Benjamin, Hussain, et al.). This theory is compatible with a wealth of data demonstrating that aging leads to greater deficits in context or source memory than in overall item memory (for review, see Spencer & Raz, 1995). Moreover, within item memory, aging impairs the conscious recollection of events, which depends more on memory for associated details of the encoding context, to a greater extent than item familiarity, which relies more on perceptual and conceptual fluency (for reviews, see Jacoby, Jennings, & Hay, 1996; Light, Prull, LaVoie, & Healy, 2000).

Considering the importance of episodic association deficits in older adults and the potential relationship of enactment to unitization of object–action associations, we now consider how episodic memory in this population is influenced by enactment. Many researchers have reported that enactment produced a level of enhancement in older adults that was proportional to that observed in young adults, but that it did not eliminate performance differences (Cohen, Sandler, & Schroeder, 1987; Earles, 1996; Earles, Kersten, Turner, & McMullen, 1999; Knopf, 1991; Knopf & Neidhardt, 1989; Nilsson & Craik, 1990). Yet when lists are relatively short (i.e., ~10–12 words) and, therefore, both memory load and the duration over which attention to encoding must be sustained was reduced, enactment appeared to produce a disproportionate memory enhancement in older adults (Nyberg, Nilsson, & Backman, 1992); in some cases, it eliminated the age gap altogether (Backman, 1985; Backman & Nilsson, 1984, 1985;

Brooks & Gardiner, 1994; Cohen & Stewart, 1982). Thus, although enactment has consistently improved memory in older adults, past studies revealed mixed degrees of that improvement.

One exception to this pattern of improvement was for unfamiliar or bizarre verb phrases. Knopf and colleague (Knopf, 1991; Knopf & Neidhardt, 1989) found that enactment did not improve memory for unfamiliar verb phrases in either younger or older adults. However, many of the unfamiliar verb phrases used by Knopf were composed of unfamiliar objects (e.g., kiwi fruit, stinging nettle, rusk, inking wheel, inscription) and actions (e.g., dyeing, sieving, dry-blowing) that were of lower lexical frequency than those used in the familiar phrases. As a result, one cannot rule out the possibility that the reduced enactment effect for unfamiliar object–action phrases in both older and younger adults may have been related to the lower frequency of the components of the association, in addition to or instead of the weaker association itself.

To our knowledge, none of the researchers in previous studies examined the effects of enactment in older adults on unitization of episodic object–action associations that not only were unrelated, and therefore could not benefit from the fluency of preexisting semantic relationships, but also were susceptible to interference from semantic relatedness with nonassociated components within the list. In addition to evidence that older adults have greater difficulty creating episodic associations between unrelated information (i.e., Knopf, 1991; Naveh-Benjamin, 2000; Naveh-Benjamin, Hussain, et al., 2003), they also appear to be more susceptible to semantic interference. Although numerous researchers have shown that the activation of associations within semantic memory is spared relative to encoding and retrieval of episodic associations (Backman, Small, Wahlin, & Larsson, 1999; Balota & Duchek, 1988; Burke & Peters, 1986; Laver & Burke, 1993; Nyberg et al., 2003), in situations where automatically activated semantic representations are not (or no longer are) task relevant, older adults appear to have difficulty in inhibiting these representations, thereby limiting the amount of relevant information that can be successfully maintained in working memory (e.g., Connelly, Hasher, & Zacks, 1991; Hartman & Hasher, 1991; Hasher & Zacks, 1988). Thus, in the present study older adults may be more impaired than young adults on recall of the unrelated object–action phrases relative to the related phrases, and the extent to which enactment is able to improve integration of unrelated phrases even in older adults will provide an important test of the unitization hypothesis.

It is important to note that in contrast to studies by Knopf and colleagues, (1991; Knopf and Neiderhardt, 1989), we constructed related and unrelated phrases from the same set of object and action components, thereby varying the strength of their semantic association while holding familiarity of the individual components constant. As such, the present study allows for a more direct test of the relationship between enactment, episodic associations, and semantic interference in both younger and older adults than in previous studies.

Method

Participants

We tested 30 young and 30 older neurologically and psychologically healthy participants. We recruited the young participants from introductory psychology courses at Columbia University (*M* age = 19.6 years, range = 18–23); they received research credit for their participation. The older participants were all healthy, independently living adults (*M* age = 73.5 years; range = 65–83), whom we recruited from Columbia alumni and the surrounding community. Older participants were compensated $15 for 1.5 hr of their time. All participants were native speakers of English and had normal or corrected-to-normal vision and hearing. Prior to testing, participants provided consent forms approved by the Internal Review Board of Columbia University (Morningside Heights).

Demographic and neuropsychological characteristics of the two groups are shown in Table 1. There were no differences between groups on a composite score of participants' subjective ratings of mental and physical health, $F(1, 58) = 0.3$, mean square error (MSE) = 9.8. The only demographic variable in which the groups significantly differed was in years of education. Because many of the young participants were tested in their first year of college, older adults had achieved significantly more years of education at the time of testing, $F(1, 58) = 14.8$, $MSE = 5.5$,

TABLE 1. Demographic and Neuropsychological Characteristics of Participants

Characteristic	Young		Old	
	M	*SEM*	*M*	*SEM*
Age	19.6	.21	73.5	.91
Gender				
Male	8		10	
Female	22		20	
Health[a]	23.1	.49	23.6	.65
Education	14.1	.24	16.4	.56
Test scores				
Information[b]	14.4	.34	13.3	.34
Digit-Span[b]	12.4	.51	11.0	.49
Digit-Symbol[b]	11.7	.51	10.9	.57
Fluency[c]	44.1	2.3	41.5	2.4

[a] Sum of ratings on three physical health and three mental health questions (min = 6, max = 30). [b] Wechsler Adult Intelligence Scale-III subtest, age-scaled scores. [c] Total number of valid words generated for all three letters of verbal fluency test.

