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Memory Organization of Action Events and Its Relationship to Memory Performance

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Previous research yielded inconsistent results regarding the memory organization of self-performed actions. The authors propose that task performance changes the very basis of memory organization. Enactment during study and test (Experiment 1) yielded stronger enactive clustering (based on motor-movement similarities), whereas verbal encoding yielded stronger conceptual clustering (based on semantic–episodic similarities). Enactment enhanced memory quantity and memory accuracy. Both measures increased with enactive clustering under self-performance instructions but with conceptual clustering under verbal instructions. Enactment only during study (Experiment 2) or only during testing (Experiment 3) also enhanced enactive clustering. It is proposed that different conditions affect the relative salience of different types of memory organization and their relative contribution to recall.

A great deal of what people remember in everyday life concerns things that they have done. For example, in recounting a trip taken a long time ago or in describing a working day, a rememberer often includes a list of activities that he or she carried out. Also, when someone expresses anger for having forgotten something, it is usually forgetting to do something that is involved. In contrast, traditional memory research has focused almost exclusively on the retention and retrieval of verbal material, typically words in a study list.

In the past two decades, however, there has been a growing interest in memory processes that are intimately tied to action (Zimmer et al., 2001). This interest is reflected in research on prospective memory, that is, remembering to perform actions in the future (see Brandimonte, Einstein, & McDaniel, 1996; Ellis, Kvavilashvili, & Milne, 1999; Kvavilashvili & Ellis, 2000; McDaniel, Robinson-Riegler, & Einstein, 1998), and in work involving the monitoring of one's own actions (e.g., Koriat, Ben-Zur, & Sheffer, 1988; Reason, 1984). In particular, a fairly large amount of research has been carried out on memory for self-performed actions, using the enactment paradigm introduced and promoted by Engelkamp and Krumnacker (1980) and Cohen (1981).

Interest in memory processes underlying motor behavior has also been spurred by the notions of embodied cognition and situated cognition, which have been gaining impetus in recent years, driving a conceptual framework in which cognitive processes are seen to be deeply rooted in the body's interactions with the world (for a review, see Wilson, 2002). For example, Glenberg (1997) argued for the idea that memory operates in the service of perception and action, and hence memory representations must arise from bodily interactions with the world. Barsalou (1999, 2002) proposed that knowledge is represented as partial simulations of sensory, motor, and introspective states. Hommel, Müsseler, Aschersleben, and Prinz (2001) criticized the view in which perception and action are treated as distinct processes. Rather, they cited extensive evidence in support of the idea that perceived events (perception) and to-be-produced events (actions) are coded within a common representational medium. Thus, the growing interest in embodiment phenomena in diverse psychological domains (e.g., Barsalou, Niedenthal, Barbey, & Ruppert, in press) brings action to the forefront of cognitive theory.

In this study, we focus on the representation of action events, applying the enactment paradigm that has been used extensively in recent studies of memory for action (see Zimmer et al., 2001). In this experimental paradigm, participants are required to enact a series of action phrases (e.g., "lift your hand," "open the door"), usually using imagined objects when the actions described require objects. Memory for such self-performed tasks (SPTs) has been typically compared with memory for a verbal task (VT) in which the same action phrases are presented to the participants without the requirement to enact them. This line of research has yielded a wealth of intriguing results. Not only has memory for SPTs been found to be superior to memory for VTs, but systematic differences were found in the variables that affect performance in the two cases to the extent that some authors raised the possibility that the laws applying to memory for actions differ from those governing memory for verbal tasks (Cohen, 1981, 1985; see Helstrup, 1986). Others argued for the existence of a specialized action output system that is designed to process performed actions (Engelkamp, 2001; for reviews, see Engelkamp, 1998; Nilsson, 2000).

However, some of the results on the effects of task performance are inconsistent, and there have been theoretical disagreements about a number of central issues. In this study, we focus on the nature of the organization that is characteristic of memory for action and attempt to resolve some of these issues. Our basic tenet is that mode of processing (e.g., verbal encoding vs. task performance) may affect the very basis of memory organization. Without

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taking into account the type of organization that is induced by enactment, we cannot address such controversial questions as whether enactment promotes or impairs memory organization or whether memory organization contributes to the memory superiority of enactment. In what follows, we first review some of the research on memory for action and then outline our proposal.

The Enactment Effect

Many experiments on memory for action have documented what has been commonly termed the *enactment effect*: Task performance improves both recall and recognition of action phrases in comparison to the encoding of the corresponding verbal phrases (e.g., Cohen, 1983; Helstrup, 1987; Mohr, Engelkamp, & Zimmer, 1989; Nilsson & Cohen, 1988; Saltz, 1988; for reviews, see Engelkamp, 1998; Nilsson, 2000). There is also evidence that even the intention to perform the described acts in the future can improve memory performance (Engelkamp, 1997; Jahn & Engelkamp, 2003; Koriat, Ben-Zur, & Nussbaum, 1990).

Some of the explanations of the enactment effect stress representational differences between VTs and SPTs, assuming that enactment increases the salience of certain features of the tasks that enhance memory. Bäckman and Nilsson (1984, 1985) attributed the enactment effect to the multimodal and contextually rich properties of task performance, assuming that enactment prompts discrimination and analysis in terms of visual, motor, and auditory aspects. Engelkamp and Zimmer (1983, 1985) emphasized specifically the motor component: What distinguishes SPTs from VTs is that the actions to be performed must be planned, programmed, and executed, and it is the encoding of the motor movements that contributes to the enactment effect.

The idea that enactment affects the memory representation that is formed during encoding or activated during retrieval gains support from both experimental studies and brain-imaging research. The experimental evidence includes the finding that the recall of SPTs is more strongly impaired by a secondary motor task than by a task that requires participants to watch a visual scene (Zimmer & Engelkamp, 1985). Also, in Engelkamp and Zimmer's study (1994), recognition memory performance was impaired equally after SPT and VT conditions when conceptually similar distractors were used. However, a stronger impairment was incurred after SPT learning when the distractors were motorically similar. Engelkamp and Zimmer (1995) also observed that distractors that were motorically similar to a studied, enacted phrase were more likely to be falsely recognized as studied phrases than motorically dissimilar distractors.

The evidence from brain-imaging studies comes from observations indicating involvement of motor areas in the brain during recollection of enacted action phrases. Nilsson et al. (2000), who monitored brain activity (using positron emission tomography, or PET) during the retrieval of action phrases, found that activity in the right motor cortex was strongest following encoding by enactment, intermediate following imaginary enactment, and lowest following verbal encoding. In a subsequent study, Nyberg et al. (2001) showed that compared with a VT condition, both SPT encoding and retrieval following enactment were associated with differential activation in several left-hemisphere regions, notably the parietal cortex and the motor cortex. Also, Heil et al. (1999) recorded event-related brain potentials during a recognition memory test after VT learning and after SPT learning. A larger fronto-central negativity was found in the SPT condition. This was taken to suggest that the enactment advantage is due to the reactivation of motor information.

In sum, a large number of studies have documented memory superiority for SPTs over VTs. Further, results suggest that this superiority may be related to the greater involvement of motor processing in SPTs.

The Effects of Enactment on Memory Accuracy

In parallel to the many studies documenting an enactment benefit for memory quantity, a study by Koriat, Pearlman-Avnion, and Ben-Zur (1998) indicated that enactment also enhances memory accuracy by reducing the number of false recalls. In terms of Koriat and Goldsmith's (1994, 1996) distinction, *memory quantity performance* is defined as the input-bound percentage of correct recall, reflecting the likelihood that a studied item can be successfully recalled. *Memory accuracy performance*, in contrast, is defined as the output-bound percentage of correct recall, that is, the percentage of reported items that are correct (conditional on the output). This measure reflects the dependability of the reported information, that is, the likelihood that a reported answer is correct. The results of the study by Koriat et al. (1998) indicated that enactment improves memory accuracy by reducing the proportion of commission errors. Leynes and Bink (2002) also found that performing actions reduced the frequency of commission errors compared with imagining these actions. The accuracy advantage of enactment may also result from the rich, multimodal properties of task performance (Bäckman, Nilsson, & Chalom, 1986), which can facilitate the encoding of distinctive, item-specific features. Indeed, increasing the distinctiveness of stimuli has been found to help protect against false recall (Hunt & McDaniel, 1993; Schacter, Israel, & Racine, 1999). For example, Dodson and Schacter (2001) found that participants who were required to say aloud words when studying were less likely to falsely recognize related lures on the test than were those who heard words when studying. It is possible that saying the words provided more distinctive cues than just hearing them.

Processing Differences Between Memory for VTs and Memory for SPTs

In addition to the findings that enactment improves memory performance and that this improvement may be mediated by changes in the memory representation of the action phrases, some results suggest that enactment creates a qualitative difference in the underlying memory processes themselves. These results (for a review, see Zimmer & Cohen, 2001) have been seen to support Cohen's proposal that SPT memory is largely automatic, unlike memory for VTs, which is generally strategic (Cohen, 1981, 1983): SPTs can be encoded without attention or intention, and their encoding is equally efficient under shallow and deep levels of processing.

This proposal has been a subject of some controversy (see Zimmer, 2001). Part of this controversy concerned the effects of enactment on memory organization, for example, as reflected in clustering in free recall (Roenker, Thompson, & Brown, 1971). Because memory organization has generally been assumed to be a sign of strategic processing (Schneider & Bjorklund, 1998; but see Koriat & Melkman, 1987), the question has been raised of whether

SPT memory indeed exhibits less sensitivity to organizational effects than does VT memory. The studies in which researchers examined this question have yielded inconsistent results and have led to contradictory theoretical conclusions. Thus, in explaining their finding that the typical old-age decline in memory is observed only for VTs but not for SPTs, Bäckman and Nilsson (1984) argued that older adults compensate for their poor memory by taking advantage of the rich properties of SPTs to achieve better organization. Indeed, using adjusted ratio of clustering (ARC) scores as a measure of organization (Roenker et al., 1971), Bäckman et al. (1986) found superior memory organization for memories of SPTs than for those of VTs, concluding that not only are SPT memories organized, but they are organized to a greater extent than are verbally presented sentences. Bäckman and Nilsson (1991) argued that the superior organization of SPT memories can counteract the detrimental effects of divided attention and can thus explain why SPT memory is impaired to a lesser extent by divided attention than VT memory.

In contrast, Engelkamp and Zimmer (1996, 2002; Zimmer & Engelkamp, 1989; Zimmer, Helstrup, & Engelkamp, 2000) argued that motor encoding does not improve memory organization and may even impair it. They failed to replicate the findings of higher ARC scores for SPTs than for VTs (e.g., Engelkamp & Zimmer, 1996; see also Norris & West, 1993). Rather, they found that motor encoding could improve the recall of organized lists of action phrases without enhancing memory organization (see Engelkamp & Zimmer, 2001). In fact, the effects of enactment on memory performance were stronger for lists composed of unrelated items than for categorized lists (Zimmer & Engelkamp, 1989). Furthermore, the correlation between percentage recalled and memory organization was positive under verbal instructions, whereas under enactment instructions, it was low or even negative (e.g., Engelkamp & Zimmer, 1996; Zimmer & Mohr, 1986). Also, a blocked presentation of the phrases by category improved both recall and ARC scores as compared with a random presentation order, but this effect was equally obtained for VTs and SPTs with no interaction between blocking and encoding condition (Engelkamp & Zimmer, 2002). In a similar vein, instructing participants to make use of the categorical structure of the list enhanced memory organization under both VT and SPT instructions but improved recall performance only under VT instructions (Engelkamp, Zimmer, & Mohr, 1990).

