Memory & Cognition
2003, 31 (3), 412-421

Memory for actions: Self-performed tasks and the reenactment effect

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Encoding action phrases by enactment (self-performed tasks, or SPTs) leads to better memory than does observing actions (experimenter-performed tasks, or EPTs) or hearing action phrases (Engelkamp, 1998). In addition, recognition memory for SPTs is enhanced when test items are reenacted. Experiment 1 demonstrated a reenactment effect for EPTs, as well as for SPTs, indicating that the effect can be based on visual, as well as motoric, feedback. However, the reenactment effect in SPTs was found even when the participants were blindfolded at test (Experiment 2), indicating that the basis for the reenactment effect differs across SPTs and EPTs. Experiments 3 and 4 provided additional evidence that visual feedback is not critical for reenactment recognition in the case of SPTs. In addition, these experiments failed to show a hand congruency effect (enhanced recognition when the same hand enacts at study and at test), indicating that this effect is not as generalizable as the reenactment effect. These results have important implications for the motor-encoding hypothesis of the enactment effect.

Simple action phrases (such as “break the toothpick” or “raise your hand”) are recalled better when participants perform the actions themselves than when they simply hear or read the action description (R. L. Cohen, 1981; see Engelkamp, 1998, and Nilsson, 2000, for reviews). The mnemonic advantage for subject-performed tasks (SPTs), relative to verbal tasks (VTs), has been called the *SPT effect.* In addition, an advantage is sometimes observed for self-performed tasks relative to observed tasks (i.e., tasks performed by another; e.g., Engelkamp & Zimmer, 1997; Hornstein & Mulligan, 2001).

Extant theories of the SPT effect focus on the multimodal nature of enacted events. For example, Backman and colleagues (Backman & Nilsson, 1985; Backman, Nilsson, & Kormi-Nouri, 1993) have argued that SPTs activate information about the verbal-semantic content of the action, as well as information from perceptual cues. According to this perspective, enacted actions are well retained as a result of a combination of the verbal-semantic, perceptual, and motor output systems that are activated during enactment. Engelkamp (1998; Engelkamp & Zimmer, 1985, 1994, 1997) focused more specifically on the motor component. According to this view, motoric output information, separate from the visual-sensory information, is responsible for the enactment advantage, an idea that has engendered debate in theoretical accounts of the SPT effect (e.g., Kormi-Nouri & Nilsson, 2001; Nilsson & Kormi-Nouri, 2001).

Engelkamp (2001a) argued that several results supported the motor-encoding view. For instance, encoding by enactment led to higher recall than did either imagining oneself perform the action or watching another perform the action (Engelkamp, 1998; Engelkamp & Zimmer, 1985, 1997). Enacting with and without real objects produced comparably sized SPT effects (Engelkamp & Zimmer, 1997). In addition, the SPT effect also occurred when participants were blindfolded at study, denied visual feedback during encoding (Engelkamp, Zimmer, & Biegelmann, 1993). These results imply that motor encoding enhances recall over and above the visual feedback that might typically be available during encoding.

More direct and, perhaps, more striking evidence for the motor-encoding hypothesis is provided by retrieval manipulations. Engelkamp, Zimmer, Mohr, and Sellen (1994, Experiment 1) presented participants with a reenactment paradigm in which enactment was varied both at study and at test. During encoding, half of the participants encoded a list of actions by listening to the verbal instructions, and half encoded the action by carrying them out with imaginary objects. All the participants were then tested under two conditions. The verbal recognition test required the participants to make old/new judgments after reading each action phrase. The SPT recognition test required participants to perform each action before making the old/new judgment. Engelkamp et al. (1994)

This article is based in part on S.L.H.’s dissertation under the direction of N.W.M. We gratefully acknowledge the assistance of the other members of the dissertation committee, Alan Brown, Jim Bartlett, and Curt McIntyre. Correspondence concerning this article should be addressed to N. W. Mulligan, Department of Psychology, University of North Carolina, Chapel Hill, NC 27599-3270 (e-mail: nmulligan@unc.edu).

found that, for items enacted at study (the SPT items), enacting during test produced greater recognition accuracy than did verbal testing, a phenomenon we refer to as the *reenactment effect.* However, enactment at test had no effect on items that were encoded verbally. Thus, enacting at test enhanced the size of the SPT effect (i.e., the SPT–VT difference). In a follow-up experiment, Engelkamp et al. (1994, Experiment 2) controlled the hand with which SPT study items were enacted. At test, these items were reenacted either with the same hand as that used at study or with the other hand. Greater recognition accuracy was found when the same hand enacted the item at study and at test, the *hand congruency effect.*

The reenactment and hand congruency effects have been taken as strong evidence for the centrality of motor information to the SPT effect (Engelkamp, 2001a, 2001b). These effects have also been interpreted as striking evidence for the more general transfer-appropriate-processing analysis of memory retrieval, prompting the conclusion that the motor component of recognition is quite specific (Roediger & Guynn, 1996, pp. 220–221).