$p < .0005$. Nonetheless, young participants exhibited a trend toward better performance on the information subtest of the Wechsler Adult Intelligence Scale, third version (WAIS-III; Wechsler, 1997) age-scaled scores, $F(1, 58) = 3.0$, $MSE = 6.8$, $p = .09$, a putative correlate of intelligence. Both groups performed within normal limits on the Digit-Span subtest of the WAIS-III (age-scaled scores), although younger adults were marginally better than were older adults, $F(1, 58) = 3.8$, $MSE = 7.4$, $p = .06$. The groups did not differ on the Digit-Symbol subtest of the WAIS-III (age-scaled scores), $F(1,58) = 1.0$, $MSE = 8.8$, nor on the Controlled Oral Word Association of Phonemic Fluency test of phonemic fluency, $p > .3$ (Benton & Hamsher, 1978).

Materials

We used four lists, each containing 20 object–action phrases. All objects were common household items that could be easily manipulated. Objects within a given list were chosen to be as semantically and physically unrelated as possible. Actions were chosen to be as specific as possible to a single item on a given list and as dissimilar as possible to other actions on that list. All actions involved one primary object that was physically present; however, some actions also involved a secondary object (e.g., “Peel *something* with the X”). Within each sentence, the object that participants were asked to manipulate (which was physically present) was designated with the article *the*, whereas objects that were not physically present were designated with indefinite articles (e.g., *a*, *some*). The only exceptions to this rule were commands involving the table in front of the participant, the wall, and certain body parts (e.g., “Lather your arm with the soap”).

For each list, we created related and unrelated object–action pairings. For the related pairs, objects were presented with a typical and familiar action command. Unrelated pairs were created by breaking associations between related object–action components and repairing them to make unusual pairs that nonetheless were still possible to perform. In other words, in the unrelated lists, an object would be paired with an action that would be unusual for that item but would be commonly performed with another list item (e.g., *String a thread through the wallet*, where *needle* was another object on the list, and *Put money in the napkin* was another action on the list). Actions and items were never “double-crossed.” Rather, the object and action components of a given phrase were always paired with complementary components from two separate phrases. In addition, object and action components that would have formed a “related” phrase were never presented sequentially. With these constraints in mind, two pseudorandom orders of each of the four object–action lists were created. The position of the objects in these two orders was varied such that no object appeared within the same quarter of the list (i.e., positions 1–5, 6–10, 11–15, 16–20) in both orders. Related and unrelated versions of each list, in one of the two pseudorandom orders, are provided in the Appendix.

For the recognition test, we created 200 digital photographs of objects. Of these, 160 were shown to a given participant. Eighty of these depicted the same objects that were presented in the four study lists (targets), 40 were new objects that were perceptually or conceptually similar to a study object (related distractors), and 40 were completely unrelated to any study object (unrelated distractors). Target and distractor objects were photographed at approximately the same size and angle at which the object would have been (targets) or could have been (distractors) viewed by the participant during the study phase. All distractors were of similar size and monetary value relative to the target items so that discrimination could not be based on general item characteristics. We prepared related distractor objects for the 20 studied items in a list, then divided them into two sets of 10 items (sets A and B). We showed only one set of related items at test so that the total number of distractors (40 related, 40 unrelated) did not exceed the number of total targets (80). We counter-balanced assignment of set to recognition list across participants.

Action choices for both target and distractor objects included two related and two unrelated actions. For target objects, one of the "related" and "unrelated" actions came directly from the study set. We created the other pair by constructing a second set of related and unrelated actions for these objects that were not shown at study but met the same criteria as actions that were used. For distractor objects, we created two lists of "related" and "unrelated" objects in a similar manner as for target objects. These four action choices were presented under the object photograph, each on a separate line. For target objects, the correct action appeared with an equal number of items in each of the four possible positions in this stack.

Design and Procedure

We presented participants with four study-test lists over the course of the experiment: verbal task, related list (VT-related); verbal task, unrelated list (VT-unrelated); subject-performed task, related list (SPT-related); subject-performed task, unrelated list (SPT-unrelated). We counterbalanced the order of these conditions across participants, such that each condition was tested equally often with each list in each group. We gave participants VT or SPT instructions prior to the study phase and told them to remember the phrases (object–action commands) for a later free-recall test. We did not tell them of the upcoming recognition test.

During study, participants sat across a table from the first author, and we placed each object individually in a central area midway between them and us. As we placed the object on the table, she read the object–action phrase. For the VT conditions, we instructed participants to look at the object placed before them, listen to the phrase carefully, and repeat it out loud clearly and accurately. For the SPT conditions, we instructed participants to look at the object placed before them, listen to the phrase carefully, and then perform the command as accurately as possible using the object for about 5 s before placing the object back on the table. Actual manipulation time varied from 3 to 6 s. Participants did not verbally repeat the command in the SPT condition. In both VT and SPT conditions, the object was within the participant's view for 8 s.

After each list, the participant performed a 1-min distractor task of counting backward by 3s from a 3-digit number. We then asked participants to recall as many of the object–action phrases as possible, in any order. In addition, we told them that if they remembered that certain objects and actions were presented together, they should say them together, but that even if they could remember only one part of the pair (action or object), they should still say this part. We instructed them to describe the object or action as well as possible if they did not remember the exact words we used. We used a specially designed scoring sheet that allowed rapid scoring of both partial recall (errors of omission and commission) and verbatim correct recall. We gave participants a minimum of 2 min to come up with as many items as possible. At the end of 2 min, we asked participants whether they remembered anything else. If they responded in the affirmative, we gave them an additional 30 s to continue. This process continued until 30 s elapsed in which no further information was recalled.

We scored only complete and correctly paired object–action phrases as correct and entered these into verbatim recall analysis. To ensure that scoring accurately reflected the full extent of a participant's memory, if a participant mentioned two objects or actions alone before providing any complete object–action phrases, we prompted that participant by saying, "Do you remember the object or action presented along with that?" If the participant was silent for several seconds, or expressed an inability to remember anything else after saying only complete object–action phrases, we prompted the participant by saying, "Do you remember any objects or actions alone?" We entered objects or actions recalled alone (errors of omission) or with an incorrect part (errors of commission) into the partial recall analysis. Note that failure to recall correctly any secondary objects in a sentence (e.g., *your arm* in the phrase *Lather your arm with the soap*) was not counted as a partial recall error. Full recall credit would be awarded for that object–action phrase if the participant recalled both *lather* and *soap*, regardless of what other information was included in the recalled sentence. However, recalling *lather* alone or with an incorrect object (e.g., "shampoo") would be scored as partial recall-action; recalling *soap* alone or with an incorrect action (e.g., *rub*) would be scored as partial recall-object.