Engelkamp and Zimmer (1996, 2001) interpreted these findings as indicating that the beneficial effects of enactment on memory are based on item-specific information rather than on relational information pertaining to interitem associations. They argued that enactment creates distinct memory entries, increasing the likelihood that individual items will pop up automatically during recall (Zimmer et al., 2000). In support of this claim, Zimmer et al. (2000) demonstrated the existence of an extended recency effect for SPTs, which accounts for a large part of the SPT memory superiority, and showed that this recency effect was not a consequence of a deliberate use of a retrieval strategy but reflects the operation of a passive process.

In summary, there is agreement that enactment brings to the fore motor features of task performance, and these features may be responsible for part of the quantity and accuracy superiority of SPT memory over VT memory. However, it is unclear whether this superiority is due to improved item information or to improved relational information. Whereas Bäckman and Nilsson (1984, 1991; Bäckman et al., 1986) maintained that SPT memory is better organized than VT memory, the work of Engelkamp, Zimmer, and Helstrup (Engelkamp & Zimmer, 1996, 2002; Zimmer & Engelkamp, 1989; Zimmer et al., 2000) suggests that memories of SPTs are less organized than those of VTs and that the memory benefit of enactment is due to enhanced item-specific information.

The Memory Organization of Action Events: Overview of Goals and Hypotheses

The foregoing review raises several issues concerning the memory organization of action events and its contribution to memory performance. We believe that addressing these issues may have implications that extend beyond the domain of memory for self-performed actions.

Our point of departure for addressing these issues is the evidence that enactment may affect the very representation of information in memory, increasing the salience of motor-enactive features of the tasks. This shift in representation must be taken into account when studying differences in the magnitude of memory organization. Surprisingly, despite the repeated emphasis on the importance of motor, kinematic features of enacted events, insufficient effort has been made to allow for memory organization along similarities in motor aspects of performance to reveal itself.

The most common vehicle for investigating memory organization is clustering in free recall. Typically, a list of items that are categorized according to some principled taxonomic classification is used, and memory organization is inferred from the tendency to recall items from the same category in immediate succession (Cooke, Durso, & Schvaneveldt, 1986; Romney, Brewer, & Batchelder, 1993; see Shuell, 1969, for a review of the early literature). The problem with this approach is that in almost all previous clustering studies, a single, experimenter-defined principle of organization has been built into the study list, so that clustering could be assessed only with regard to that principle. Under these conditions, measures of clustering may be misleading if the principle along which memory is organized departs from what researchers assume, and particularly so if the independent variable studied actually affects the very basis of organizing events. In fact, such might be the case in studies comparing memory organization for VTs and SPTs.

In contrast, the assumption underlying the present study is that information that is committed to memory may be represented and organized in many different forms, and the relative dominance of different types of memory organization may vary depending on a variety of factors that operate during encoding and/or during retrieval (see Koriat & Melkman, 1987). Indeed, evidence suggests that the basis of memory organization may change systematically with age (e.g., Denney & Ziobrowski, 1972), may vary with the level of processing (Koriat & Melkman, 1987), and may also differ for different individuals (Koriat & Melkman, 1981).

An alternative approach to the assessment of memory organization, which was introduced by Tulving (1962), involves focusing on subjective organization. It has the advantage that it allows the degree of memory organization to be assessed without the need to specify the basis of the memory organization a priori, and, in fact, memory organization can be measured even for a list of "unrelated" items. The measurement of subjective organization requires several recall tests so that memory organization can be gauged from the tendency of sequential contingencies to recur across repeated tests. However, although this approach has the advantage of circumventing the need to consider the basis of memory organization in assessing degree of memory organization, this is also its weakness: It does not allow a simple specification of the nature of the memory organization whose degree is being assessed.

Koriat et al. (1998; see also Engelkamp et al., 1990) used the subjective organization approach to examine memory organization of self-performed actions. Participants were presented with 20 action phrases for 10 consecutive study–test cycles and were required to enact these phrases during study and/or during recall. The results yielded two general findings. First, the magnitude of subjective organization was not affected by enactment: It was high for all conditions, increased systematically with repeated study–test cycles, and was positively correlated with recall. Thus, enactment did not seem to either enhance or impair memory organization, nor did it seem to affect the contribution of memory organization to recall. Second, and more important, a post hoc examination of the nature of the recurrent clusters in recall suggested that when the phrases were enacted either during encoding or during testing, memory organization was dominated by the similarity in the bodily movements involved and the body parts implicated. In contrast, verbal encoding and verbal reporting tended to reveal semantic aspects of relatedness to a greater extent.

Thus, the kind of memory organization suggested by these results is quite different from the organizing principles used in previous experiments in which researchers examined the effects of enactment on memory organization. For example, in the study of Bäckman et al. (1986), the items were categorized primarily according to the objects used (e.g., actions with clothes: "put on the glove," "put the boot on the floor"). However, the results of Koriat et al. (1998) suggest that the nature of the object is less critical than the bodily action involved. Also, in the study of Engelkamp et al. (1990; see also Zimmer & Engelkamp, 1989), the taxonomically categorized list included such categories as cleaning (e.g., "wipe," "sweep"), and the episodically organized list included everyday episodes such as cooking or driving a car (e.g., "get in," "buckle up"). Neither of these two types of organization necessarily involves memory organization along similarities in bodily action. The same is true for the lists used by Engelkamp and Zimmer (2002), which were organized according to scripts (e.g., in the car: "fasten the seat belt," "open the window," "fold over the seat").[1] If indeed action events tend to be organized in terms of the bodily movement and body part involved, then previous clustering studies evaluating the effects of enactment on memory organization may have missed the mark.

Assuming that the enactment of action phrases promotes a different type of memory organization than does the verbal encoding of these phrases, then it is necessary to provide opportunities for the two alternative modes of memory organization to manifest themselves. These modes can best be described by reference to Bruner's early work on modes of representation (Bruner, 1966). Building on Piaget's work, Bruner proposed a distinction between three modes of representation: enactive, iconic, and symbolic. The first and last modes roughly parallel the modes of representation that appear to be most distinctive of SPT memories and VT memories, respectively, according to the results of Koriat et al. (1998). Thus, according to Bruner, in the enactive representation, we know something by doing it. For example,

> With regard to a particular knot, we learn the act of tying it, and when we "know" the knot, we know it by the habitual pattern of action we have mastered. The habit by which the knot is represented is serially organized, governed by some sort of schema that holds its successive segments together, and in some sense related to other acts that either facilitate it or interfere with it. There is a fair amount of sensorimotor feedback involved in carrying out the act in question, yet what is crucial is that such a representation is executed in the medium of action. (Bruner, 1966, p. 6)

This type of memory organization is similar to what has been implied by proponents of the embodied cognition view (Glenberg, 1997; Wilson, 2002; see Klatzky, Pellegrino, McCloskey, & Lederman, 1993). However, in Bruner's (1966) scheme, the enactive mode is only one of several possible modes of representation. We propose that this mode becomes particularly dominant following enactment, so that performed actions tend to be organized along similarities in the motor movements involved and the bodily parts implicated. In contrast, verbal processing of the corresponding action phrases tends to make salient symbolic, semantic–episodic aspects of relatedness.

The experimental paradigm we used to examine this idea is similar to that of Koriat and Melkman (1987), who tested the hypothesis that different types of memory organization become salient under different attentional conditions. In the present study, we used a list of action phrases that could reveal the relative dominance of two types of organization, enactive and conceptual. The list consisted of 33 action phrases that could be organized into either 11 enactive categories or 11 conceptual categories of 3 phrases each. The phrases included in an enactive category entailed similar bodily movements (e.g., "to twist a toothpaste cap," "to screw a wire in place," "to focus the lens of a microscope"), whereas the phrases included in a semantic category shared a common semantic–episodic concept (e.g., gardening: "to water a plant," "to snip a rose," "to shut the water tap"). The recall protocols were scored for both enactive and conceptual clustering. The advantage of this methodology, then, is that it permits assessment of the relative dominance of the two modes of organization as well as the absolute level of each.

The first hypothesis to be tested is that task enactment affects the very basis of memory organization of action phrases. We expect a crossover interaction between processing modality (verbal vs. performance) and organization mode (conceptual vs. enactive): Self-performed actions should reveal stronger enactive organization than conceptual organization, whereas verbal encoding should yield stronger conceptual organization than enactive organization. Furthermore, only modality-consistent organization—conceptual in the case of verbal processing and enactive in the case of task performance—should yield the typical increase in clustering with repeated presentations of the list.

Second, once the distinction between the two different modes of memory organization has been established, the question of whether

[1] Only one previous experiment (Zimmer & Engelkamp, 1989, Experiment 3) used motor categories in which the actions were organized according to similarity of the global movement pattern (e.g., "to pull out a needle," "to pick up a crumb"). ARC scores in this experiment were quite low and sometimes negative, allegedly because participants consistently used alternative organizational schemes to those intended by the experimenter.

enactment enhances or reduces each of these modes can be addressed.

Third, the question of the potential benefit of memory organization to recall performance should also be addressed in the context of the distinction between the different modes of memory organization. It has been generally assumed that recall performance depends strongly on the available relational information (Gillund & Shiffrin, 1984; Hunt & Einstein, 1981; Kahana & Wingfield, 2000). Indeed, previous research using word lists has yielded strong correlations between memory organization and recall (e.g., Basden, Basden, & Bartlett, 1993; Tulving, 1962, 1964; Waters & McAlaster, 1983). In studies of memory for action, however, several experiments in which categorized lists were used yielded no correlation between clustering and recall following enactment (Engelkamp & Zimmer, 1996; Zimmer & Mohr, 1986). This was taken to suggest that memory organization is not beneficial to the recall of enacted tasks.

However, we propose that memory organization should contribute to recall even in the case of SPTs (cf. Engelkamp, 1986, 1988; Engelkamp, Zimmer, & Denis, 1989), but with SPTs, enactive organization should be what matters. In general, we maintain that the strongest benefit for recall should ensue from modality-consistent memory organizations. Therefore, we expect recall performance to increase with the magnitude of conceptual organization under verbal-processing instructions. Under task-performance instructions, in contrast, it should increase with the magnitude of enactive organization.

Fourth, a similar interactive pattern may be expected for memory accuracy: Conceptual organization should be most beneficial to memory accuracy under verbal processing, whereas enactive organization should contribute best to accuracy under task performance. The latter two hypothesized interactions are based on the idea that both retrieval and source monitoring are most efficient when participants exploit the distinctive features of the task that are rendered salient by the encoding instructions. Thus, for example, the enactive features of action phrases should contribute to recall and source monitoring to the extent that participants make use of the enactive organization of the list.

Experiment 1

Experiment 1 included two conditions. Participants in the enactment condition were required to enact the list of action phrases both during study and during testing, whereas participants in the verbal condition read the phrases aloud during study and recalled them verbally during testing. The manipulation of enactment during both encoding and retrieval was intended to maximize the expected differences in organization between the two conditions (but see Experiments 2 and 3). In Session 1 of the experiment, the list was presented for four study–test cycles. Session 2 was conducted a week later: Participants recalled the action phrases and were then presented with an additional study–test cycle, using the corresponding procedure (enactment or verbal) as was used in Session 1.

We expected verbal processing to induce organization along conceptual dimensions, whereas we expected enactment to reveal a greater organization along similarities in bodily movements. With regard to memory performance, we expected that in the verbal condition, both recall quantity and recall accuracy would increase with increasing conceptual organization. In the enactment condition, in contrast, we anticipated that the magnitude of enactive organization would be the best predictor of both recall quantity and recall accuracy. A question of interest was whether these expected patterns of results would survive when memory was tested after a 1-week interval.

Method

Participants. Forty Hebrew-speaking University of Haifa undergraduates participated in the experiment. There were 14 women and 6 men in the verbal group, and 17 women and 3 men in the enactment group.

Stimulus materials. The memory list included 33 common action phrases in Hebrew, each two to four words long (e.g., “to snip a rose,” “to hammer a nail”). Most of the sentences denoted action phrases requiring the manipulation of an external object (e.g., “to water a plant”), but some involved mainly bodily actions (e.g., “to wash one’s hair”).