The reenactment effect has also been at the center of a debate about whether the motor component is, in fact, crucial to the SPT effect (cf. Engelkamp, 2001a, 2001b; Kormi-Nouri & Nilsson, 2001; Nilsson & Kormi-Nouri, 2001). Kormi-Nouri and Nilsson argued that several studies had shown no effect of enactment during retrieval when the test was recall (as opposed to recognition, as used by Engelkamp et al., 1994). For example, in Saltz and Dixon's (1982) study, the participants enacted or read action sentences during encoding. During the test, the participants were cued with the verb phrase and were required either to enact the verb before attempting to recall the entire sentence or to attempt recall without enactment. Recall was affected by enactment at study (as was expected, the typical SPT effect), but not by enactment at test. Because similar results have been reported by other researchers (Kormi-Nouri, Nyberg, & Nilsson, 1994; Norris & West, 1993), Kormi-Nouri and Nilsson argued that motor information does not mediate the SPT effect and characterized the results of Engelkamp et al. (1994) as a single inconsistent finding (Kormi-Nouri & Nilsson, 2001, p. 102).

A first order of business, then, is to determine whether the reenactment effect in recognition is a replicable phenomenon. However, even if this effect is replicable, it may not be produced solely by motor information. Engelkamp et al. (1994) interpreted their results in terms of encoding specificity (Tulving & Thomson, 1973), arguing that the critical factor was the presence of motor information at study and at test. However, visual feedback accompanied enactment both when the action was initially enacted at study and when it was reenacted at test. This raises the possibility that visual information mediates the reenactment effect. In the present experiments, this issue was investigated in two ways. In Experiment 1, we investigated the reenactment effect for observed, as well as for self-performed, acts. In Experiments 2–4, we investigated the effect of eliminating visual feedback (with a blindfold) on test enactment.

EXPERIMENT 1

In most of the research on the enactment effect and all of the research on the reenactment effect, SPTs have been compared with verbal information (VTs). To a lesser degree, researchers have also investigated differences between enacted and observed events. The latter research contrasts memory for SPTs with memory for actions performed by the experimenter and merely observed by the participant (EPTs, for experimenter-performed tasks). EPTs are often characterized as falling on a continuum between VTs and SPTs (e.g., Backman et al., 1993; Engelkamp, 1998). They are similar to verbal tasks in that no overt motor action is required of the participant, but they resemble SPTs in that the verbal instructions are accompanied by perceptual feedback. It should be noted that the motoric output view (Engelkamp, 1998; Engelkamp & Zimmer, 1985, 1994, 1997) contends that SPTs result in better memory because EPTs do not contain the critical motor information that accompanies enactment.

In Experiment 1, we examined the reenactment effect, using both SPTs and EPTs. During the study portion, participants performed some actions themselves (SPTs) and observed the experimenter perform other actions (EPTs). During the recognition test, some of the test items were presented in the verbal condition; the participant heard the action phrase and then made an old–new recognition decision. Other test items were enacted (by the participant for SPT study items and half the new items and by the experimenter for EPT study items and the other half of the new items) before the old–new judgment was made. Implementing the reenactment paradigm with respect to the SPT–EPT difference allowed us to examine the contributions of visual and motor information, because only visual information was available during reinstatement of EPTs.

Experiment 1 had several goals. First, as was noted above, it was critical to determine whether the original reenactment effect was replicable. We assessed this issue by comparing recognition accuracy for SPT study items tested verbally and via enactment. Second, test enactment increases the size of the SPT effect relative to VTs, but it was not known whether test enactment would enhance the size of the SPT–EPT difference. The third goal was to determine whether repeated perception of the EPTs also would produce a reenactment effect (as encoding specificity suggests). If so, it cannot be attributed to the reinstatement of motoric information. Such a result would call into question the interpretation of the reenactment effect with SPTs, requiring a more thorough analysis of the effect and its theoretical interpretation.

Method

Participants. Thirty-six undergraduates at Southern Methodist University participated in exchange for credit in psychology courses.

Design and Materials. In the experiment, a 2 × 2 design was used in which encoding condition (SPT vs. EPT) and testing condition (enacted vs. verbal) were manipulated within subjects.

Ninety simple action phrases were assembled and randomly assigned to one of three sublists, resulting in three sets of 30 items each (copies of all materials can be obtained from the first author or found in Hornstein, 2001). Each sublist was rotated through the SPT, EPT, and distractor conditions an equal number of times across participants. Therefore, 60 critical items were presented to the participants during encoding, with the other 30 serving as distractors during the subsequent recognition test. Four additional items were placed at the beginning of the study list to serve as practice items, resulting in a study list of 64 items. On the test lists, 15 items from the SPT and EPT study conditions were presented as enacted items, and 15 were presented as verbal items. The 30 distractor items consisted of 10 items enacted by the participant, 10 enacted by the experimenter, and 10 verbal items. A fully counterbalanced set of test lists was used so that each item appeared in each condition an equal number of times across participants.

Procedure. All the participants were tested individually. The experiment began with the study phase. The experimenter and the participant sat facing each other so that each had a clear view of the other. The participants were informed that they would hear a series of action events and that their task was either to perform the action or to observe the experimenter perform the action. The action phrases were presented aurally over computer speakers at a rate of one item every 6 sec. The study phase began with four practice items, two in the SPT condition and two in the EPT condition. The critical SPT and EPT items alternated in sets of five. Each set was preceded by the word "participant" or "experimenter," indicating who was to perform the next five items. As soon as the action was presented, the task was carried out by the appropriate person. Imaginary objects were used in all the actions.