We gave a selected set of neuropsychological tests before, after, and in-between the four study-test blocks, in the same order for each participant. All participants first completed a mental and physical health questionnaire in which they indicated how they felt that day, as well as how they had been feeling over the previous year, using a 5-point scale (1 = *very poor*; 5 = *very good*). We interleaved WAIS-III subtests (Digit-Span, Digit-Symbol; Wechsler, 1997) and the phonemic fluency test (Benton & Hamsher, 1978) between study-test blocks in a manner that kept the delay between blocks at approximately 5 min. We gave the WAIS-III Information subtest at the completion of all four study-test blocks.

At the conclusion of the Information subtest, we gave participants a surprise computerized recognition test for the objects and actions in the preceding four lists. We first showed participants a digitized photograph of an object against a neutral background and asked to make an old or new recognition judgment. We cautioned them to identify an object as "old" only if it was exactly the same (perceptually and conceptually) to one presented in any of the four studied lists. Targets and distractors for the four lists were randomly intermixed. When participants judged objects to be "old," we gave participants the four-alternative, forced-choice action judgment. As a result of computer error, we lost recognition data from three older adults. One additional older adult was too tired to complete this phase of the experiment.

Results

Verbatim Recall

Figure 1 illustrates the percentage of correctly recalled object–action phrases. A 2 (Group: old vs. young) × 2 (Task: VT vs. SPT) × 2 (List: related vs. unrelated) analysis of variance (ANOVA) revealed main effects for all factors. Overall, older adults recalled fewer phrases than younger adults, $F(1, 58) = 31.6$, $MSE = 24.2$, $p < .001$; recall performance was superior under SPT conditions, $F(1, 58) = 48.7$, $MSE = 6.7$, $p < .001$; and related phrases were remembered better than unrelated phrases, $F(1, 58) = 12.9$, $MSE = 6.2$, $p < .001$. However, these latter main effects were qualified by a Task by List interaction, $F(1, 58) = 7.0$, $MSE = 5.8$, $p = .01$, which post-hoc Tukey's highly significant difference (HSD) tests revealed was the result of unrelated object–action phrases being remembered more poorly than related pairs in the VT condition, but not in the SPT condition. There was also a marginally significant List by Group interaction, $F(1, 58) = 2.8$, $MSE = 6.2$, $p = .1$, and because we had predicted a priori that older adults would be more affected than would young adults by the semantic interference present in the unrelated list, we cautiously explored this interaction. Planned comparisons revealed a larger overall difference (collapsed over task) between related and unrelated lists in the older adults, $t(29) = 3.8$, $p < .001$, compared with the younger adults, $t(29) = 1.3$, $p = .2$.

The absence of a significant three-way interaction between Task, List, and Group, $F(1, 58) = 1.1$, $MSE = 5.8$, $p = .3$, however, indicated that the extent to which enactment minimized the relatively poorer memory for the unrelated object–action phrases was not statistically different in older and younger adults. In addition, despite the main effect of task and interaction with list type, enactment did not eliminate the overall gap in performance between old and young, as there was no interaction between group and encoding condition, $F(1, 58) = 0.9$, $MSE = 6.7$, $p = .3$.

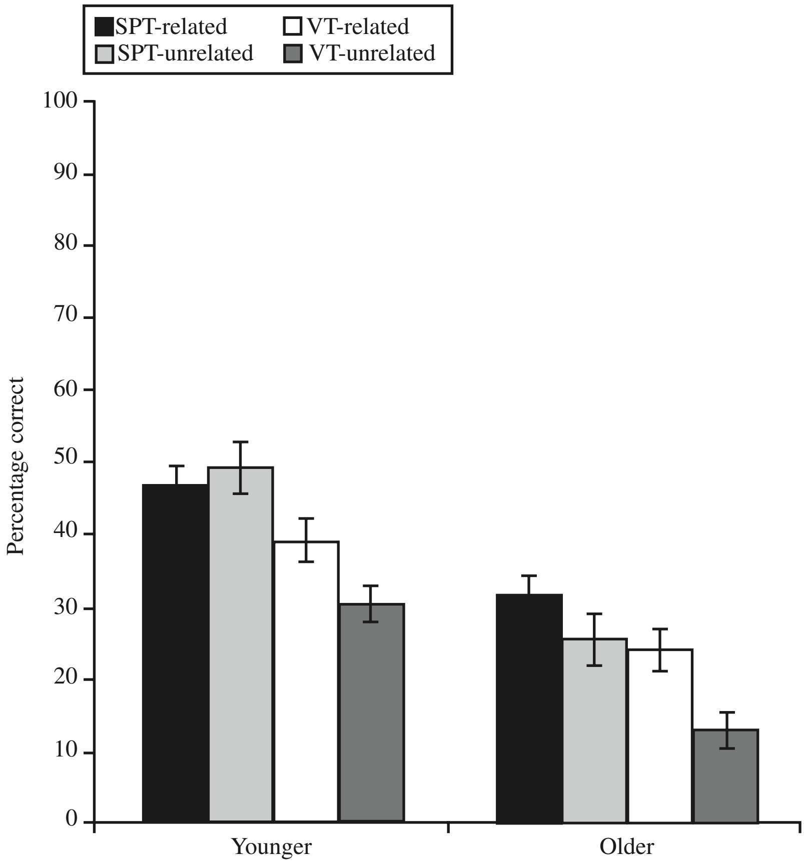

FIGURE 1. Percentage recalled as a function of task and list type. Error bars show the standard error of mean. SPT = subject-performed task; VT = verbal task.