The list was constructed so that the phrases could be grouped into either 11 mutually exclusive conceptual categories or 11 mutually exclusive enactive categories of three phrases each. The phrases within a conceptual category shared a common semantic–episodic concept, whereas the phrases within an enactive category entailed similar bodily movements. The action phrases were composed on the basis of judgments obtained from several judges, and the list was repeatedly modified after several pretests in an attempt to minimize consistent clustering in the recall of phrases from disparate conceptual or enactive categories. The 33 phrases included in the final list (translated from Hebrew) are listed in the Appendix according to both their conceptual grouping and their enactive grouping.

Apparatus and procedure. The experiment was conducted individually, using an IBM-compatible personal computer for the presentation of the stimuli. Participants were told that the experiment involved memory for everyday tasks and that they would be asked to study a list of action phrases for later recall. Half of the participants were instructed to enact each action when it appeared on the computer screen (enactment instructions), whereas the remaining participants were required to say the phrase aloud (verbal instructions). The enactment-condition participants were instructed that when the action phrase required the manipulation of an external object, they should imagine the appropriate object and pantomime the described action as if the object were there. They were also told that they would be tested by having to perform the actions, whereas the verbal-condition participants were told that they would have to say the action phrases aloud during the recall test. Participants were assigned randomly to the enactment and verbal conditions.

During Session 1, all participants were given practice with a printed list of three action phrases, which they were instructed to either say aloud or enact. They then were tested by having to say aloud or enact the phrases from memory, depending on their assigned condition. During the study phase of the experiment proper, the 33 action phrases were presented at the center of the computer screen, at a rate of 4 s per phrase, with a 1-s interval between presentations. During the presentation, the participants would say or enact the phrase, as per their assigned condition. When the presentation was over, participants were instructed to turn to the experimenter and recall the action phrases either verbally or by enacting them. Enactment-condition participants were also instructed to say aloud what they were enacting so that the experimenter could write it down. The experimenter recorded the action phrases the participants recalled. At the end of the test phase, participants were told that they would be presented with the same list of action phrases again and that they should follow the same instructions. This study–test cycle was repeated three more times.

All participants were scheduled to return a week later for Session 2, ostensibly to participate in a different study. During Session 2, they were first tested under their respective condition and then presented with a final study–test cycle as in Session 1. The order of presentation of the action phrases on each of the five study trials was randomly determined for each participant.

Results

Recalls were scored as correct if both the verb component and the noun component were correct. They were scored as commission errors when either of the two components was incorrect or when they were correct but incorrectly combined (e.g., "to spread jam"). They were scored as partial recalls if only one of the two components was recalled (e.g., "to do something with a test tube," "to saw something"). There were 0.6% partial recalls on average in Session 1, which were eliminated from the following analyses. Most of these occurred on Trial 1: 1.52% for the verbal condition and 1.97% for the enactment condition.

Recall performance. Memory performance was scored for both quantity and accuracy. Memory quantity performance is the percentage of correct recalls out of 33, whereas memory accuracy performance is the percentage of correct phrases out of those reported (see Koriat & Goldsmith, 1996). Partial recalls were ignored in calculating both quantity and accuracy scores.

Figure 1 (top panel) presents mean recall quantity scores for the enactment and verbal conditions for each of the six memory tests. Focusing first on memory quantity performance in Session 1, it can be seen that the recall superiority of enactment was obtained on the first trial and was maintained across all subsequent trials. A two-way analysis of variance (ANOVA), Condition (2) × Trial (4), yielded significant effects for condition, $F(1, 38) = 10.96$, $MSE = 43.12$, $p < .002$, $\eta^2 = .22$; for trial, $F(3, 114) = 382.09$, $MSE = 4.23$, $p < .0001$, $\eta^2 = .91$; and for the interaction, $F(3, 114) = 3.64$, $MSE = 4.23$, $p < .05$, $\eta^2 = .09$. Recall quantity averaged 74.0% and 63.6% for the enactment and verbal conditions, respectively, across all trials. The effect of enactment was significant on the first trial, $t(38) = 4.75$, $p < .0001$, $\eta^2 = .37$, and although it decreased with trial, it was still significant even on the fourth trial, $t(38) = 2.20$, $p < .05$, $\eta^2 = .11$. These results are consistent with the SPT-memory superiority that typically has been obtained in previous studies.

The enactment effect was maintained in Session 2. A Condition (2) × Trial (2) ANOVA yielded significant effects for condition,

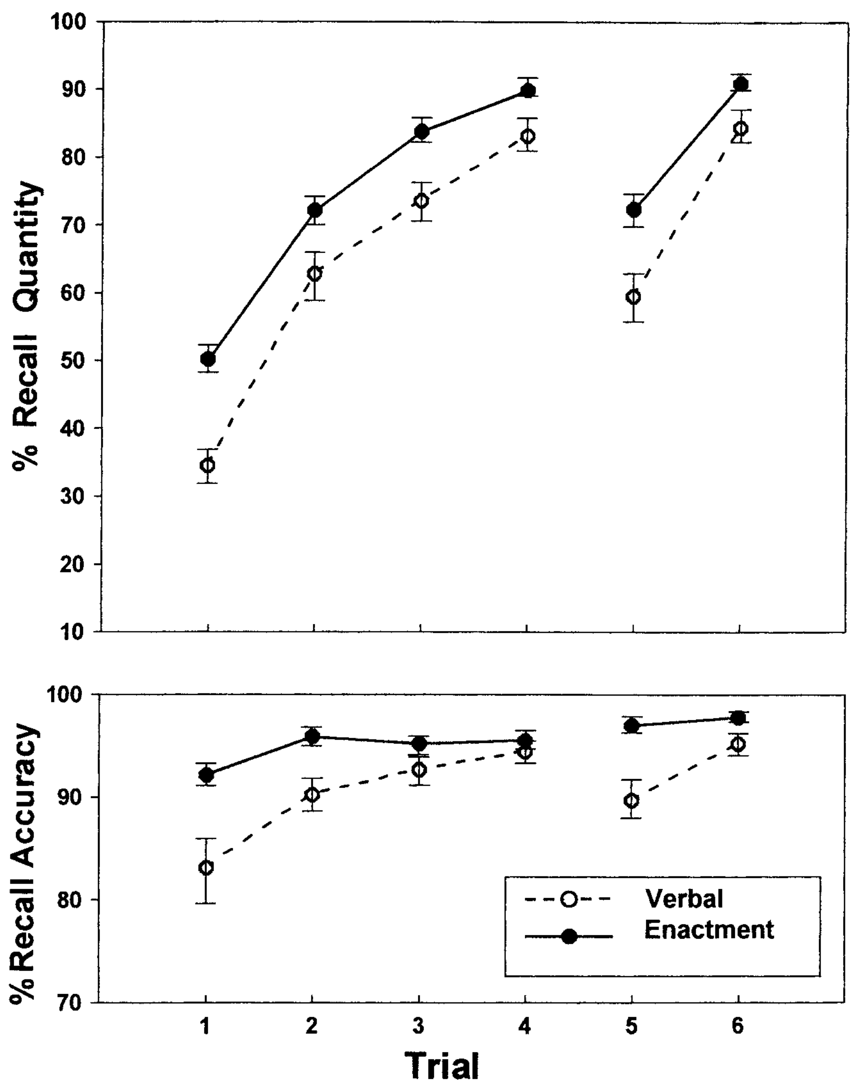

Figure 1. Recall quantity (top panel) and recall accuracy (bottom panel) for the verbal and enactment conditions as a function of trial (Experiment 1). Error bars represent ± 1 standard error of the mean.

$F(1, 38) = 8.92$, $MSE = 204.27$, $p < .005$, $\eta^2 = .19$; for trial, $F(1, 38) = 178.36$, $MSE = 51.91$, $p < .0001$, $\eta^2 = .82$; and for the interaction, $F(1, 38) = 3.54$, $MSE = 51.91$, $p < .07$, $\eta^2 = .09$.

With regard to memory accuracy, consistent with the results of Koriat et al. (1998), enactment also improved recall accuracy (Figure 1, bottom panel). In Session 1, a Condition × Trial ANOVA yielded significant effects for condition, $F(1, 38) = 6.50$, $MSE = 130.71$, $p < .02$, $\eta^2 = .15$; for trial, $F(3, 114) = 11.02$, $MSE = 38.36$, $p < .0001$, $\eta^2 = .22$; and for the interaction, $F(3, 114) = 3.18$, $MSE = 38.36$, $p < .05$, $\eta^2 = .08$. Recall accuracy increased with trial, and enactment yielded better accuracy (94.69%) than did verbal processing (90.09%) across the four trials. The interaction possibly derives from a ceiling effect. The enactment superiority was significant on the first and second trials, $t(38) = 2.34$, $p < .05$, $\eta^2 = .13$, and $t(38) = 2.78$, $p < .01$, $\eta^2 = .17$, respectively, but not on Trials 3 and 4 ($p > .15$). Thus, enactment protects against false recalls, thereby increasing the dependability of memory report.

The accuracy superiority of enactment was maintained in Session 2. Although the Condition × Trial interaction was significant, $F(1, 38) = 6.04$, $MSE = 18.28$, $p < .05$, $\eta^2 = .14$, enactment's memory accuracy superiority was obtained for both Trial 5, $t(38) = 3.25$, $p < .005$, $\eta^2 = .22$, and Trial 6, $t(38) = 2.04$, $p < .05$, $\eta^2 = .10$. It is interesting to note that whereas accuracy performance in the verbal condition decreased markedly over the 1-week interval, $t(39) = 2.56$, $p < .05$, $\eta^2 = .26$, there was no similar decline for the enactment condition. In sum, the results indicate that enactment enhances both memory quantity and memory accuracy and that these effects survive even after a 1-week interval.

The previous study by Koriat et al. (1998) indicated that enactment also improves output monitoring (see Koriat et al., 1988), resulting in fewer item repetitions than are found with the verbal instructions. However, the results of Experiment 1 failed to replicate this effect. The mean number of repetitions, averaged across the four trials of Session 1, was 0.913 for the enactment group and was 0.813 for the verbal group, $t(38) = 0.5$, *ns*. The respective means for the first trial were 0.800 and 0.600, $t(38) = 0.59$, *ns*. Only in Session 2 was there some evidence that enactment may improve output monitoring: Mean number of repetitions in Trials 5 and 6 averaged 0.225 and 0.625 for the enactment and verbal conditions, respectively, $t(38) = 2.51$, $p < .02$, $\eta^2 = .14$.

Memory organization. We turn now to the data on memory organization. The major variable in obtaining organization scores was the specification of the stimulus categories. Two ratio of repetition (RR) scores (Bousfield, 1953) were calculated for each trial and for each participant by counting the number of times an action phrase from one category was followed by an action phrase from the same category during the test phase and dividing this number by $n - 1$, where n represents the total number of action phrases recalled (ignoring partial recalls). For the conceptual clustering scores, two action phrases were defined as belonging to the same category if they belonged to the same conceptual group, and, for the enactive clustering scores, they were so defined if they belonged to the same enactive group. In calculating these scores, we disregarded (i.e., skipped over) commission errors, partial recalls, and items listed a second time.

Figure 2 presents mean conceptual and enactive RR scores for each of the tests for the verbal and enactment conditions. The results for Session 1 disclose three trends. First and foremost, a clear interaction is evident between processing modality and type of memory organization: Whereas verbal processing induced a stronger conceptual organization than enactive organization, enactment induced a stronger enactive organization. Indeed, a three-way ANOVA, Condition × Trial × Clustering Mode, yielded a significant Condition × Clustering Mode interaction, $F(1, 38) = 61.37$, $MSE = 0.035$, $p < .0001$, $\eta^2 = .62$. This analysis also yielded a significant effect for clustering mode, $F(1, 38) = 9.96$, $MSE = 0.035$, $p < .005$, $\eta^2 = .21$, indicating that conceptual clustering was overall more dominant than enactive clustering, and a significant effect for trial, $F(3, 114) = 30.30$, $MSE = 0.004$, $p < .0001$, $\eta^2 = .44$, indicating that clustering generally increased with trial. The triple interaction was also significant, $F(3, 114) = 14.34$, $MSE = 0.005$, $p < .0001$, $\eta^2 = .27$, as will be discussed shortly.