The test phase was given after a 48-h interval. The participants were informed that they would be presented with another list of action events, again presented over the computer's speakers, some of which had been in the first part of the study and some of which were new. For each action, they were asked to indicate whether it was an old or a new item. They were instructed not to consider who originally enacted each item but, rather, whether it was presented at all. The recognition test included two different types of items: (1) verbal recognition items, for which the tasks were presented aurally to the participant and an old/new judgment was made, and (2) enactment recognition items, for which the actions were presented aurally and then enacted by the participant or the experimenter before the participant made an old/new judgment. Half of the items presented as SPTs and EPTs in the study phase were presented as verbal items, and half were presented as enacted items. For the enacted items, the SPTs from the study phase were presented as SPTs in the test phase, and the EPTs from the study phase were presented as EPTs at test. In other words, all enacted items were carried out by the same person at study and at test; no item was enacted by both the participant and the experimenter.

Of the 30 distractor items, 10 were presented as SPTs, 10 as EPTs, and 10 as verbal items. As in the encoding phase, each item was presented over computer speakers at a rate of 6 sec per item. Enacted SPT, EPTs, and verbal items were alternately presented in sets of five; within these sets, old and new items were randomly intermixed. Each set was preceded by instructions indicating the test condition. The instruction "participant" indicated that the participant was to enact the items, "experimenter" instructed the participants to observe the experimenter perform the items, and "listen" indicated that the participant was to listen to the items without performance. Old/new judgments were made orally and were recorded by the experimenter.

Results and Discussion

The results of the recognition test (Table 1) show that test enactment enhanced recognition memory for both SPT and EPT items. Statistical analyses support this summary (an alpha level of .05 was established for all statistical tests).

Recognition accuracy was assessed with discrimination scores (hits minus false alarms [FAs]) and with d'.[1] Both analyses produced the same conclusions; only the analyses of the discrimination scores will be reported below. Discrimination scores were analyzed with a 2 × 2 analysis of variance (ANOVA), using encoding condition (SPT vs. EPT) and testing condition (reenactment vs. verbal) as within-subjects factors. The analysis revealed main effects of encoding [$F(1,35) = 50.81$, $MS_e = 0.0203$], indicating a better recognition for SPTs than for EPTs, and of testing [$F(1,35) = 15.02$, $MS_e = 0.0152$], with higher recognition for enacted items than for verbal test items. The interaction between encoding and testing was not significant ($F < 1$). Because one of the goals of the experiment was to determine whether the reenactment effect reported by Engelkamp et al. (1994) is replicable, it is important to evaluate this effect for the SPT condition alone. For SPT items, the difference in accuracy between enacted and verbal test items was significant [$t(35) = 3.46$]. This difference was also significant for the EPT items [$t(35) = 2.43$].

For present purposes, the critical dependent variable is recognition accuracy but, for completeness, we will also present the subsidiary analyses of its components, hits and FAs. Hits were analyzed with a 2 (encoding condition) × 2 (testing condition) ANOVA. The analysis revealed main effects of encoding [$F(1,35) = 48.13$, $MS_e = 0.0159$], indicating more hits for SPTs than for EPTs, and of testing [$F(1,35) = 29.42$, $MS_e = 0.0065$], with more hits for enacted items than for verbal test items. The interaction approached significance [$F(1,35) = 3.95$, $p = .06$]. To examine this nearly significant interaction, the effect of testing condition was assessed separately for SPTs and EPTs. Both effects were significant [SPTs, $t(35) = 2.69$; EPTs, $t(35) = 4.04$]. The three FA rates were analyzed with a one-way ANOVA, which revealed a significant effect [$F(2,70) = 3.75$, $MS_e = 0.0055$]. Post hoc t tests indicated that the FA rate for subject-enacted test items was significantly lower than the FA rate for experiment-enacted test items [$t(35) = 2.76$] and was

Table 1
Experiment 1: Mean Hit Rates, False Alarm Rates, and Discrimination Scores (With Standard Deviations) as a Function of Encoding and Testing Condition

	Testing Condition			
	Enactment		Verbal	
Encoding Condition	*M*	*SD*	*M*	*SD*
Hits				
Subject-performed task	.94	.07	.90	.08
Experimenter-performed task	.83	.12	.73	.15
False Alarms				
Subject-performed task	.04	.06	.06	.08
Experimenter-performed task	.08	.10		
Discrimination Scores				
Subject-performed task	.91	.08	.84	.11
Experimenter-performed task	.75	.20	.67	.15

Note—The verbal testing condition gives rise to a single false alarm rate.

marginally lower than the FA rate for verbal test items [$t(35) = 1.99, p = .054$]. The latter two FA rates did not significantly differ.

There are several aspects of the results to consider. First, the main effect of encoding condition demonstrates the advantage of enactment encoding over observing during encoding (e.g., Engelkamp & Zimmer, 1997; Hornstein & Mulligan, 2001). Second, the SPT condition replicates Engelkamp et al.'s (1994) results in finding that reenactment at test enhances recognition accuracy for items enacted at study. This indicates that the reenactment effect in recognition is a replicable phenomenon (cf. Kormi-Nouri & Nilsson, 2001). Furthermore, the difference in results between studies in which recognition was used (which show the reenactment effect) and those in which recall was used (which have not shown a reenactment effect) are, in all likelihood, a result of principled differences (as has been argued by Engelkamp, 2001b, see pp. 145–147 for a discussion), rather than any unreliability of the reenactment effect in recognition. For example, in the case of a recognition test, the entire action is reinstated, whereas in the case of recall, only part of the action (e.g., the verb portion) is reinstated. Perhaps a more complete reinstatement of the action is required to demonstrate the reenactment effect (other potential accounts have been considered in Kormi-Nouri & Nilsson, 2001).