Partial Recall

When participants failed to recall a complete object–action phrase, it was not always the case that both components of the association were simply forgotten. Rather, there were occasional instances in the recall protocol in which only an action or an object was provided, or only one was provided accurately and the other was misremembered. We argue that these "partial recall errors" inform how the object–action association has become fragmented in the face of intact memory for a component of the association. To evaluate the nature and extent of this fragmentation (as well as the portion of the association that remained salient in memory), we analyzed instances of partial recall as a function of whether it was the object or action that was recalled correctly. Furthermore, at least at a descriptive level, we examined whether the incorrectly retrieved component was simply forgotten (only errors), was remembered in a gist-like manner (related errors), or was intruded from another, unrelated association (unrelated and mismatch errors). Although we report the raw number of errors in these analyses, we found identical results when partial recall was expressed as a proportion of total responses given, which provides a relative measure of the frequency of these errors in the response protocol of each group.

To fully characterize the nature of partial recall errors, we first broke down partial recall errors into seven subtypes (Object Only, Object + Related, Object + Unrelated, Action Only, Action + Related, Action + Unrelated, Mismatches), which are shown in Table 2 as a function of Group, Task, and List in Table. Inspection of this data reveals that although partial recall errors were relatively rare overall, the most common type in both groups was the recall of the object without any action (i.e., Object Only). Object + Related errors, which represented cases in which the correct object was recalled with an incorrect action that was semantically similar to the correct action (e.g., *wipe* instead of *sweep*), were the second most common type of error. These errors could be interpreted as situations where verbatim memory for the action failed, but some gist memory was retained. All other subtypes of errors were extremely rare, including errors in which the correct object was paired with an unrelated action (i.e., Object + Unrelated), errors in which the correct action was given alone (i.e., Action Only) or with an incorrect object (i.e., Action + Related, Action + Unrelated), and errors in which the action and object were both on the studied list but had originally been paired with a different object and action from that list (i.e., mismatches).

The data in Table 2 suggest this general pattern of subtype errors held for both younger and older adults. Therefore, given the rare occurrence of subtypes, we opted to collapse over Only, Related, and Unrelated errors to create two broader categories: Partial Recall-Object and Partial Recall-Action. These categories were subsequently analyzed as a function of Task, List, and Group. Mismatches between studied objects and actions, which almost never occurred, were not analyzed further.

A 2 (Partial Recall: object vs. action) × 2 (Task: SPT vs. VT) × 2 (List: related vs. unrelated) × 2 (Group: old vs. young) mixed-design ANOVA revealed a significant three-way interaction of Partial Recall, Task, and List, $F(1, 58) = 24.5$, $MSE = 45.4$, $p < .001$, as well as a number of significant two-way interactions and main effects. None of the higher order interactions with group reached conventional levels of significance, although the Task × List × Group interaction was marginally significant, $F(1, 58) = 3.1$, $MSE = 64.4$, $p = .09$. To pursue the Partial Recall × Task × List interaction, we opted to examine partial recall of the object and action with separate ANOVAs.

As shown in Figure 2, recall of the correct object without the correct action (Partial Recall-Object) occurred more often for unrelated object–action pairs,

TABLE 2. Partial Recall Responses (Mean [*M*] and Standard Error of Measurement [*SEM*]) as a Function of Group and Encoding Condition

	Object Only		Object+ Related		Object+ Unrelated		Action Only		Action+ Related		Action+ Unrelated		Mismatch	
	M	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*
Young														
Subject-performed task														
Related	0.03	0.03	0.27	0.11	0.03	0.03	0.07	0.05	0.13	0.06	0.0	0.0	0.0	0.0
Unrelated	0.80	0.22	0.30	0.12	0.13	0.08	0.60	0.17	0.17	0.07	0.03	0.03	0.07	0.05
Verbal task														
Related	0.07	0.05	0.40	0.10	0.0	0.0	0.07	0.05	0.03	0.03	0.0	0.0	0.03	0.03
Unrelated	2.40	0.36	0.60	0.16	0.07	0.5	0.73	0.21	0.17	0.07	0.03	0.03	0.13	0.08
Mean	0.83	0.13	0.39	0.08	0.06	0.03	0.37	0.07	0.13	0.03	0.17	0.02	0.06	0.02
Old														
Subject-performed task														
Related	0.17	0.08	0.43	0.16	0.07	0.05	0.07	0.05	0.13	0.06	0.03	0.03	0.0	0.0
Unrelated	1.20	0.24	0.23	.09	0.0	0.0	0.60	0.18	0.10	0.06	0.17	0.10	0.17	0.07
Verbal task														
Related	0.43	0.16	0.33	0.11	0.10	0.06	0.03	0.03	0.10	0.06	0.0	0.0	0.03	0.03
Unrelated	2.33	0.36	0.23	0.10	0.23	0.12	0.17	0.07	0.0	0.0	0.03	0.03	0.03	0.03
Mean	1.03	0.13	0.31	0.08	0.10	0.03	0.22	0.07	0.08	0.03	0.06	0.02	0.06	0.02

$F(1, 58) = 82.4$, $MSE = 101.5$, $p < .001$, and for pairs encoded under VT conditions, $F(1, 58) = 31.4$, $MSE = 86.6$, $p < .001$. However, the difference between related and unrelated conditions was smaller under SPT conditions than VT conditions in both groups, as indicated by a significant Task × List interaction, $F(1, 58) = 22.9$, $MSE = 78.1$, $p < .001$, and lack of three-way interaction with group, $F(1, 58) = 0.8$, $MSE = 78$.[1] Thus, enactment was equally effective in younger and older adults in reducing the likelihood that objects would be recalled without the correct action, particularly under conditions where episodic integration could not be supported by a semantic association (i.e., unrelated conditions).