Second, as suggested by the triple interaction, the divergence between the clustering modes induced by the two types of instructions increased with trial. On the first trial, the enactment condition evidenced the same amount of enactive and conceptual organization.[2] By the fourth trial, however, a clear crossover interaction was found: Whereas values for enactive clustering averaged .334 and .098 for the enactment and verbal conditions, respectively, the respective values for conceptual clustering were .195 and .366. The increased divergence with practice was produced by the increase in modality-consistent clustering. On the one hand, both the increase in conceptual clustering in the verbal condition and the increase in enactive clustering in the enactment condition yielded a significant effect for trial, $F(3, 57) = 14.11$, $MSE = 0.005$, $p < .0001$, $\eta^2 = .43$, and $F(3, 57) = 22.19$, $MSE = 0.005$, $p < .0001$, $\eta^2 = .53$, respectively. On the other hand, there was no reliable change in modality-inconsistent clustering, either in enactive clustering under verbal instructions, $F(3, 57) = 1.52$, $MSE = 0.004$, $p > .20$, or in conceptual clustering under enactment instructions, $F(3, 57) = 1.79$, $MSE = 0.004$, $p > .15$.

Finally, a third trend is that the enactment condition induced a less pronounced modality-specific organization than did the verbal condition. Thus, across all trials of Session 1, the amount of enactive clustering induced by enactment was somewhat lower ($M = .271$) than the amount of conceptual clustering induced by the verbal instructions ($M = .319$), $t(38) = 1.61$, $p < .12$. At the same time, the amount of conceptual clustering induced by enactment ($M = .173$) was higher than the amount of enactive clustering induced by the verbal instructions ($M = .090$), $t(38) = 4.73$, $p < .0001$, $\eta^2 = .37$. These results suggest that memory organization according to conceptual–episodic categories dominates, although it can be partly replaced by organization according to movement similarity under instructions that emphasize enactment.

[2] To permit comparison with previous studies, which used pure, conceptually organized lists and a single study–test trial, we also computed ARC scores (Roenker et al., 1971) for the first trial. For the verbal condition, these scores averaged .545 and .111 for the conceptual and enactive clustering, respectively. The respective means for the enactment condition were .227 and .240. Except for the first of these means, which is of about the same order as that reported by others for taxonomically categorized lists (Bäckman et al., 1986; Engelkamp & Zimmer, 1996, 2002; Zimmer & Engelkamp, 1989), the other three means are lower, possibly because of the alternative modes of organization built into the list.

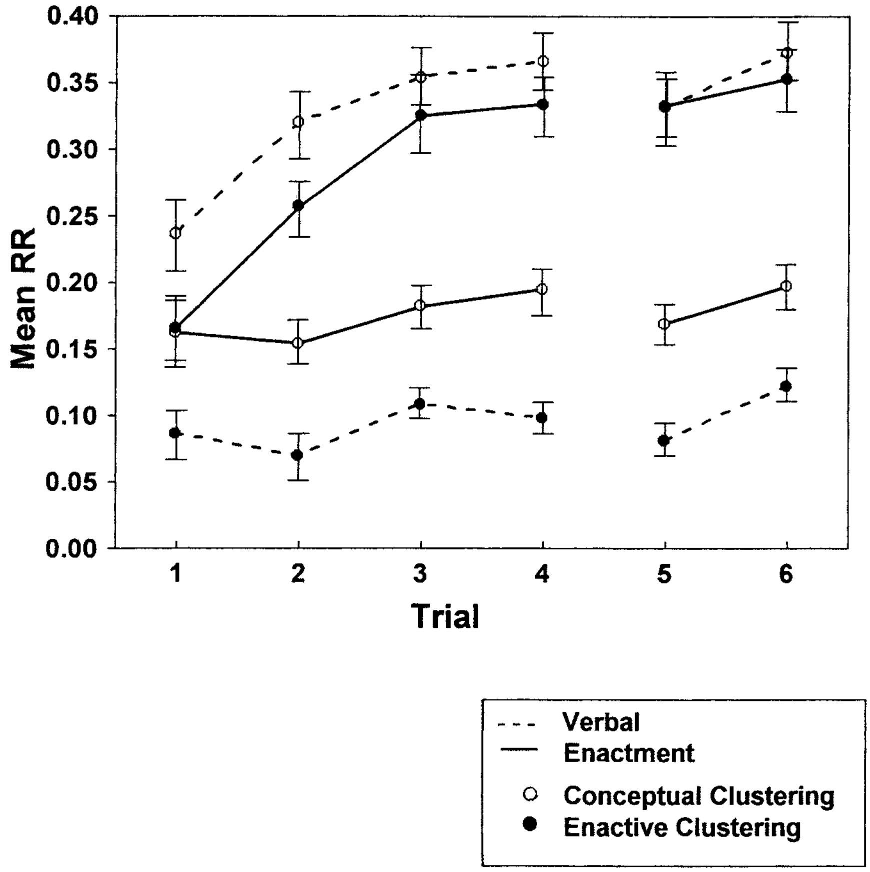

Figure 2. Mean conceptual clustering and enactive clustering for the verbal and enactment conditions as a function of trial (Experiment 1). RR = ratio of repetition. Error bars represent ± 1 standard error of the mean.

Turning next to Session 2, the results (shown in Figure 2) indicate that the preference for modality-specific clustering was maintained even after a 1-week interval. A three-way ANOVA, Condition × Trial (5 vs. 6) × Clustering Mode, yielded significant effects for condition, $F(1, 38) = 7.63$, $MSE = 0.007$, $p < .01$, $\eta^2 = .16$; for trial, $F(1, 38) = 10.72$, $MSE = 0.004$, $p < .005$, $\eta^2 = .21$; and for clustering mode, $F(1, 38) = 4.70$, $MSE = 0.018$, $p < .05$, $\eta^2 = .11$. More important, the Condition × Clustering Mode interaction was significant, $F(1, 38) = 95.40$, $MSE = 0.018$, $p < .0001$, $\eta^2 = .71$: Verbal instructions induced stronger conceptual ($M = .35$) than enactive ($M = .10$) clustering, $t(19) = 9.68$, $p < .0001$, $\eta^2 = .83$, whereas enactment instructions induced stronger enactive ($M = .34$) than conceptual ($M = .18$) clustering, $t(19) = 4.83$, $p < .0001$, $\eta^2 = .54$.

A comparison of the results for recall and clustering (Figures 1 and 2) is instructive. Whereas recall quantity decreased markedly from the fourth to the fifth trial, $t(39) = 10.97$, $p < .0001$, $\eta^2 = .76$, modality-consistent clustering exhibited little reduction over the 1-week interval: $t(19) = 0.00$ for enactive clustering under enactment instructions, and $t(19) = 1.60$, $p > .12$, for conceptual clustering under verbal instructions. Thus, recall and clustering exhibited a similar pattern as far as the effects of practice are concerned but different patterns as far as the effects of retention interval are concerned.

The results depicted in Figure 2 raise the question of whether the interaction between processing condition and clustering mode could derive from systematic differences between the two conditions in the number and type of action phrases recalled. We have seen that participants in the two processing conditions differ in recall performance, but they might also differ in the type of action phrases recalled if mode of processing also affects the retrieval of action phrases that fit into a modality-specific organization. To examine this possibility, we calculated two maximum clustering scores, representing the largest possible score given the number of items recalled by the participant. First, all of the phrases that were recalled by a participant on a given trial, excluding commission errors, partial recalls, and repetitions, were ordered according to their conceptual class, and a maximum conceptual RR score was calculated. The action phrases were then rearranged according to their enactive class, and a maximum enactive RR score was calculated. The means of these maximum RR scores are presented in Figure 3 for the enactment and verbal groups as a function of trial. Apart from the fact that maximum organization was higher for the enactment condition than for the verbal condition, it can be seen that the modality-consistent clustering effects depicted in Figure 2 cannot be explained in terms of the number and type of action phrases recalled under the two conditions. Furthermore, the actual degree of clustering exhibited by participants (Figure 2) is considerably lower than what they could have potentially achieved given their recall performance (Figure 3). Thus, enactment affects clustering mode independent of any effect that it might have on the number and type of action phrases recalled.

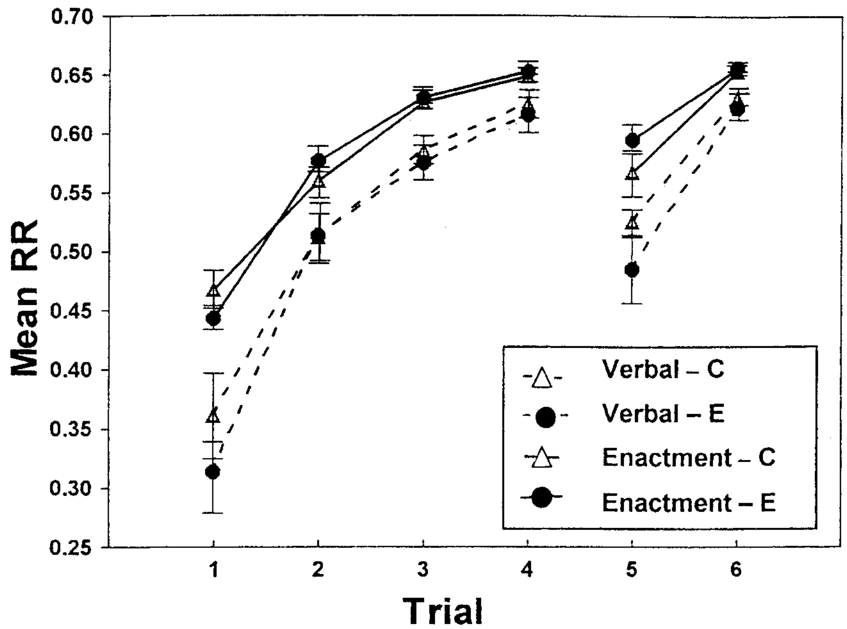

Figure 3. Maximum conceptual clustering (C) and enactive clustering (E) for the verbal and enactment conditions as a function of trial (Experiment 1). RR = ratio of repetition. Error bars represent ± 1 standard error of the mean.

Another question concerns the extent to which the observed clustering patterns depart from what might be expected by chance. To estimate the magnitude of chance clustering, we randomly ordered all words recalled by a participant on any given trial (excluding commissions, partial recalls, and repetitions) and calculated two RR scores, one for enactive clustering and one for conceptual clustering. This procedure was repeated 100 times, and the average RR scores were used as estimates of the amount of chance clustering. The expected degree of clustering was found to be quite uniform across conditions, clustering mode, and trials, ranging only from .06 to .08. A Condition × Clustering Mode × Trial ANOVA on the expected RR scores yielded no significant effects (all *p*s $>$ .05). A comparison of the observed clustering scores with those expected by chance revealed that, on the one hand, the enactment condition produced not only a significantly stronger enactive organization than expected by chance, even on the first trial, $t(19) = 3.43$, $p < .005$, $\eta^2 = .38$, but also a significantly stronger conceptual organization than expected by chance, $t(19) = 3.93$, $p < .001$, $\eta^2 = .47$. On the other hand, the verbal condition induced a stronger conceptual organization than expected by chance, $t(19) = 6.42$, $p < .0001$, $\eta^2 = .68$, but no better enactive organization than chance, $t(19) = 1.18$, $p > .20$. By the fourth trial, however, the amount of enactive organization was better than chance even in the verbal condition, $t(19) = 2.65$, $p < .05$, $\eta^2 = .20$. These results suggest that modality-specific clustering is not perfect. In fact, although by the fourth trial the amount of modality-consistent clustering was 4.75 times and 5.59 times larger than chance for the enactment and verbal conditions, respectively, the amount of modality-inconsistent clustering exceeded chance by factors of 2.86 and 1.60 for the enactment and verbal conditions, respectively. Still, it appears clear that conceptual clustering is less sensitive to encoding and testing conditions than is enactive clustering.