Third, the reenactment effect occurs in the EPT condition, as well as in the SPT condition. Seeing the EPT items reenacted by the experimenter during test increases accuracy, relative to verbal testing. In addition, the size of the reenactment effect is comparable in the EPT and the SPT conditions. Thus, test enactment does not enhance the SPT–EPT difference, as it does the SPT–VT difference (Engelkamp et al., 1994). This aspect of the results is significant in several ways. First, it reveals a similarity between SPTs and EPTs and a difference between EPTs and VTs. SPTs and EPTs are both sensitive to test enactment, whereas VTs are not (Engelkamp et al., 1994). This is consistent with the general notion of encoding specificity (Tulving & Thomson, 1973), as well as with the transfer-appropriate-processing approach to memory retrieval (e.g., Roediger & Guynn, 1996). In the case of SPTs and EPTs, enactment at test recapitulates the encoding circumstances, whereas for VTs, test enactment does not. Second, this result is contrary to the view that actions are encoded predominantly in terms of verbal-semantic information (e.g., Helstrup, 1986; Kormi-Nouri & Nilsson, 2001). Because test reenactment increases recognition accuracy, modality-specific information appears to have been encoded.

Finally, these results complicate the interpretation of the reenactment effect. The test reenactment effect has been taken as evidence that motor information is the critical factor in SPT encoding (Engelkamp, 2001a; Engelkamp et al., 1994). However, the present results demonstrate a reenactment effect for EPTs. In this condition, no motor information was available to the participant; the participant merely observed the experimenter perform the actions. Consequently, motor encoding cannot explain the reenactment effect for EPTs. The obvious explanation is that visual information is encoded at study, rendering efficacious its reinstatement at test. The challenge to the motor-encoding view is that visual information, which is likewise reinstated when SPTs are reenacted, might likewise account for the reenactment effect for SPTs.

A proponent of the motor-encoding view might argue that visual information underlies the reenactment effect for EPTs, whereas motor information underlies the effect for SPTs. However, in attributing the same apparent effect to different causes, this argument is not parsimonious and is not to be preferred without more direct evidence. A simpler account attributes the reenactment effect of both SPTs and EPTs to the same type of information—viz., visual information.

If visual information drives the reenactment effect for SPTs, removing visual feedback during reenactment (e.g., with a blindfold) should eliminate or, at least, reduce the reenactment effect for SPTs. In contrast, if restricting visual feedback during test enactment has no effect, visual information plays little role in the reenactment effect for SPTs. This would favor the view that motor information is critical and that reenactment effects for SPTs and EPTs differ.

EXPERIMENT 2

Several studies of action memory have used conditions with limited sight, but none has included this manipulation in a reenactment design. Visual feedback at encoding has been examined in two studies. Engelkamp et al. (1993) observed better memory for SPTs than for VTs with participants who had kept their eyes closed during the study phase, a result taken as evidence of the importance of motor encoding. Kormi-Nouri (2000) manipulated the presence of visual information in two ways. First, half of the participants were blindfolded during encoding. Second, study actions used either real or imaginary objects, as well as real and imaginary movement. That is, the participants either performed the action with a real or an imaginary object or imagined performing an action with a real object (presented but not manipulated) or an imaginary object. Although a reliable SPT effect was observed (relative to a VT control condition), there was no effect of vision, action, or object.

More directly relevant to the present experiment is the study of R. L. Cohen, Peterson, and Mantini-Atkinson (1987), who varied visual feedback at test. In R. L. Cohen et al.'s study, participants enacted study items with real objects, followed by a free recall test in which the objects were not presented. Half of the participants in this study recalled the list with their eyes closed, and half recalled it with eyes open. No difference in recall was found between the groups. This is not particularly surprising, because the participants in the eyes-open condition did not receive visual information related to the enacted items, as they would in a reenactment experiment. In particular, the participants who kept their eyes open during test did not have the benefit of seeing the objects or actions that had been present at study.

In the present experiment, the participants enacted all the items at study. At test, half of the items were enacted, and half were tested verbally. In addition, half of the participants were blindfolded during the test in order to eliminate visual information while preserving the effects of motor involvement; the other half of the participants performed the test fully sighted. If visual information is an important determinant of the reenactment effect, the effect should be reduced or eliminated by the blindfold. More specifically, the blindfolded group should produce lower performance than does the sighted group in the test enactment condition; no difference is expected for the verbal-testing condition, in which there is no visual enactment information to restrict. Alternatively, if motor information is responsible for the reenactment effect, the groups should exhibit similar levels of accuracy, on average, and a reenactment effect of a similar size.

Method

Participants. Forty-eight undergraduates participated in exchange for credit in psychology courses.

Design and Materials. The experiment used a 2 × 2 design in which testing condition (enacted vs. verbal) was manipulated within subjects and sight condition (blindfolded vs. sighted during test) was manipulated between subjects.

One hundred twenty simple action phrases were assembled, many of which were from Experiment 1. This set of actions was compiled for subsequent experiments, in which the effects of hand congruency were examined, as well as for the sight condition (see the Method section of Experiment 3). These materials were used so that the present experiment could be directly compared with the subsequent experiments. The critical actions were randomly divided into two sets of 60; one set was presented at study and served as the old items on the test, and the other set served as distractors on the recognition test. Two study lists were created to counterbalance the items over old and new status. On the study list, all of the items were presented in the enactment (SPT) condition. Four additional items were placed at the beginning of the study list to serve as practice items, resulting in a study list of 64 items. The recognition test consisted of all 120 critical action phrases. Half of the old items and half of the new items were assigned to the enactment test condition, and the other half of each set was assigned to the verbal test condition. Two test lists were constructed to counterbalance test items over the testing conditions. The study and test lists were varied across participants so that all items were equally often old and new and equally often in the enacted and the verbal test conditions.