A somewhat different pattern of effects was found for Partial Recall-Action errors, as illustrated in Figure 3. Although these errors also occurred more often for unrelated than for related pairs, $F(1, 58) = 24.5$, $MSE = 40.4$, $p < .001$, again reflecting the difficulty of integrating unfamiliar object–action pairs, these errors were either more likely (older adults) or equally likely (younger adults) to occur in the SPT condition than in the VT condition: main effect of task, $F(1, 58) = 4.6$, $MSE = 24.1$, $p < .05$; Task × Group Interaction:

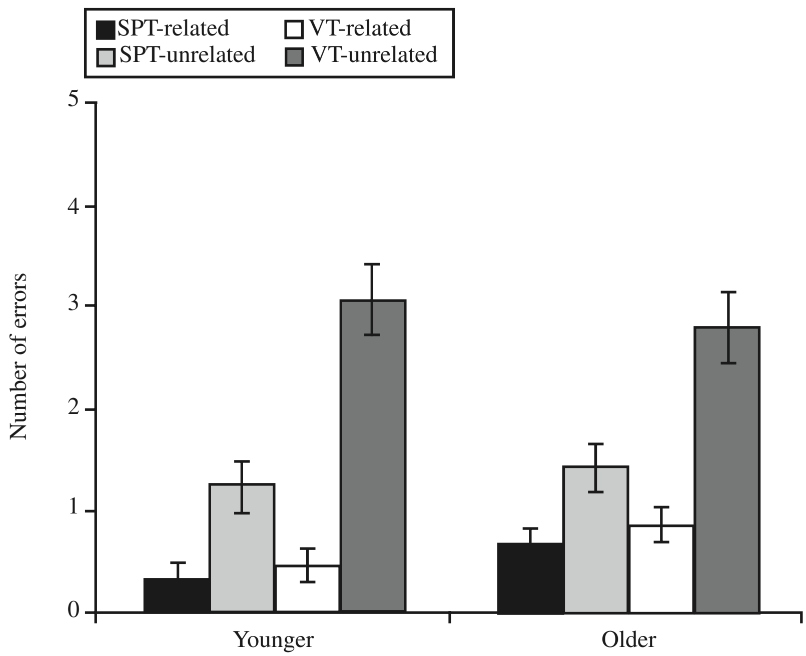

FIGURE 2. Partial Recall-Object (objects correctly recalled with an incorrect or missing action), as a function of the task and list. Error bars show the standard error of mean. SPT = subject-performed task; VT = verbal task.

$F(1, 58) = 5.8$, $MSE = 24.1$, $p < .02$. There was also a significant Task × List × Group interaction, $F(1, 58) = 4.5$, $MSE = 30.7$, $p < .05$. Post-hoc Tukey's HSD tests indicated that for younger adults, List effects did not vary as a function of Task; more errors were made in the unrelated than related phrases in both the SPT and VT conditions. However, these factors did interact for older adults, who made more errors in the SPT-unrelated condition than in the VT-unrelated condition. Although these results could be taken to suggest that enactment enhanced the salience of the action for older adults, allowing them to recall more actions despite fragmentation because of interitem "crossing" of object–action components, these error data are generally more difficult to interpret than the Partial Recall-Object errors because Partial Recall-Action errors were rare in all conditions.

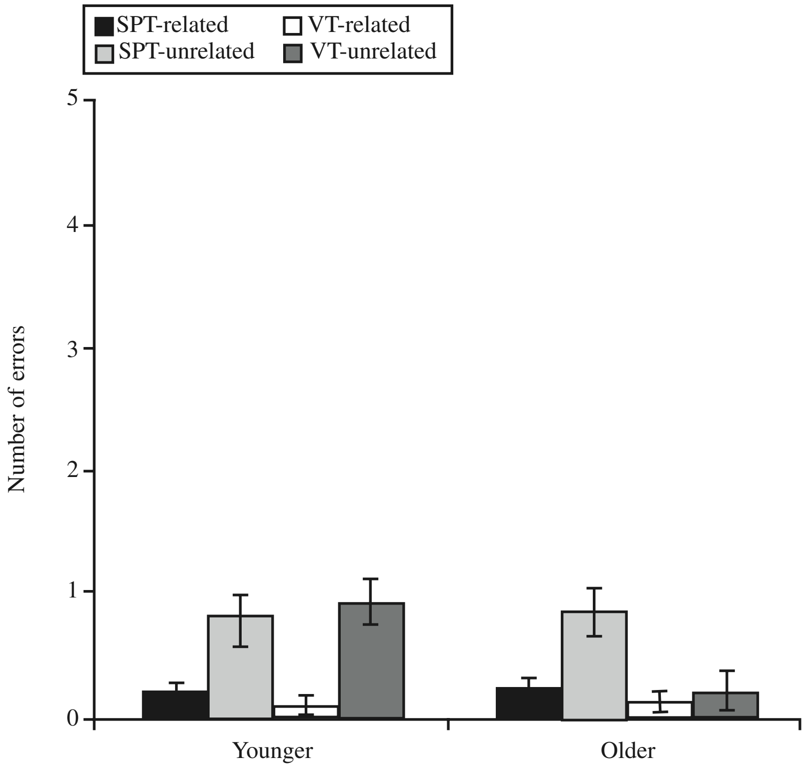

FIGURE 3. Partial Recall-Action (action correctly recalled within incorrect or missing action) as a function of task and list. Error bars show standard error of mean. SPT = subject-performed task; VT = verbal task.

Recognition

Table 3 illustrates object recognition performance, related and unrelated object false alarms, and action recognition performance for those objects correctly recognized. Because only related distractors were matched to targets in the lists, it was not possible to correct object recognition performance for both related and unrelated false alarms. Therefore, we first considered whether false alarm rates for related and unrelated false alarms differed, and whether related false alarms differed as a function of the Task and List in which their yoked target had been presented. A 2 (Distractor Type: related vs. unrelated) × 2 (Group: old vs. young) ANOVA revealed that older adults made more false alarms than did younger adults, $F(1, 54) = 11.9$, $MSE = 66.5$, $p < .005$, and both groups were more likely to false alarm to related than to unrelated distractors, $F(1, 54) = 13.7$, $MSE = 38.8$, $p < .001$. There was no interaction between Group and Distractor

TABLE 3. Recognition Performance (Mean [*M*] and Standard Error of Measurement [*SEM*]) as a Function of Group and Encoding Condition

	Subject-Performed Task				Verbal Task			
	Related		Unrelated		Related		Unrelated	
Group	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*
				Object Memory-Hits[a]				
Young	93.8	1.9	92.7	1.8	91.2	2.2	91.3	2.2
Old	86.5	2.1	85.2	2.2	85.8	2.3	81.9	2.4
				False Alarms-Related[b]				
Young	3.3	2.2	4.3	2.1	5.0	2.1	2.3	1.8
Old	11.2	2.3	11.9	2.3	8.8	2.3	9.2	1.9
				False Alarms-Unrelated[c]				
Young					0.5	1.3		
Old					4.7	6.9		
				Action Memory[d]				
Young	96.8	2.4	94.8	2.3	95.9	2.6	93.7	3.4
Old	86.9	2.6	80.8	2.5	77.8	2.8	75.3	3.6

[a]Percentage correct out of 20 (max). [b]Percentage of errors out of 10 (max). [c]Percentage of errors out of 40 (max). [d]Percentage of correct object recognition accompanied by correct action choice.