The relationship between memory organization and recall quantity. As noted in the introduction, it is generally assumed that recall performance is intimately tied to memory organization. However, results concerning memory for enacted tasks have yielded no correlation between clustering and recall (Engelkamp & Zimmer, 1996; Zimmer & Mohr, 1986).

However, we hypothesized that the recall–clustering correlation should vary depending on the combination of processing modality (verbal vs. performance) and organization mode (conceptual vs. enactive): It should be strongest for modality-consistent organization. To examine this hypothesis, we calculated the cross-participant Pearson correlations between recall quantity, on the one hand, and enactive and conceptual RR scores, on the other hand, for each condition and trial. Table 1 presents these correlations as well as the correlation between conceptual and enactive RR scores (CE) for each condition and trial.

We examine the latter results first. As can be seen, all 12 correlations between the two RR scores are negative ($p < .001$, by a binomial test), averaging $-.44$ and $-.28$ for the enactment and verbal conditions, respectively, across trials. In addition, a trend suggests that the negative correlation increased with practice. Of course, the two RR scores must be negatively correlated for statistical reasons, because each recalled phrase could be related to the previously recalled phrase either enactively or conceptually. However, note that when a similar correlational analysis was carried out on the RR scores that are expected by chance (computing the correlation on each random arrangement of the recalled phrases and then averaging across all 100 runs), the correlations were low and, in fact, positive, averaging .10 and .05 for the enactment and verbal conditions, respectively.

Table 1
The Correlations Between Recall Quantity and Clustering (E = Enactive, C = Conceptual) and Between the Two Clustering Scores (EC), Experiment 1

	Condition					
	Enactment			Verbal		
Trial	E	C	EC	E	C	EC
1	.61*	−.09	−.04	.01	.56*	−.18
2	.42	−.01	−.15	.11	.68*	−.19
3	.52*	−.42	−.84*	−.02	.64*	−.31
4	.44	−.21	−.72*	−.28	.62*	−.20
5	.30	−.11	−.20	.43	.14	−.48*
6	.30	−.15	−.70*	.18	.47*	−.32
M	.43	−.17	−.44	.07	.52	−.28

* $p < .05$.

These results suggest that participants tend to consistently converge on one rather than the other mode of organization throughout the entire list, with the extent of convergence increasing from trial to trial. This pattern of results is consistent with the findings of Koriat and Melkman (1981) that participants' preference for one mode of clustering over the other (conceptual or associative in that case) was consistently maintained throughout all seven trials of that experiment.

Turning next to the recall–organization correlations, it can be seen that in the enactment condition, enactive clustering was clearly a better predictor of recall than was conceptual clustering: All six correlations between enactive clustering and recall were positive ($p < .02$, by a binomial test), averaging .43 across trials, whereas those between conceptual clustering and recall were consistently negative (also $p < .02$, by a binomial test), averaging −.17. In contrast, in the verbal condition, the correlations between conceptual clustering and recall were all positive ($p < .02$, by a binomial test), averaging .52, whereas the correlations between enactive clustering and recall were not consistent in sign ($p > .20$, by a binomial test), averaging .07.

The relationship between memory organization and recall accuracy. The results for recall accuracy (Table 2) display the same pattern as that observed for recall quantity (Table 1). On the one hand, in the enactment condition, enactive clustering was clearly a better predictor of recall accuracy than was conceptual clustering: The correlation between enactive clustering and recall accuracy was positive for each of the six trials ($p < .02$, by a binomial test) and averaged .29 across all trials. On the other hand, the correlation between conceptual clustering and recall accuracy was consistently negative, averaging −.13 (also $p < .02$, by a binomial test). The verbal condition, in contrast, yielded the opposite trend: Whereas the correlations between conceptual clustering and recall accuracy were consistently positive ($p < .02$, by a binomial test), averaging .35, those between enactive clustering and recall accuracy were less consistent in sign ($p > .20$ by a binomial test), averaging only .02.

Discussion

The results of Experiment 1 were generally consistent with our predictions. First, the enactment effect for quantity performance was replicated: A stable recall superiority was observed for the first four trials and was maintained over a 1-week interval without an intervening study trial. An enactment effect was also found for accuracy performance, replicating the results of Koriat et al. (1998).

Can the effects of enactment on memory accuracy be explained in terms of the strategic control of memory reporting (Koriat & Goldsmith, 1996)? The trademark of such control is the quantity–accuracy trade-off: Participants enhance the accuracy of their memory report by withholding a larger proportion of the information that comes to mind, thus sacrificing memory quantity in return for improved accuracy. Here, however, memory quantity and accuracy were found to increase together as a function of enactment. This suggests that the enhanced memory accuracy that occurs as a result of enactment is due to improved effectiveness of the monitoring process that is used to screen out incorrect memory responses rather than to the adoption of a stricter control policy. Presumably, the added enactive and visual cues produced by enactment not only facilitate retrieval but also help in discriminating between true and false memories.

Second, consistent with predictions, a crossover interaction was observed between processing modality (enactment vs. verbal) and mode of organization (enactive vs. conceptual): Whereas verbal processing induced a stronger conceptual organization than enactive organization, enactment induced a stronger enactive organization than conceptual organization. Furthermore, modality-consistent organization—enactive in the case of task performance, conceptual in the case of verbal processing—increased systematically with trial, whereas modality-inconsistent organization yielded no such increase.

On the face of it, these results appear to be inconsistent with those reported by Engelkamp and Zimmer (e.g., Engelkamp & Zimmer, 2002; Zimmer & Engelkamp, 1989) for the clustering of categorized lists. However, as we have argued (see also Koriat et al., 1998), previous studies of memory clustering have not provided sufficient opportunities for the manifestation of the type of organization that seems to be compatible with enactment, namely, an organization in terms of similarity of motor movements. When such opportunities exist, as in Experiment 1, it becomes clear that enactment does enhance memory organization.

However, we should note that enactive clustering was overall less dominant than was conceptual clustering. Thus, conceptual

Table 2
The Correlations Between Recall Accuracy and Clustering (E = Enactive, C = Conceptual), Experiment 1

	Condition			
	Enactment		Verbal	
Trial	E	C	E	C
1	.29	−.23	.04	.47*
2	.39	−.07	−.04	.38
3	.24	−.20	−.32	.43
4	.16	−.17	.01	.44
5	.40	.24	.23	.17
6	.23	−.33	.17	.22
M	.29	−.13	.02	.35

* $p < .05$.

clustering was much stronger than enactive clustering in the verbal condition, with the latter mode of organization leading to results that were overall no better than chance. Although enactment reversed this pattern, it did not eliminate conceptual organization altogether. These results are consistent with the claim that motor processing always includes semantic–conceptual processing as well (Engelkamp, 2001; Zimmer, 2001). More generally, the prevalence of conceptual clustering even in the enactment condition may be taken to argue against an extreme version of embodied cognition in which even conceptual processing is seen to involve modality-specific reenactment (Barsalou, Simmons, Barbey, & Wilson, 2003).

Third, the correlations between memory organization on the one hand and recall quantity and accuracy on the other hand suggest that it is modality-consistent memory organization that contributes to recall performance, whereas modality-inconsistent organization has little beneficial effect. These results are consistent with the idea that a mode of organization that exploits the features of studied items that are most distinctive in terms of the prevalent processing modality is the one that is most beneficial for memory quantity and also helps protect against false recalls. Clearly, then, the unqualified conclusions that, in the case of SPTs, memory organization either enhances recall (e.g., Bäckman et al., 1986) or impairs it (e.g., Engelkamp & Zimmer, 1996; Zimmer & Mohr, 1986) are both unwarranted. The trends depicted in Table 1 suggest that both conclusions are correct depending on which type of memory organization is examined.

Experiment 2

The verbal and enactment conditions of Experiment 1 differed both at the encoding phase and at the recall phase. This was intended to sharpen the contrast between the verbal and enactment conditions. The purpose of the following experiments was to specify more precisely the contribution of enactment during study (Experiment 2) and during testing (Experiment 3).

In a typical experiment on memory for action (see Engelkamp, 1998), enactment is manipulated during study by contrasting VT and SPT instructions, but memory is then tested by the recall or recognition of the action phrases. This paradigm captures a common situation in everyday life, in which people recount their past activities or attempt to recall whether they have already carried out a planned action, such as taking a medicine (Koriat & Ben-Zur, 1988). The question is whether task performance during study is sufficient to produce a different type of memory organization, as was found in Experiment 1.

Experiment 2 involved the typical contrast between VT and SPT conditions. Results for the typical VT condition are already available from Experiment 1: Participants in the verbal condition simply read aloud the action phrases during study and recalled them verbally during testing. A corresponding SPT condition was therefore added in Experiment 2. It was similar in every respect to the verbal condition of Experiment 1 (which is labeled the VT condition in the context of Experiment 2) except that participants were required to carry out the tasks during study.

Method

Participants. Twenty Hebrew-speaking University of Haifa undergraduates (16 women and 4 men) participated in the SPT condition of this experiment for course credit. They were drawn from the same pool as those who participated in Experiment 1.

Apparatus, materials, and procedure. The apparatus and the memory list from Experiment 1 were used. The SPT condition in Experiment 2 was similar to the verbal condition of Experiment 1 except that participants were required to carry out the tasks during study.

Results

Recall performance. For the SPT condition, recall quantity averaged 49.4%, 68.8%, 83.0%, and 85.5% for Trials 1 through 4, respectively. The respective means for the VT condition (drawn from Experiment 1) were 34.6%, 63.0%, 73.6%, and 83.3%. A Condition × Trial ANOVA yielded $F(1, 38) = 5.74$, $MSE = 49.41$, $p < .05$, $\eta^2 = .13$, for condition; $F(3, 114) = 375.56$, $MSE = 4.07$, $p < .0001$, $\eta^2 = .91$, for trial; and $F(3, 114) = 7.83$, $MSE = 4.07$, $p < .0001$, $\eta^2 = .17$, for the interaction. Thus recall was better for the SPT condition than for the VT condition, but the effect was strongest on the earlier trials. This effect did not persist over the 1-week interval: Mean recall quantity totals for Trials 5 and 6 were 62.4% and 87.0%, respectively, for the SPT condition, compared with 59.9% and 84.4%, respectively, for the VT condition, $t(38) = 0.49$, *ns*, for Trial 5, and $t(38) = 0.88$, *ns*, for Trial 6.

Memory accuracy performance for the SPT condition was high, averaging 95.4%, 99.1%, 98.9%, and 98.8% for Trials 1 through 4, respectively. (The respective means for the VT condition were 83.1%, 90.3%, 92.6%, and 94.4%.) A Condition × Trial ANOVA yielded significant effects for condition, $F(1, 38) = 20.67$, $MSE = 122.04$, $p < .0001$, $\eta^2 = .35$; for trial, $F(3, 114) = 17.75$, $MSE = 24.65$, $p < .0001$, $\eta^2 = .32$; and for the interaction, $F(3, 114) = 4.60$, $MSE = 24.65$, $p < .005$, $\eta^2 = .11$. The interaction seems to derive from the fact that the SPT condition yielded very high accuracy even on the first trial. By and large, however, enactment seemed to protect against false recalls: Memory accuracy performance averaged 98.0% for the SPT condition and 90.1% for the VT condition across the four trials.