Procedure. The experiment consisted of an encoding phase followed 48 h later by the memory test. The encoding and test phases were similar to those in Experiment 1, with the following exceptions. During the study phase, the participants enacted every action; no EPT condition was included. Similarly, during the recognition test, test items were either verbal or enacted by the participant; the experimenter did not enact any of the test items. In addition, half of the participants were blindfolded during the recognition test. Pilot testing indicated that the blindfold was effective. However, to be absolutely sure that visual information was eliminated, the blindfolded participants were also asked to shut their eyes. As in Experiment 1, enacted and verbal test items were presented aurally (read aloud by the experimenter) and alternately in sets of five. In addition, each item was preceded by the instructions “enact” or “listen,” indicating whether the participants was to enact the test item or simply listen to the item without performance. After enacting or listening, the participants made an (oral) old/new recognition judgment, which was recorded by the experimenter.

Results and Discussion

The results of the recognition test are presented in Table 2. Recognition accuracy (using the discrimination scores) was analyzed with a 2 × 2 ANOVA, with testing condition (enacted vs. verbal) as a within-subjects variable and sight condition (blindfolded vs. sighted) as a between-subjects variable. The only significant effect was that of testing condition [$F(1, 46) = 26.96, MS_e = 0.0085$], indicating greater recognition accuracy for enacted items than for verbal test items (i.e., the reenactment effect). Neither the main effect of sight condition nor its interaction with testing condition was significant (Fs < 1). An additional analysis verified that the reenactment effect was obtained within the blindfolded condition [$t(23) = 3.33$]. The reenactment effect was also significant within the sighted condition [$t(23) = 4.25$]. An analysis of the d' scores produced the same pattern of results.

Hits were analyzed with a 2 (testing condition) × 2 (sight condition) ANOVA. The effect of testing condition was significant [$F(1,46) = 24.34, MS_e = 0.0072$], indicating more hits for enacted items than for verbal test items. The other effects were nonsignificant (Fs < 1). FA rates were likewise analyzed and produced no significant effects (Fs < 1.7, ps > .20).

The results of the sighted group replicated the results of Engelkamp et al. (1994) and the SPT condition of Experiment 1: Reenactment at test enhanced recognition accuracy for items enacted at study. Importantly, the reenactment effect was also found for the blindfolded group, and the size of the reenactment effect was comparable across the two groups. These results indicated that visual feedback during reenactment does not mediate the reenactment effect for SPTs. This provided preliminary evidence that the reenactment effect found with SPTs may have a different basis than the reenactment ef-

Table 2
Experiment 2: Mean Hit Rates, False Alarm Rates, and Discrimination Scores (With Standard Deviations) as a Function of Sight and Testing Condition

	Testing Condition			
	Enactment		Verbal	
Sight Condition	*M*	*SD*	*M*	*SD*
	Hits			
Sighted	.86	.09	.78	.14
Blindfolded	.89	.10	.81	.16
	False Alarms			
Sighted	.09	.05	.10	.05
Blindfolded	.10	.06	.12	.06
	Discrimination Scores			
Sighted	.77	.10	.68	.14
Blindfolded	.79	.13	.69	.19

fect found for EPTs. Experiments 3 and 4 provided additional evidence that visual feedback is not critical to reenactment recognition. In these experiments, we also investigated the related effect of hand congruency.

EXPERIMENT 3

In Experiment 3, participants enacted items at study, in a fully sighted condition, and again at test, either with or without a blindfold. In addition, in Experiment 3, the hand congruency effect was examined. Engelkamp et al. (1994) reported that items enacted with the same hand at study and at test resulted in better recognition than did those enacted with different hands. Like the reenactment effect, the hand congruency effect has been attributed to the increased similarity of motor information that is produced when actions are enacted and reenacted with the same hand. However, as was argued in the case of the reenactment effect, it is unclear whether visual information plays a role in the effect of hand congruency, because visual information is also varied by the hand congruency manipulation. In the present experiment, the participants were instructed to use either the same hand or different hands at study and at test. Following the logic of Experiment 2, if visual information contributes to the hand congruency effect, the effect of hand congruency should be reduced or eliminated in the blindfolded group, as compared with the sighted group. If motor information alone is responsible, the effect of hand congruency should be comparable across groups. On a final note, in the present experiment, a verbal testing condition was not used (all the test items were enacted). It should be noted that the verbal condition is not required to assess the effects of visual versus motoric feedback in the reenactment paradigm. None of the theoretical perspectives on the SPT effect suggests that blindfolding should impair verbal testing, because this condition has no visual enactment information to restrict. In addition, the results of Experiment 2 indicated that verbal testing is unaffected by the sight condition.

Method

Participants. Forty undergraduates participated in exchange for credit in psychology courses.