Type, $p = .3$. When related distractors were considered alone in an analysis that included factors of Task and the List in which the yoked target was shown, only a significant main effect of age was found, $F(1, 54) = 7.2$, $MSE = 3.3$, $p < .05$. No other effects were significant (ps > .2).

Object recognition (hit rate) was very high overall, most likely because of the use of object photographs. A 2 (Task) × 2 (List) × 2 (Group) ANOVA on object hits revealed only a significant main effect of group in favor of younger adults, $F(1, 54) = 10.8$, $MSE = 280.9$, $p < .005$, and a marginal overall advantage for related relative to unrelated lists, $F(1, 54) = 2.9$, $MSE = 45.8$, $p = .09$. We found similar results when object recognition was corrected for related false alarms.

When we considered the accuracy of the action choice following correct object recognition, we also found an age gap, $F(1, 54) = 24.9$, $MSE = 512.0$, $p < .001$, as well as main effects of Task, $F(1, 54) = 5.8$, $MSE = 169.1$, $p < .05$, and List, $F(1, 54) = 5.2$, $MSE = 110.3$, $p < .05$, similar to free recall. There was also a marginal interaction of Task and Group, $F(1, 54) = 3.3$, $MSE = 169.1$, $p = .08$, apparently because SPTs significantly improved action memory only in older adults. This interaction must be treated with caution, however, given the ceiling effects in performance of the younger adults.

Discussion

Episodic object–action associations that were not supported by preexisting semantic associations (i.e., unrelated phrases) were more difficult to recall verbatim than related phrases following verbal encoding (VTs), but not following enactment (SPTs). Thus, enactment was successful in strengthening episodic associations, even those that were not supported by semantic associations. These findings provide support for the view that enactment unitizes object–action associations regardless of the strength of the preexisting object–action relationship. In addition, given that the benefit from enactment was sufficient to bring recall of the unrelated "crossed" phrases to approximately the same level as related phrases, enactment also appeared to overcome any interference generated by the interitem semantic relatedness present in the unrelated lists. The ability of enactment to reduce interference from interitem associations is consistent with the view that enactment focuses attention on item-specific encoding of a particular object–action unit and away from relational, organizational processing between units (e.g., Engelkamp & Zimmer, 2002).

Our finding that the enactment effect was stronger for unrelated phrases than related phrases runs counter, however, to studies that find a larger or equivalent enactment effect for "stronger" relative to "weaker" associations (Knopf, 1991; Kormi-Nouri, 1995; Mohr et al., 1989; Nilsson, Nyberg, Kormi-Nouri, & Ronnlund, 1995). It is likely that variations in the precise manner in which associative strength was varied across these studies accounts, at least in part, for these differences. Studies that varied the specificity of the object–action association (*read the book* vs. *lift the book*) have generally found greater SPT effects for stronger associations (Helstrup, 1993; Kormi-Nouri). However, actions with low specificity could be associated with multiple items on the list, perhaps increasing interitem inference to a level that could not be overcome by enactment. This interpretation receives some support from the very low free-recall performance of the weaker associations in both verbal and enactment conditions. In the present study, however, even the unrelated phrases used actions that were made relatively specific by inclusion of a secondary object (i.e., *Remove a splinter with the X, Take a sip from the X*) and were only semantically related to one object on the list.

The manner in which relatedness was varied in the present study was most similar to studies employing specific, but unfamiliar or bizarre object–action associations (Engelkamp et al., 1993; Knopf, 1991; Knopf & Neidhardt, 1989; Mohr et al., 1989). In those studies, however, the familiarity of the object and action components in the bizarre and common pairs was not necessarily well controlled. Although an appendix of the list items was not provided by most of these studies, in one study that did provide this information, the unrelated or bizarre phrases contained lower frequency objects or actions than the related or familiar phrases (Knopf). Although enactment may facilitate integration of object–action associations, the low frequency of object and action components may decrease the likelihood that either is recalled and then able to cue recall of the associated component. Partial recall data were not reported in these studies, so it is not possible to determine how bizarreness influenced memory for the components of the association, independently of the association itself.

With regard to the specific effects of these manipulations on aging, enactment did not eliminate age differences, similar to other studies using relatively long lists of items (e.g., Cohen et al., 1987). Nonetheless, for both related and unrelated phrases, enactment produced a level of improvement in older adults that was not significantly different from that found in younger adults. The similar effects of enactment in older and younger adults provides support for the hypothesis that manipulation can convey a substantial benefit toward use of unrelated associations, even for a group (i.e., older adults) who traditionally have difficulty associating this type of information (Naveh-Benjamin, 2000; Naveh-Benjamin, Hussain, et al., 2003) and who may be particularly vulnerable to interference from information that is related, but in conflict with the to-be-learned association (Bowles & Salthouse, 2003; Connelly et al., 1991; Hartman & Hasher, 1991; Lustig, May, & Hasher, 2001).

An analysis of the nature and extent of partial-recall errors provides additional evidence for the view that enactment improved recall memory in these groups by improving unitization of object and action components in memory. In the conditions producing the poorest verbatim recall memory (VT-unrelated), participants were sometimes more likely to recall objects in isolation or with an incorrect action (Partial Recall-Object). Under VT conditions, the object may have been more salient than either the action or the object–action association because it was physically present during the entire 8-s study period, whereas the verbal statement of the action was relatively brief. Enactment specifically reduced these errors, particularly for the unrelated phrases, in both older and younger adults. It is interesting that although partial recall-action errors were very low overall, they were equally likely (younger adults) or more likely (older adults) to occur in the SPT conditions as in the VT conditions, suggesting that even when enactment failed to support object–action integration, it nevertheless increased the salience of the action relative to the object. Enactment also facilitated recognition of the correct action (given correct item recognition) compared with verbal encoding, providing additional support for the unitization hypothesis. Although enactment did not convey the same disproportionate benefit to unrelated items in the recognition test that was observed in free recall, a Task by List interaction may have been more difficult to observe in recognition because the difference in performance between related and unrelated pairs was smaller overall on this test (recognition: $\eta_p^2 = .087$ vs. free recall: $\eta_p^2 = .182$), and memory performance was close to ceiling overall.