A similar trend was evident in Session 2: Memory accuracy performance in the SPT condition averaged 97.8% and 98.7% for Trials 5 and 6, respectively. (The respective means for the VT condition were 89.7% and 95.2%.) A two-way ANOVA yielded $F(1, 38) = 15.00$, $MSE = 45.97$, $p < .001$, $\eta^2 = .28$, for condition; $F(1, 38) = 11.71$, $MSE = 17.55$, $p < .01$, $\eta^2 = .24$, for trial; and $F(1, 38) = 5.99$, $MSE = 17.55$, $p < .05$, $\eta^2 = .14$, for the interaction. The interaction indicates that only in the VT condition did memory accuracy improve from Trial 5 to Trial 6, whereas for the SPT condition, it was quite high, even on Trial 5.

Memory organization. Conceptual clustering was lower for the SPT condition than for the VT condition, averaging .143, .171, .179, and .185 for Trials 1 through 4, respectively. (The respective means for the VT condition were .237, .320, .354, and .366.) In contrast, enactive clustering was higher for the SPT condition, averaging .171, .248, .307, and .294 for Trials 1 through 4, respectively. (The respective means for the VT condition were .086, .069, .108, and .099.) Thus the interaction obtained in Experiment 1 between condition and mode of clustering was replicated in Experiment 2 when contrasting the SPT and VT conditions. A Condition × Trial × Clustering Mode ANOVA yielded significant effects for clustering mode, $F(1, 38) = 14.24$, $MSE = 0.029$, $p < .0005$, $\eta^2 = .27$, and for trial, $F(3, 114) = 29.43$, $MSE = 0.004$, $p < .0001$, $\eta^2 = .44$. In general, conceptual clustering was higher than enactive clustering, and there was an overall increase in clustering with trial. More important, the Condition × Clustering Mode interaction was highly significant, $F(1, 38) = 68.22$, $MSE = 0.029$, $p < .0001$, $\eta^2 = .64$. The triple interaction was also significant, $F(3, 114) = 8.41$, $MSE = 0.005$, $p < .0001$, $\eta^2 = .18$, reflecting the observation that modality-consistent clustering increased more steeply with trial than did modality-inconsistent clustering. Thus, conceptual clustering increased by .129 from Trial 1 to Trial 4 for VTs but only by .042 for SPTs. Conversely, enactive clustering increased by .123 for SPTs but only by .013 for VTs. In fact, the effects of trial were not significant for enactive clustering in the VT condition (as reported earlier; see Experiment 1), and the same was true for conceptual clustering in the SPT condition, $F(3, 57) = 1.70$, $p > .15$. Separate analyses for each mode of clustering indicated that the SPT condition produced significantly stronger enactive clustering than did the VT condition, and the reverse was true for conceptual clustering. Thus, a Condition × Trial ANOVA on enactive clustering yielded $F(1, 38) = 60.69$, $MSE = 0.018$, $p < .0001$, $\eta^2 = .62$, for condition; $F(3, 114) = 11.77$, $MSE = 0.004$, $p < .0001$, $\eta^2 = .24$, for trial; and $F(3, 114) = 6.61$, $MSE = 0.004$, $p < .0005$, $\eta^2 = .15$, for the interaction. A similar ANOVA on conceptual clustering yielded $F(1, 38) = 38.11$, $MSE = 0.023$, $p < .0001$, $\eta^2 = .50$, for condition; $F(3, 114) = 13.33$, $MSE = 0.004$, $p < .0001$, $\eta^2 = .25$, for trial; and $F(3, 114) = 3.60$, $MSE = 0.004$, $p < .02$, $\eta^2 = .09$, for the interaction.

The interaction between condition and mode of clustering was also found in Session 2. For Trials 5 and 6, enactive clustering for SPTs averaged .270 and .319, respectively, whereas for VTs it averaged .082 and .122, respectively. The respective means in Trials 5 and 6 for conceptual clustering were .165 and .195 for SPTs and .332 and .372 for VTs. A Condition × Clustering Mode ANOVA for Trial 5 yielded $F < 1$ for condition; $F(1, 38) = 9.00$, $MSE = 0.012$, $p < .005$, $\eta^2 = .20$, for mode of clustering; and $F(1, 38) = 53.97$, $MSE = 0.012$, $p < .0001$, $\eta^2 = .58$, for the interaction. Thus, the effects of enactment on memory organization persisted over the 1-week interval. The Condition × Clustering Mode interaction was also significant for Trial 6, $F(1, 38) = 79.24$, $MSE = 0.009$, $p < .0001$, $\eta^2 = .67$.

The effects of enactment during testing: Recall performance. The results of Experiment 2 indicated that task performance during study exerts pervasive effects on both recall and memory organization. A question of interest is whether the added features included in the enactment condition of Experiment 1—of preparing for future task performance, as well as actually being tested by task performance—made any contribution to recall and memory organization over that achieved by the SPT condition of Experiment 2.

With regard to recall quantity performance, the results yielded little difference between the enactment condition of Experiment 1 and the SPT condition of Experiment 2. A Condition × Trial ANOVA on the results of Session 1 yielded $F < 1$ for condition; $F(3, 114) = 294.18$, $MSE = 4.28$, $p < .0001$, $\eta^2 = .89$, for trial; and $F < 1$ for the interaction. Recall across all four trials averaged 24.41% and 23.64% for the enactment and SPT conditions, respectively.

However, the effects of enactment during testing appeared nevertheless to manifest themselves in the delayed memory test: Recall percentage for Trials 5 and 6 for the SPT condition of Experiment 2 averaged 20.60% and 28.70%, respectively, compared with 23.90% and 30.00% for the enactment condition of Experiment 1: $t(38) = 2.18$, $p < .05$, $\eta^2 = .11$, for Trial 5, and $t(38) = 1.71$, $p < .10$, $\eta^2 = .07$, for Trial 6.

Recall accuracy, if anything, was better for the SPT condition than for the enactment condition, averaging 98.03% and 94.69%, respectively, across the first four trials, $t(38) = 3.70$, $p < .001$, $\eta^2 = .27$. The respective means for Session 2 were 98.29% and 97.38%.

The effects of enactment during testing: Memory organization. Somewhat surprisingly, analyses of memory organization too yielded little difference between the enactment and SPT conditions. A Condition (enactment vs. SPT) × Trial × Clustering Mode ANOVA yielded significant effects for trial, $F(3, 114) = 44.40$, $MSE = 0.003$, $p < .0001$, $\eta^2 = .54$; for clustering mode, $F(1, 38) = 19.67$, $MSE = 0.034$, $p < .0001$, $\eta^2 = .34$; and for the Trial × Clustering Mode interaction, $F(3, 114) = 9.87$, $MSE = 0.006$, $p < .0001$, $\eta^2 = .21$. However, the Condition × Clustering Mode interaction was not significant, $F < 1$.

In Session 2, there was a trend indicating that enactive clustering was weaker for the SPT condition than for the enactment condition. (Mean enactive clustering totals for Trials 5 and 6 were .270 and .319, respectively, for the SPT condition of Experiment 2, compared with .333 and .353, respectively, for the enactment condition of Experiment 1.) However, the effect of condition was not significant, $F(1, 38) = 2.47$, $MSE = 0.019$, $p < .13$. There was also little difference in conceptual clustering between the two conditions.

Discussion

The results of Session 1 revealed the typical recall superiority of SPT over VT. More important, the two conditions differed in the type of memory organization induced: Whereas the VT condition elicited more conceptual than enactive clustering, the reverse was true for the SPT condition. Furthermore, whereas for the VT condition, conceptual clustering increased more steeply with trial than did enactive clustering, for the SPT condition, it was primarily enactive clustering that increased with practice. Finally, a comparison of the SPT condition of Experiment 2 with the enactment condition of Experiment 1 yielded very small differences overall, suggesting that if enactment takes place during study, enactment during testing has little added effect either on recall or on memory organization. This finding supports Helstrup's (1996) conclusion that preparing to enact actions in the future does not improve memory over and above the memory benefits realized when actual enactment of the actions takes place during study.

The results of Experiment 2 have important theoretical and methodological implications. On the theoretical side, they indicate that the modal, motor properties of enacted tasks are revealed even when recall is verbal rather than through enactment. These results support the postulation of an enactive mode of representation whose mediating role is not confined to behavioral expression, as is generally assumed to be the case for procedural memory (Tulving, 1985; see the General Discussion section). Indeed, consistent with the notion of embodied cognition, several studies demonstrated that even visual input can activate covert motor representations (e.g., Tucker & Ellis, 1998) and that conceptually activated stereotypes can affect associated motor components (Bargh, Chen, & Burrows, 1996). On the methodological side, the results of Experiment 2 suggest that the conclusions drawn on the basis of the results of Experiment 1 are indeed applicable to the typical experimental conditions in which the effects of enactment have been evaluated and that have given rise to heated controversies.

Experiment 3

Experiment 3 concerns another common aspect of memory in real life: the fact that people have to remember to perform certain actions in the future, such as calling the doctor or buying milk. Interest in prospective remembering has engendered a great deal of research in recent years (see Brandimonte et al., 1996; Ellis et al., 1999). Several studies (Engelkamp, 1997; Goschke & Kuhl, 1993; Jahn & Engelkamp, 2003; Koriat et al., 1990) indicated that prospective enactment enhances memory performance. For example, Koriat et al. (1990) found better recall of action phrases when participants expected recall to be tested through enactment (prospective SPT) rather than verbally (prospective VT). Brooks and Gardiner (1994) failed to replicate this effect, but Engelkamp (1997) showed that the effect is found when prospective enactment is manipulated between participants (as in Koriat et al., 1990) but not when it is manipulated within participants.

The question of interest in Experiment 3 is whether planning actions for future enactment also changes memory organization of these actions. If such is the case, this would support the view that the preparation for action is functionally equivalent to the activation of motor programs (Jeannerod, 1997). We used two conditions that differed in the expected mode of testing. In the first three study–test cycles, however, all participants were actually tested by verbal recall. By comparing the results for the two conditions, we can see whether expected enactment, in itself, induces greater organization of the phrases in terms of bodily movements. In addition, in the fourth study–test cycle, half of the prospective-SPT participants were tested by enactment, whereas the remaining participants were tested by verbal recall, as before. A comparison of the results for these two groups can establish whether actual mode of testing exerts an effect on memory organization over and above that of expected enactment.

Method

Participants. Participants were 60 Hebrew-speaking University of Haifa undergraduates (41 women, 19 men) who took part in the experiment for course credit. They were divided randomly between the prospective-VT and prospective-SPT conditions.

Apparatus, materials, and procedure. The apparatus and memory list from Experiment 1 were used. The procedure was also similar to that used in Experiment 1 except for the following differences. First, the procedure for the prospective-SPT group was the same as that of the enactment group except that participants did not perform the action phrases during study but were told to memorize them so that they would be able to perform them during the recall test. They were instructed that when the action phrase required an object, they would have to perform the action on an imaginary object during testing. Participants in the prospective-VT group were told that during testing, they would be asked to say the action phrases aloud. During the practice phase, participants read the three practice phrases, and, depending on their assigned condition, they were instructed to prepare either for future verbal recall or for future enactment of the phrases. However, no actual test was given.

Second, at the end of the study phase, participants in the prospective-SPT group were told that the recall-by-enactment test was postponed and that they should simply recall the action phrases verbally in any order they wished. This study–test cycle was repeated two more times; each time, the prospective-SPT participants were instructed to expect an enactment test but were actually tested verbally. A similar study–test cycle then followed, but in the test phase of that cycle, half of the prospective-SPT participants were tested by enactment, whereas the other half were asked to verbally recall the action phrases as in the previous trials.