Design and Materials. In the experiment, a 2 × 2 design was used in which hand congruency (same hand vs. different hand) was manipulated within subjects and sight condition (blindfolded vs. sighted) was manipulated between subjects. The materials of Experiment 2 were used. These materials were developed for the hand congruency manipulation, which necessitates items that can be enacted with one hand. These actions were randomly divided into two sets of 60 in order to allow for the old–new counterbalancing. Each set of 60 critical items was used to produce two study lists. On one of the study lists, 30 actions were designated to be performed with the right hand during encoding, and 30 were designated to be performed with the left hand. On the other list, the hand used to perform the action was reversed. Four additional items were placed at the beginning of each study list to serve as practice items, resulting in a study list of 64 items. The recognition test list consisted of all 120 critical action phrases. For the 60 old items, half of the right-hand items and half of the left-hand items were reenacted with the same hand; the other half of each set was reenacted with the opposite hand. The 60 distractor items consisted of 30 items enacted with the right hand and 30 with the left hand. Two versions of the test list were created in order to balance the new items over right- and left-hand test enactment. The study and test lists were structured so that, across participants, each action phrase appeared equally often as old or new and, when old, equally often in the same-hand or the different-hand congruency condition.

Procedure. The encoding and test phases were similar to those in Experiment 2, with the following exceptions. During the study phase, the tasks were read aloud by the experimenter with instructions to use either the left or the right hand to carry out each action. Items were presented in sets of five; in each set, only the left hand or only the right hand was used. Prior to each set, the experimenter announced "right hand" or "left hand," indicating which hand should be used to carry out the task. The experimenter watched the participants closely to ensure that all actions were enacted with the correct hand. The recognition test occurred 48 h later, as in the prior experiments. During the recognition test, all the test items were enacted by the participant. As in the study phase, left- and right-handed actions alternated in sets of five, and instructions were read by the experimenter, indicating which hand should be used to carry out the tasks. Immediately following presentation of each item, the participants carried out the task and made an old/new recognition judgment. Responses were recorded by the experimenter.

Results and Discussion

Preliminary analyses of hits, FAs, and recognition accuracy revealed that there were no significant effects of the hand used at study (right vs. left) and that this factor did not participate in any significant interactions. Thus, the recognition data were collapsed over this variable (Table 3).

Recognition accuracy was assessed with discrimination scores, which were analyzed with a 2 × 2 ANOVA, using hand congruency (same vs. different) as a within-subjects variable and sight condition (blindfolded vs. sighted) as a between-subjects variable. Neither main effect was significant, nor was the interaction (Fs < 1.1). An analysis of the d' scores led to the same results.

Hits were assessed with a 2 (hand congruency) × 2 (sight condition) ANOVA, which produced a significant effect of sight condition [$F(1,38) = 7.90$, $MS_e = 0.0184$; other Fs < 1]. The analysis of the FA rates also revealed a significant effect of sight condition [$F(1,39) = 5.22$, $MS_e = 0.0059$]. Thus, the blindfolded participants produced significantly fewer hits and FAs than did the sighted participants. We consider this apparent criterion shift an isolated effect, because it did not appear in the other two experiments in which sight condition was manipulated (effects of sight condition on hits and FAs were nonsignificant in Experiments 2 and 4; Fs < 1). In terms of the critical accuracy results, however, there was great consistency across the three experiments.

The accuracy results correspond to the results of Experiment 2. The blindfolded and the sighted groups produced equivalent levels of recognition accuracy, implying that visual feedback during reenactment does not mediate the reenactment effect for SPTs. A second purpose of the present experiment was to replicate the hand

Table 3
Experiments 3 and 4: Mean Hit Rates, False Alarm Rates, and Discrimination Scores (With Standard Deviations) as a Function of Sight Condition and Hand Congruency

	Hand Congruency									
	Hit Rate				False Alarm Rate		Discrimination Score			
	Same		Different				Same		Different	
Sight Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
	Experiment 3									
Sighted	.90	.07	.89	.09	.17	.08	.73	.11	.72	.12
Blindfolded	.80	.10	.81	.14	.11	.07	.69	.11	.70	.15
	Experiment 4									
Sighted	.82	.11	.79	.13	.29	.10	.53	.13	.50	.09
Blindfolded	.77	.12	.77	.10	.29	.09	.48	.13	.48	.10

Note—Hand congruency is only relevant for old items. Consequently, the same false alarm rate applies to both hand congruency conditions.

congruency effect and determine whether it generalized to the blindfolded test condition. However, there was no significant effect of hand congruency in the present experiment, indicating that we failed to replicate this aspect of the results of Engelkamp et al. (1994). This discrepant result will be considered in detail after Experiment 4, an experiment meant to investigate one potentially important difference between the present study and that of Engelkamp et al. (1994).

EXPERIMENT 4

In the present experiments, the participants were presented with the entire action sequence (i.e., "knock on the door"), whereas the participants in Engelkamp et al.'s (1994, Experiment 2) study were simply presented with the verb component (i.e., "knock"). In an effort to replicate the hand congruency finding of Engelkamp et al. (1994), we ran Experiment 4 using only the verb component, instead of the entire action sequence.

Method

Participants. Twenty undergraduates participated in exchange for credit in psychology courses.

Design and Materials. In the experiment, a 2 × 2 design was used in which hand congruency (same hand vs. different hand) was manipulated within subjects and sight condition (blindfolded vs. sighted) was manipulated between subjects. One hundred twenty action verbs were assembled, and the study and test lists were constructed in the same way as in Experiment 3.

Procedure. The encoding and test phases were identical to those in Experiment 3, with the exception that the study and test lists consisted of single words, the action verbs. The study and test instructions reflected this difference.