As mentioned previously, although enactment improved recall and recognition of both related and unrelated phrases in older adults, it did not bring their performance up to the level of young adults. The failure of enactment to fully compensate for age deficits is consistent with findings from other SPT studies in which the overall memory load was relatively high (Cohen et al., 1987; Earles, 1996; Earles et al., 1999; Knopf, 1991; Knopf & Neidhardt, 1989; Nilsson & Craik, 1990). Although the magnitude of the age effect in object recognition ($\eta_p^2 = .167$) was smaller than in recognition of the object–action association ($\eta_p^2 = .351$), which is consistent with previous studies demonstrating relatively spared item memory compared with context memory, the magnitude of the age-related recognition deficit for the object–action association was similar to that found in free recall ($\eta_p^2 = .353$). Therefore, it is likely that age differences were not due solely to impairment in strategic retrieval, but rather represent a fundamental deficit in associative encoding that could not be eliminated by enactment.

Earles (1996) suggested that age differences persist because cognitive effort and strategic processing can improve memory not only for phrases that are verbally encoded, but also for those that are enacted, thereby arguing against the view that enactment effects are conveyed only through automatic processes. In support of this view, she found that working memory (reading span, comprehension span) and perceptual speed (letter and pattern comparison) mediated the relationship between age and memory for verb phrases regardless of whether they were read or performed (see also Earles & Coon, 1994). Although we did not include these specific tests in our neuropsychological test battery, neither group demonstrated any significant correlations between memory performance and age-scaled scores on the Digit-Span or Digit-Symbol Substitution subtests, the latter of which is sensitive not only to working memory, but also to processing speed (Lezak, 1995). It is possible that the longer lists employed in the present study (i.e., 20 items) reduced the dependence of memory performance on working memory. It is interesting that we did find a significant positive correlation between phonemic fluency and recall of VT-related pairs in older adults (Spearman's $\rho = .449$, $p < .02$), but not younger adults ($p = .9$). Although phonemic fluency performance taps both strategic and automatic retrieval processes (Troyer, Moscovitch, & Winocur, 1997), this result provides some indirect support that older adults relied more on the fluency of preexisting semantic or lexical representations following verbal encoding than following enactment.

Enactment could reduce associative memory deficits in older adults either by boosting processing within the same systems that lead to conscious recollection in younger adults or by circumventing these processes altogether. In support of the view that enactment facilitates conscious recollection, research with younger adults, using standard phrases, suggests that enactment increases "remembering" to a greater extent than "knowing" (Dehn & Engelkamp, 1997). In addition, associative memory performance following either enactment or verbal encoding tends to be highly correlated, particularly in older adults, suggesting that these tests rely fundamentally upon similar processes (Earles, 1996). In the present study, however, the pattern of correlations between SPT and VT performance did not provide a clear picture with regard to whether they depended on similar processes or not. Free recall of VT-unrelated phrases, but not VT-related phrases, was significantly correlated with both SPT-related and SPT-unrelated phrases, in both younger (*p*s < .01) and older (*p*s < .001) adults. In contrast, object–action recognition memory for VT-related phrases was significantly correlated with both SPT-related and SPT-unrelated phrases in older adults only (*p*s < .05). There were no significant correlations with VT-unrelated phrases in either group.

Alternatively, SPTs may permit novel associations to be encoded via cognitive and neural mechanisms that would normally contribute only to familiarity. Yonelinas (1999) has suggested that familiarity processes cannot support encoding of novel associations except in situations in which the pair is perceived as a unified whole. Our demonstration of increased unitization following enactment bears directly on this issue. Recently, Caldwell and Masson (2001) found that familiarity could contribute to memory for object–location associations if participants moved objects into different locations within complex realistic scenes. In addition, this study found no difference between younger and older adults in the contribution of familiarity to memory performance. Although it is not clear what aspect of their task enabled familiarity to contribute to associative learning, it cannot be ruled out that engaging in a self-generated movement was a critical component. Given that deep encoding also may be a necessary condition for associative priming of novel associations (Graf & Schacter, 1985), it is possible that the requirement to plan and execute a movement creates a meaningful relationship between object and action (or object and spatial position) without need for further effortful elaboration. The unitization of object–action associations resulting from enactment then may permit retrieval of novel associations on the basis of either familiarity, such that retrieval of one element automatically cues retrieval of the other, or by more controlled, strategic retrieval. Having multiple routes to associative retrieval would increase the likelihood of retrieval success, particularly for older adults who may be less able to rely on conscious recollection.

In summary, the results of the present study provide more direct evidence that enactment unitizes or strengthens episodic object–action associations than have the results of previous studies (Kormi-Nouri, 1995; Kormi-Nouri & Nilsson, 1998). In addition, these results have implications for ameliorating associative memory deficits in normal aging. Given that enactment appears to be a successful method of reducing memory impairments for unrelated associations in normal older adults, it may also be an effective means of improving memory in older adults with lesions in the dorsolateral prefrontal cortex. Such individuals are even less likely than normal older adults to spontaneously use effortful organizational strategies (Gershberg & Shimamura, 1995; Mangels, 1997) and are even more impaired in inhibiting semantic interference (Mangels; Shimamura, Jurica, Mangels, Gershberg, & Knight, 1995). Thus far, patients with frontal lobe damage have been shown to benefit from enactment on tests of temporal order memory (Butters, Kaszniak, Glisky, Eslinger, & Schacter, 1994; McAndrews & Milner, 1991), an aspect of memory that is also sensitive to interference from preexisting semantic associations (Mangels), but free recall has not been assessed. It would also be of interest to examine the effects of enactment on memory performance in older adults with amnestic mild cognitive impairment (MCI). Individuals with MCI, which has been viewed as a transitional state between normal cognitive aging and Alzheimer's disease (Peterson et al., 1999), have been characterized as having particular deficits in learning novel associations (Amieva, Rouch-Leroyer, Fabrigoule, & Dartigues, 2000; Collie, Myers, Schnirman, Wood, & Maruff, 2002; Karantzoulis, Rich, & Mangels, 2004; Peterson et al., 1999). Enactment may benefit this group nonetheless, given that it has been shown to benefit patients with Alzheimer's disease (Herlitz, Adolfsson, Bäckman, & Nilsson, 1991; Karlsson et al., 1989; Lekeu, Van der Linden, Moonen, & Salmon, 2002).