Results

Recall performance. Recall quantity for the prospective-SPT group averaged 41.1%, 62.4%, and 76.5%, respectively, for Trials 1 through 3. The respective means for the prospective-VT group were 33.6%, 56.4%, and 69.9%. The results for the first trial replicate the prospective enactment effect reported previously (Engelkamp, 1997; Koriat et al., 1990), $t(58) = 2.14$, $p < .05$, $\eta^2 = .07$. This effect was maintained across the first three trials, although a Condition × Trial ANOVA yielded only a near-significant effect for condition, $F(1, 58) = 3.68$, $MSE = 53.38$, $p < .06$, $\eta^2 = .06$; a significant effect for trial, $F(2, 116) = 320.83$, $MSE = 6.58$, $p < .0001$, $\eta^2 = .85$; and $F < 1$ for the interaction. Thus, a prospective enactment effect was found even though participants were tested verbally.

Recall accuracy failed to yield a prospective enactment effect. Memory accuracy for the prospective-SPT group averaged 93.2%, 95.4%, and 95.1%, respectively, for Trials 1 through 3. The respective means for the prospective-VT group were 91.7%, 94.8%, and 95.2%. A Condition × Trial ANOVA yielded a significant effect for trial, $F(2, 116) = 4.19$, $MSE = 28.86$, $p < .02$, $\eta^2 = .07$, but not for condition or the interaction, $F < 1$ in both cases.

Memory organization. Was the expectation to perform the actions during testing sufficient to affect mode of organization? Focusing on the first three trials (see Figure 4), the results revealed the same type of interaction between condition and mode of clustering as that obtained in Experiment 1, although this interaction was now much weaker. Enactive clustering was stronger for the prospective-SPT condition than for the prospective-VT condition, and conceptual clustering was generally stronger for the verbal condition than for the enactment condition. This pattern is most clearly seen in Trials 2 and 3. A three-way ANOVA, Condition × Trial × Clustering Mode, for the first three trials yielded significant effects for trial, $F(2, 116) = 23.13$, $MSE = 0.005$, $p < .0001$, $\eta^2 = .28$, and for clustering mode, $F(1, 58) = 18.55$, $MSE = 0.033$, $p < .0001$, $\eta^2 = .24$ (indicating stronger conceptual than enactive clustering overall). However, the interaction between clustering mode and trial, as well as the triple interaction, were significant, $F(2, 116) = 4.30$, $MSE = 0.10$, $p < .05$, $\eta^2 = .07$, and $F(2, 116) = 3.95$, $MSE = 0.10$, $p < .05$, $\eta^2 = .06$, respectively. When only Trials 2 and 3 were included in the ANOVA, the only interaction that was significant was that between condition and clustering mode, $F(1, 58) = 6.17$, $MSE = 0.029$, $p < .05$, $\eta^2 = .10$. It can be seen that the strongest difference between the two conditions was in the extent of enactive clustering, whereas conceptual clustering yielded the expected effect only in Trials 2 and 3. In fact, conceptual clustering was significantly higher than enactive clustering, even for the prospective-SPT condition, averaging .219 and .160, respectively, across the first three trials, $t(39) = 2.39$, $p < .05$, $\eta^2 = .13$.

A second question that was examined concerned the effects of actual mode of testing: Given that a person expects future enactment, does actual enactment during testing affect mode of organization? To address this question, we compared recall perfor-

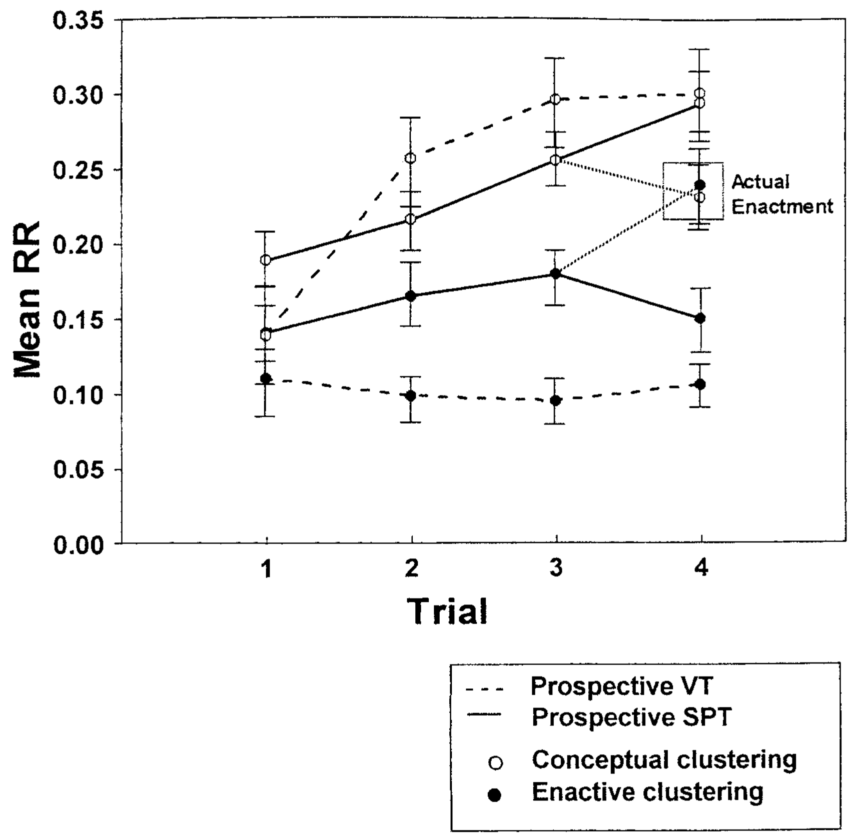

Figure 4. Mean conceptual clustering and enactive clustering for the prospective-VT and prospective-SPT conditions as a function of trial (Experiment 3). RR = ratio of repetition; VT = verbal task; SPT = self-performed task. Error bars represent ± 1 standard error of the mean.

mance in Trial 4 for participants in the prospective-SPT condition who were tested by actually performing the actions with that of participants (in the same condition) who were tested verbally. Conceptual clustering was higher for those who were tested verbally (M = .293) than for those who were tested by enactment (M = .230), whereas enactive clustering was higher for those who took part in enactment testing (M = .238) than for those who took part in verbal testing (M = .149). A two-way ANOVA on these means yielded a significant effect for clustering mode, $F(1, 38) = 6.28$, $MSE = 0.015$, $p < .05$, $\eta^2 = .14$, indicating stronger conceptual than enactive clustering overall. However, the interaction was also significant, $F(1, 38) = 7.82$, $MSE = 0.015$, $p < .01$, $\eta^2 = .16$, indicating that mode of testing affects mode of organization, such that enactment testing promotes stronger enactive clustering. Enactive clustering was stronger under enactment testing than under verbal testing, $t(38) = 2.77$, $p < .01$, $\eta^2 = .17$, and conceptual clustering was somewhat stronger under verbal testing than under enactment testing, $t(38) = 2.00$, $p < .06$, $\eta^2 = .10$.

Discussion

The results of Experiment 3 yielded a significant effect of prospective enactment on recall quantity, although this effect was less pronounced than that obtained in Experiment 2 for actual enactment. In contrast, recall accuracy was not affected by prospective enactment.

More important, the results for memory organization indicated that the expectation for future enactment was sufficient to increase enactive organization compared with the expectation for verbal recall. These results are consistent with Koriat et al.'s (1990) proposal that expected enactment affects encoding processes by activating internal, symbolic enactment of the actions and with Jeannerod's (1997) view that action planning activates motor programs. However, note that conceptual clustering was nevertheless stronger than enactive clustering even in the prospective-SPT condition, suggesting that symbolic representations exert pervasive effects even when enactment is anticipated.

How can mode of testing influence the output order of report and performance? One possibility is that task performance increases the salience of motor aspects of the tasks, so that performed tasks tend to prime encoded tasks that share motor features with them, thus enhancing enactive organization online. This possibility implies that organization need not reflect strategic processes but may occur on the fly as a result of automatic associative processes during retrieval (Koriat & Melkman, 1987; McDaniel & Einstein, 2000).

General Discussion

The issues addressed in this study concern the manner in which information about action events is represented in memory and how that information is used. These issues are reminiscent of the classic debate between proponents of the propositional approach, which assumes a languagelike, symbolic mental representation, and those who postulate an analogical, picturelike representation (see Anderson, 1978; Kosslyn, Pinker, Smith, & Shwartz, 1979; Pylyshyn, 1981). Whereas that debate has centered on visual imagery and the processing of visuospatial information (vs. verbal-propositional processing), the focus of the present study is on enactive rather than iconic modes of representation (Bruner, 1966). Such enactive-motor representations have recently gained renewed interest in the context of theories of embodied cognition (e.g., Barsalou, 2002; Glenberg, 1997; Hommel et al., 2001; see Wilson, 2002).

The results of the present study as well as previous findings (for a review, see Engelkamp, 2001) clearly indicate that motor aspects of performed tasks are retained in addition to the verbal description of the action phrases. Furthermore, there is evidence (also reviewed by Engelkamp, 2001) that it is specifically the motor features rather than the visual features of the tasks that are critical for the enactment effect (e.g., the SPT effect is obtained even when participants close their eyes while performing the actions; Engelkamp, Zimmer, & Biegelmann, 1993). Engelkamp (2001) took these results to argue for the existence of a specialized system—an action output system—that supports the processing of performed actions.

In what follows, we summarize and discuss the results pertaining to the following issues: (a) the effects of enactment on memory performance, (b) memory organization of action events, (c) the relationship between memory organization and recall performance, and (d) the question of whether the results on memory organization can explain the enactment effect. We conclude with a discussion of the implications of our results for the notion of an enactive memory representation.

The Effects of Enactment on Memory Performance

Our results confirmed the beneficial effect of enactment on memory quantity performance. This benefit amounted to about 15% in the enactment condition of Experiment 1 and in the SPT condition of Experiment 2 and was maintained even after a week's interval. Prospective enactment, in itself (Experiment 3), also improved recall even when recall was tested verbally. In addition, the results also replicated the accuracy superiority of enactment (Koriat et al., 1998) in both Experiments 1 and 2, and this superiority too survived the 1-week interval.

A question of interest is whether the effects of enactment on both memory quantity and memory accuracy derive from the same source: the added enactive and visual cues produced by enactment. Possibly, these cues not only facilitate retrieval, as claimed by Engelkamp and Zimmer (1983, 1985), but also protect against false recall by assisting source monitoring. Dodson and Schacter (2001), for example, found that saying words at study, rather than just hearing them, reduced false recognition. They attributed the effect to the use of a distinctiveness heuristic during testing, whereby participants demanded access to distinctive information connected to saying the words. In a similar vein, performing actions during study may be assumed to provide distinctive cues that can help avoid commission errors.

Memory Organization of Action Events

The results on memory organization yielded two general findings. First, a crossover interaction was found in Experiments 1 and 2 between processing modality (verbal vs. enactment) and mode of organization (enactive vs. conceptual), such that the verbal condition resulted in stronger conceptual than enactive clustering, whereas the reverse was true for the enactment condition. This interactive pattern was evident even after a week's retention interval in the absence of an intervening study phase, suggesting that enactment has a long-lasting effect on memory organization. The interaction between condition and clustering mode was less pronounced in Experiment 3, but the results still indicated that prospective enactment modified the relative dominance of enactive and conceptual organization.

The second finding concerns the changes in organization that occur with learning. It was the modality-consistent clustering that increased from the first to the fourth trial: Thus, only enactive clustering increased with trial in both the enactment (Experiment 1) and the SPT (Experiment 2) conditions, whereas only conceptual clustering increased with trial in the verbal condition (Experiment 1). In Experiment 3, enactive clustering increased with trial in the prospective-SPT condition but not in the prospective-VT condition, whereas conceptual clustering increased relatively steeply in both the prospective-VT and the prospective-SPT conditions.