Results and Discussion

As in Experiment 3, preliminary analyses of hits, FAs, and recognition accuracy revealed that the hand used at study (right vs. left) did not participate in any significant effects; the data were collapsed across this variable (Table 3). A 2 × 2 ANOVA, using hand congruency (same vs. different) as a within-subjects variable and sight condition (blindfolded vs. sighted) as a between-subjects variable, produced no significant results for discrimination scores or d' scores (Fs < 1). Likewise, analyses of hit and FA rates produced no significant effects (Fs < 1).

The results of Experiment 4 are the same as those of Experiment 3. Blindfolding again produced no decrement in recognition accuracy, consistent with the view that visual feedback does not mediate the reenactment effect. And again, the hand congruency effect failed to replicate. Given the consistency in the results of Experiments 3 and 4, the results were merged to produce a more powerful analysis of the effect of hand congruency. Discrimination scores were submitted to a 2 × 2 × 2 ANOVA, using testing condition, hand congruency, and experiment as factors. The only significant effect was that of experiment [$F(1,56) = 49.27$, $MS_e = 0.0238$], indicating that performance was higher in Experiment 3 than in Experiment 4 (all other effects, $p > .25$). Most important, the effect of hand congruency was nonsignificant ($F < 1$). The same results were obtained using d' as the measure of accuracy. To evaluate the power of this analysis, an effect of hand congruency was estimated from the results of Engelkamp et al. (1994, Experiment 2), using the procedures of J. Cohen (1988). The estimated effect size was $d = 0.92$. The power of the present analysis to detect an effect of hand congruency of this size (with $n = 60$, $\alpha = .05$, one-tailed) exceeded .99. The power to detect an effect one third smaller ($d = 0.62$) was .96, and the power to detect an effect half this size ($d = 0.46$) was .80. Thus, the present experiments had substantial power to detect an effect of hand congruency even one half the size of that found in Engelkamp et al. (1994).

Two subsidiary analyses were also performed. First, in Engelkamp et al.'s (1994) analysis, participants with hit rates of 1.0 in the different-hand condition were excluded from the analysis. In the present results (combining Experiments 3 and 4), 6 of the participants had hit rates of 1.0 in the different-hand condition. Removing these participants did not change the results: The effect of hand congruency was still nonsignificant ($F < 1$). Second, an analysis restricted to the sighted test condition (which provided the closer approximation to Engelkamp et al.'s, 1994, study) likewise produced no effect of hand congruency ($F = 1.28, p > .25$).

Despite the fact that our experiments were modeled on those of Engelkamp et al. (1994), there were some differences that may have contributed to the discrepant results. One possibly important difference was that Engelkamp et al. (1994) presented the test phase immediately after the study portion, whereas a 48-h retention interval was used in the present study. The longer retention interval was necessary because preliminary experiments revealed that recognition performance was at ceiling with an immediate test.[2] Therefore, we would not have been able to observe a hand congruency effect had an immediate test been used. It is possible that the hand congruency effect is short-lived and does not appear after 48 h. On the other hand, if the hand congruency effect has the same basis as the reenactment effect (as proposed by the motor hypothesis; Engelkamp, 2001a, 2001b; Engelkamp et al., 1994), there is no reason to suspect that one effect would be more short-lived than the other, and the reenactment effect was successfully observed after 48 h.

Other methodological differences appear minor. For example, the presentation modality of the test varied across the experiments. Although both sets of experiments used auditory presentation of study lists, Engelkamp et al. (1994) presented test items visually (on a computer screen), whereas in the present experiments auditory test presentation was used. In addition, the items themselves differed across studies. In the present experiments, all of the phrases (Experiment 3) or verbs (Experiment 4) denoted actions normally carried out with one hand (e.g., "hammer," "point"). Engelkamp et al. (1994) used one-hand items intermixed with two-hand items (actions typically carried out with both hands; e.g., "peel," "tear up"). In the present experiments, study items were blocked by hand of enactment (i.e., left hand or right hand) in sets of five. In Engelkamp et al.'s (1994) experiment, left-hand, right-hand, and two-hand study items were randomly intermixed. Finally, Engelkamp et al.'s (1994) materials were in German (for German-speaking participants), whereas our materials were in English (for English-speaking participants). There are no clear theoretical reasons why any of these differences should be pertinent. Consequently, our failure to find the hand congruency effect implies that this effect may not generalize over the incidental differences that normally arise in the process of replicating results from other laboratories.

Next, we combined the results of Experiments 2–4 to provide a more powerful analysis of the sight condition (blindfolded vs. sighted). From Experiment 2, we used recognition accuracy from the test enactment condition. From Experiments 3 and 4, we computed recognition accuracy as the average of the same-hand and the different-hand conditions. The combined analysis produced no effect of testing condition ($F < 1$). As in the individual experiments, this implies that there is no measurable effect of restricted visual feedback on recognition in a reenactment paradigm. Next, we considered the power of this analysis. Under the hypothesis that visual information contributes to the reenactment effect of SPTs, we used to-be-detected effect sizes based on the observed reenactment effect for SPTs from Experiment 1 and Experiment 2 (sighted condition). The average effect size was $d = 1.06$. The power of the present analysis to detect an effect of testing condition of this size (with $n = 54$, $\alpha = .05$, one-tailed) exceeded .99. The power to detect an effect one third smaller ($d = 0.71$) was .98, and the power to detect an effect half this size ($d = 0.53$) was still quite substantial at .86. Thus, our failure to obtain an effect of the blindfold during testing was not an artifact of low power.