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APPENDIX

Objects and associated action commands are shown in the Related and Unrelated versions for each of the four lists in one of the two possible pseudo-random orders (see text for details). (Note that in the experiment, the object was substituted for the 'X' in each command.)

List 1

Object	Related action	Unrelated action
Peeler	Peel something with the X	Remove a splinter with the X
Napkin	Wipe some crumbs off your mouth with the X	Put money in the X
Picture frame	Place a photograph in the X	Look at your face in the X
Paintbrush	Dip the X in some paint	Swat a bug on the table with the X
Hairdryer	Point the X at your hair	Take a sip from the X
Headphones	Put the X over your ears	Dip the X in some paint
Ice cream cone	Take a lick from the X	Squeeze the X over a roast
Tweezer	Remove a splinter with the X	Unlock a door with the X
Mirror	Look at your face in the X	Wipe some crumbs off your mouth with the X
Glove	Slip your hand in the X	Place a photograph in the X
Balloon	Blow some air into the X	Lather your arm with the X
Wallet	Put money in the X	String a thread through the X
Flyswatter	Swat a bug on the table with the X	Put the X over your ears
Cup	Take a sip from the X	Slip your hand into the X

Key	Unlock a door with the X	Peel something with the X
Needle	String a thread through the X	Blow some air into the X
Soap	Lather your arm with the X	Take a lick from the X
Rolling pin	Roll out some dough with the X	Tap a nail with the X
Hammer	Tap a nail with the X	Point the X at your hair
Baster	Squeeze the X over a roast	Roll out some dough with the X

List 2

Object	Related action	Unrelated action
Pen	Sign your name with the X	Mix some batter with the X
Whisk	Mix some batter with the X	Look through the X
Hanger	Take a piece of clothing off the X	Run the X over your hair
Tape measure	Measure the length of your thumb with the X	Rub some fuzz off your shirt with the X

Object	Related action	Unrelated action
Camera	Look through the X	Blow into the X to play some music
Nail clippers	Trim a nail with the X	Sign your name with the X
Disk	Insert the X into a computer	Measure the length of your thumb with the X
Dreidel	Spin the X	Take a piece of clothing off the X
Hat	Put the X on your head	Toss the X across the table
Sandpaper	Smooth out some wood with the X	Cool yourself with the X
Lint brush	Rub some fuzz off your shirt with the X	Dab the X on your hand
Band-aid	Stick the X on your finger	Insert the X into a computer
Chapstick	Apply the X to your lips	Stick the X on your finger
Comb	Run the X over your hair	Apply the X to your lips
Fork	Bring food to your mouth with the X	Remove the X from a bulletin board
Pushpin	Remove the X from a bulletin board	Spin the X
Trumpet	Blow into the X to play some music	Put the X on your head
Frisbee	Toss the X across the table	Bring food to your mouth with the X
Fan	Cool yourself with the X	Trim a nail with the X
Cotton ball	Dab the X on your hand	Smooth out some wood with the X

List 3

Object	Related action	Unrelated action
Sunglasses	Put the X up to your eyes	Shake the X over your food
Water pistol	Squirt some water at me with the X	Put the X up to your eyes
Flashlight	Shine the X on the back wall	Draw a circle with the X
Toothbrush	Clean your teeth with the X	Flip something over with the X
Soda can	Take a drink from the X	Bounce the X on the table
Spatula	Flip something over with the X	Sift some flour through the X
Sponge	Scrub a pot with the X	Hold the X up to your ear
Duster	Brush some dirt off the table with the X	Squirt some water at me with the X
Flower	Sniff the X	Hang some laundry on a clothesline with the X
Telephone	Hold the X up to your ear	Swing the X

Object	Related action	Unrelated action
Compass	Draw a circle with the X	Pet the X
Golf club	Swing the X	Sniff the X
Salt shaker	Shake the X over your food	Shine the X on the back wall
Croissant	Spread some jam on the X	Brush some dirt off the table with the X
Paper	Fold the X in half	Scrub a pot with the X
Clothespin	Hang some laundry on a clothesline with the X	Wipe off a blackboard with the X
Sieve	Sift some flour through the X	Take a drink with the X
Dog	Pet the X	Fold the X in half
Ball	Bounce the X on the table	Spread some jam on the X
Eraser	Wipe off a blackboard with the X	Clean your teeth with the X

List 4

Object	Related action	Unrelated action
Bubble wand	Wave the X in the air	Cut the X in half
Telescope	Look through the X	Inject something into your arm with the X
Shoe	Tie the X	Turn a pencil in the X
Atomizer	Spray some perfume onto your wrist with the X	Pour some cream from the X
Towel	Wipe some dishes with the X	Stretch the X

Gluestick	Rub the X on the paper	Wave the X in the air
Candle	Blow out the flame on the X	Rub the X on a paper
Mask	Cover your face with the X	Blow out a flame on the X
Syringe	Inject something into your arm with the X	Look through the X
Doll	Hug the X	Cover your face with the X
Scissors	Cut some paper with the X	Lick the back of the X
Pencil sharpener	Turn a pencil in the X	Suck some water through the X
Rubber band	Stretch the X	Tie the X
Straw	Suck some water through the X	Cut some paper with the X
Pitcher	Pour some cream from the X	Dig a hole with the X
Shovel	Dig a hole with the X	Hug the X
Orange	Cut the X in half	Spray some perfume onto your wrist with the X
Bell	Shake the X back and forth	Twist a cork out of a bottle with the X
Object	Related action	Unrelated action
Stamp	Lick the back of the X	Wipe some dishes with the X
Corkscrew	Twist a cork out of the bottle with the X	Shake the X back and forth

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