What is the process by which enactment changes the basis of memory organization, inducing a greater reliance on interitem similarity in bodily movements? Presumably, information is represented in memory along a variety of dimensions (Underwood, 1969). What enactment does is to increase the salience of certain features of action events rather than others. In particular, features of action phrases that are more directly related to their actual performance gain priority in guiding the encoding and retrieval of the information. Our results suggest that these features become part of the memory trace to the extent of influencing recall clustering. This conclusion is consistent with the view advanced by Engelkamp and his associates (e.g., Engelkamp, Zimmer, Mohr, & Sellen, 1994) and runs counter to the argument of Kormi-Nouri and Nilsson (2001) that enacted phrases are stored in a verbal code rather than in a motor code.

A comparison of the results across the three experiments suggests that enactment may affect memory organization at any of a number of phases. First, as the results of Experiment 3 suggest, even the expectation to perform the tasks during testing is sufficient to change the balance between conceptual and enactive clustering. This result supports the claim that the representation underlying memory for future assignments may capitalize on the enactive properties of the planned acts (Koriat et al., 1990). This component—the expectation of future performance—also exists in the enactment condition of Experiment 1 and is possibly one of the contributors to the strong enactive clustering observed in that condition.

In addition to the contribution of expected enactment, actual enactment at test also strengthens the extent to which motor similarity affects the organization of retrieved memories. This occurred in Experiment 3 even when participants had no previous opportunity to perform the tasks either during learning or during testing. This finding implies that task performance during testing, in itself, exerts an online effect, enhancing the prominence of the enactive features of the recalled or performed tasks. Why should the mere performance during testing change the mode of organization? One possibility is that actual performance of a task during retrieval causes its enactive features to prime other tasks that share similar enactive features with it. This kind of automatic activation may also explain the recall superiority of prospective enactment, if it can be assumed that the activation of motor features does not come entirely at the expense of the activation of conceptual features (see below).

Actual performance during study, which is a defining characteristic of SPTs, certainly has a pervasive effect on memory organization. In fact, a comparison of the SPT condition of Experiment 2 with the enactment condition of Experiment 1 yielded very small differences in the extent of enactive organization, suggesting that given enactment during study, enactment during testing has little added effect on memory organization. Note that in the enactment condition of Experiment 1, the motor traces generated on one block during testing could influence retrieval on the subsequent block. This should have resulted in a stronger increase in the magnitude of enactive organization with trial than what was found in the SPT condition of Experiment 2. However, the results yielded similar effects of trial for the two conditions, suggesting that enactment during testing has little added effect on memory organization.

In discussing the interaction between qualitative aspects of encoding and retrieval operations, Fisher and Craik (1977) considered the possibility that rememberers may adopt either a semantic or a structural–phonemic mode of retrieval in searching for stored words. Applying this idea to the present results, it may be proposed that in recalling previously enacted events, rememberers tend to adopt an enactive mode, attempting to retrieve these events in terms of their enactive characteristics, whereas they tend to adopt a semantic mode in retrieving verbally encoded events. According to this formulation, the results of the present study may be seen to accord with the encoding-specificity principle (Tulving & Thomson, 1973), which holds that information that has been stored under specific encoding operations can be most effectively accessed by retrieval cues that are compatible with these operations (but see Kormi-Nouri, Nyberg, & Nilsson, 1994).

The Relationship Between Memory Organization and Recall Performance

An important finding of the present study is that the correlations between recall performance and memory organization differ systematically as a function of the combination of processing modality and type of organization. This finding was obtained in a within-individual analysis as well as in a between-individual analysis, and for recall quantity as well as recall accuracy. First, the improvement in recall quantity and recall accuracy that occurred with trial in Experiment 1 (Figure 1) mimicked best the increase in modality-consistent organization. Second, across participants, recall performance increased most strongly with modality-consistent organization.

How can these correlational patterns be explained? Assume that enactment indeed brings to the fore motor aspects of the tasks, whereas verbal processing emphasizes the semantic–propositional aspects. Then memory performance should benefit best from the type of encoding and organization that makes use of enactive aspects under enactment conditions and of semantic–conceptual aspects under verbal conditions. This proposition can explain the interactive pattern observed only if a competition exists between the two types of encoding and organization such that, for example, enactment makes salient motor features of the task at the expense of conceptual–semantic aspects. Only then should modality-inconsistent organization be expected to yield little correlation (or even a negative correlation) with recall performance.

However, researchers in the area of action memory have generally stressed that enactment provides sensorimotor cues in addition to the verbal content of the act. Thus, Bäckman and Nilsson (e.g., Bäckman et al., 1986) claimed that the memory trace of an action phrase is enriched by performance because of the added visual, auditory, and tactual cues, and it is this enrichment that is responsible for the enactment effect. Similarly, Engelkamp and Zimmer, who emphasized specifically the motor components that are activated by the planning and execution of the tasks, also stressed that these components are added to the verbal–semantic components (see Zimmer, 2001).

Is there competition, then, between conceptual and enactive encoding or organization? Although such competition is a built-in feature of the experimental paradigm we used, the results suggest that the enactment of action phrases does not eliminate conceptual organization altogether. In fact, conceptual organization was significantly better than chance even in the enactment condition of Experiment 1. It was also very high in the prospective-SPT condition of Experiment 3, suggesting that prospective enactment enhances enactive clustering without reducing conceptual clustering. In general, conceptual clustering was found to exhibit greater indifference to encoding and testing conditions than was the case for enactive clustering. These results accord with the position of Engelkamp and Zimmer that motor processing always includes semantic–conceptual processing as well (Engelkamp, 2001; Zimmer, 2001). Thus, the question of competition remains open and deserves particular interest in view of the different correlational patterns observed between recall performance and memory organization for different combinations of processing modality and type of organization.

Can Memory Organization Explain the Enactment Effect?

Given the observations that (a) enacted phrases display a significant degree of enactive clustering and that (b) the amount of enactive clustering correlated positively with recall quantity, is it possible, then, that the recall superiority of enactment is mediated by greater organization? The results on the whole do not support this possibility. First, there was no evidence that clustering, even modality-consistent clustering, was any stronger for the enactment condition than for the verbal condition. In fact, conceptual clustering was consistently higher than motor clustering. Second, there was little indication that memory organization makes a larger contribution to recall in the enactment condition than in the verbal condition. This pattern of results would seem to support the position advanced by Engelkamp and Zimmer that the beneficial effects of enactment on memory do not derive from relational information pertaining to interitem associations (Engelkamp & Zimmer, 1996, 2001).

However, it is important to warn against such a tempting conclusion because of the problem of making quantitative comparisons between qualitatively different memory organizations (see Koriat & Melkman, 1987). For example, to establish that enactment induces a stronger modality-consistent clustering than does verbal processing, we must first establish that our list of action phrases offers equal opportunities for the two types of organization to emerge. However, there is no simple common ground for comparing the strength of conceptual relatedness between two items with the strength of enactive relatedness between two other items. Therefore, our results do not allow us to reach firm conclusions about the question of whether enactment helps memory organization in general.

The Implications of the Results for the Nature of Enactive Representation

In concluding this article, we comment on some general implications of the present study with regard to the internal representation of action events. As was noted in the introduction, there has been growing interest in recent years in the study of memory for action, inspired by the fact that in everyday life, a great deal of what people remember or must remember concerns their own activities (see Zimmer et al., 2001). This interest has brought attention to the role of sensorimotor aspects of task performance in the encoding and retrieval of information. Such modality-specific aspects have also been gaining interest in recent years as a result of the growing concern with memory accuracy (see Koriat, Goldsmith, & Pansky, 2000). Contextual details, including modality-specific features of the encoded information, are assumed to play an important role in recollection, by helping rememberers specify the source of their experience and thus protect against false memories (Johnson, 1997; Lindsay, 1994; Smith & Hunt, 1998). In parallel, the embodiment zeitgeist (see Glenberg, 1997; Wilson, 2002) has given rise to a conceptual framework in which experiences are represented in terms of their modal, sensory, and motor features rather than in terms of an amodal, symbolic description of these experiences (Barsalou, 1999, 2002). In light of these theoretical developments, what could be the contribution of the present work regarding the representation of action events?

First, we should note that certain discussions of embodied or situated cognition question the need to postulate a representational cognitive system that mediates some of the interactions between perception and action (Brooks, 1991). The idea is that cognitive processes occur in the context of task-relevant inputs that circumvent the need to consult or build up an internal model of the environment. Gibson's (1979) direct-perception view, for example, with the notion of affordance, emphasizes the direct, unmediated link between perception and action. Similarly, discussions of procedural memory (see Tulving, 1985) sometimes imply a kind of "knowing by doing": a memory that can only be expressed directly in behavior according to a relatively rigid format.

In contrast, the results of this study would seem to lean toward Bruner's (1966) conceptualization, in which enactive representations are seen to mediate between input and output without necessarily dictating an overt behavior. Indeed, taken together, the results of the present study support the postulation of an enactive system of representation that can be activated to different degrees by different encoding conditions (e.g., actual enactment, planned future enactment) and can also be expressed to different degrees through different retrieval modes (e.g., actual performance, verbal report).

Second, our results appear also to count against an extreme view of embodied cognition, which grants a monopoly to enactive representations (e.g., Barsalou et al., 2003). Conceptual clustering was relatively high even in the enactment conditions of Experiment 1. Furthermore, enactive clustering was generally no better than chance in the verbal condition of that experiment, despite the fact that the list of action phrases afforded organization along motor similarities. These observations suggest that semantic aspects of action phrases are stored along with enactive features (although not necessarily in terms of enactive features, see Barsalou et al., 2003). Second, the observation that the balance between conceptual and enactive organizations was finely tuned to encoding and testing variations would seem also to suggest the availability of alternative modes of organization that can be flexibly used under different conditions. Thus, although on the whole the results of the present study are commensurate with the embodied cognition approach that is now in fashion, they raise some issues for that approach that call for further investigation.

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(*Appendix follows*)

Appendix

English Translation of the Action Phrases Used in the Experiments

Category	Action phrases		
	Conceptual organization		
A car	To wax the car	To pour oil into the engine	To spread a cover over the car
Music	To play a xylophone	To play a flute	To play a piano
Scouts	To drive a stake (into the ground)	To close the water canteen	To cut the wire fence
A carpenter	To spread the glue on the furniture	To hammer a nail	To saw wood
Cooking	To carve the roast	To open a jam jar	To blow on hot soup
Gardening	To water a plant	To shut the water tap	To snip a rose
A nurse	To spread ointment on a wound	To cover a patient with a blanket	To apply a Band-Aid
Washing or bathing	To twist a toothpaste cap	To wash one's hair	To wrap oneself in a towel
A birthday	To put a wreath on one's head	To slice a cake	To blow out a candle
An electrician	To screw a wire in place	To put on goggles	To sever an electric wire
A scientist	To focus the lens of a microscope	To pour liquid into a test tube	To type an article
	Enactive organization		
Twisting	To twist a toothpaste cap	To screw a wire in place	To focus the lens of a microscope
Spreading	To wax the car	To spread the glue on the furniture	To spread ointment on a wound
Cutting or splitting	To cut the wire fence	To snip a rose	To sever an electric wire
Covering	To spread a cover over the car	To cover a patient with a blanket	To wrap oneself in a towel
Tightening	To close the water canteen	To open a jam jar	To shut the water tap
Blowing	To play a flute	To blow on hot soup	To blow out the candle
With fingers	To play a piano	To apply a Band-Aid	To type an article
Banging	To drive a stake (into the ground)	To play a xylophone	To hammer a nail
Slicing	To saw wood	To carve the roast	To slice a cake
Pouring	To pour oil into the engine	To water a plant	To pour liquid into a test tube
Hands to head	To wash one's hair	To put a wreath on one's head	To put on goggles

Note. The English translation is very approximate and does not capture some of the features of the original Hebrew phrases. First, the phrases in Hebrew were generally shorter, each containing two to four words. Second, none of the action terms (verbs) was repeated across the 33 phrases (e.g., in Hebrew, the verbs that designate the action of playing differ depending on the instrument that is being played—piano, flute, or xylophone).

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