GENERAL DISCUSSION

The present experiments were designed to investigate the reenactment and hand congruency effects because they have been central in the debate about the role of motor information in memory for actions (Engelkamp, 2001a; Kormi-Nouri & Nilsson, 2001). Experiment 1 produced two important results. First, the reenactment effect was found with SPTs, indicating that the effect is replicable. Second, the reenactment effect was also found for EPTs, indicating that the reinstatement of visual information (unaccompanied by motor information) may also produce a reenactment effect. Experiment 2 demonstrated the reenactment effect for SPTs under blindfolded test conditions, as well as under sighted conditions, indicating that visual feedback at retrieval plays little role in the reenactment effect for SPTs. This distinguishes the reenactment effect for SPTs from the reenactment effect found with EPTs. Experiments 3 and 4 produced consistent results, demonstrating that blindfolding did not significantly reduce recognition accuracy for reenacted actions. The last two experiments also manipulated hand congruency but failed to find the effect. We will focus on each of these results in turn.

The finding of a reenactment effect for EPTs is significant in several regards. First, it indicates a similarity between EPTs and SPTs: Memory for both encoding conditions is enhanced by the reinstatement of the original action. This implies that modality-specific information is encoded in memory for actions, in addition to verbal-semantic information (cf. Helstrup, 1986; Kormi-Nouri & Nilsson, 2001). The present experimental paradigm may even underestimate the potency of reenactment, because the verbal and the enactment test conditions were intermixed. The presence of the enactment condition at test might encourage imaginal processing (of a visual or motoric nature) in the verbal condition, rendering this condition more similar to actual enactment. It would be of interest to determine whether the reenactment effect is accentuated in a between-subjects design, in which the processing of verbal test items would be uninfluenced by enactment testing.

Another important point is that the reenactment effect for EPTs is presumably due to the reinstatement of visual information. This complicates the interpretation of the original reenactment effect for SPTs by underscoring the point that test enactment reinstates both visual and motor information. Thus, the reenactment effect for EPTs compelled additional evaluation of the reenactment effect for SPTs—specifically, to determine whether the latter effect might also be mediated by visual feedback. The results of Experiments 2–4 provide convincing evidence on this point. The presence of a reenactment effect in the blindfolded condition (Experiment 2) and the equality of the blindfolded and the sighted conditions in enactment recognition (Experiments 2–4) indicate that visual feedback plays little role in the reenactment effect with SPTs. The most likely account of this reenactment effect remains that of Engelkamp (1998, 2001a), who argued that the effect is due to the reinstatement of motor information.[3]

As a set, the present experiments support the conclusion that the reenactment effects for EPTs and SPTs are the product of different forms of information: visual and motoric, respectively. This attribution fits the data and is also sensible in terms of the likely focus of attention during encoding. In the SPT condition, the focus is on performing the action, rather than on watching oneself perform the action. In contrast, the encoding instructions of the EPT condition explicitly ask the participant to watch the action. Presumably, visual information is much more heavily attended and encoded in the latter condition than in the former.

However, it should be noted that there is a great deal of flexibility in human memory encoding. It is possible that some SPT conditions render visual information quite salient, producing greater attention to and encoding of this form of information. For example, the use of real objects during enactment might have this effect. Under these conditions, test enactment (if also performed with real objects) might produce a reenactment effect for SPTs supported by both visual and motoric information.

Finally, we add a word on the hand congruency effect. This effect has also been taken as evidence for the motor account of the SPT effect (Engelkamp, 2001b; Engelkamp et al., 1994). However, our failure to find this effect (see the Discussion section of Experiment 4 for some possible reasons) suggests that the finding may not be readily observed. It may be prudent to place less theoretical weight on this effect until it is replicated and its limiting conditions are clearly specified. The outcome of such research will tell us whether the motor contribution to recognition is as specific as currently thought (Roediger & Guynn, 1996).

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NOTES

1. To compute d', hit rates of 1 were set to .99 and FA rates of 0 were set to .01.

2. There are at least two potential reasons why our preliminary experiments found ceiling effects with immediate testing, whereas Engelkamp et al.'s (1994) experiments did not. First, in Engelkamp et al.'s (1994) Experiment 1, most of the distractor items in the test were produced by recombining objects and actions from the studied set. Highly similar targets and distractors ought to reduce recognition accuracy relative to our materials, in which distractors were not based on studied items. Second, our preliminary experiments used entire action phrases (as in the present Experiments 1–3), whereas Engelkamp et al.'s (1994) Experiment 2 used only the verb component. As can be seen by comparing the present Experiments 3 and 4, using only the verb component reduces recognition accuracy substantially (see Hornstein, 2001, for details).

3. Although the reenactment effect in the blindfolded condition of Experiment 2 indicates that actual visual feedback does not mediate the reenactment effect for SPTs, one might wonder whether visual imagery plays a role. If so, this would provide an alternative account based on visual information, rather than on motoric information. However, such an account seems unlikely. It is possible that blindfolding participants could induce a strategy of using visual imagery during retrieval. However, if visual imagery is efficacious, both testing conditions (enactment and verbal) would be affected, eliminating the reenactment effect. Alternatively, it could be the case that enacting with a blindfold induces visual imagery, whereas verbal testing with a blindfold does not. With this account, one would need to explain why an efficacious visual imagery strategy does not generalize to a second retrieval condition in a within-subjects design. Barring such an explanation, the simpler motor-encoding account is to be preferred.

(Manuscript received July 30, 2002;
revision accepted for publication January 29, 2003.)