THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY
2010, 63 (3), 425–433

Psychology Press
Taylor & Francis Group

Rapid Communication

Environmental context change affects memory for performed actions

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The current study investigated the effect of environmental context change between the study and test on the recall of action phrases that either were performed during encoding (subject-performed tasks, SPTs) or were verbally encoded (verbal tasks, VTs). Both SPTs and VTs showed the same magnitude of impaired recall when the study and test contexts mismatched. Furthermore, changing the context between the two study lists reduced cross-list intrusion errors compared to encoding the lists in the same context. Both SPTs and VTs benefited from studying the lists in different contexts as evidenced by reduced intrusions. Taken together, the results suggest that SPTs are integrated with their context because they suffered when context changed between the study and test, and they also benefited when they were performed in two environments versus the same environment.

Keywords: Action memory; Environmental context change

Performing simple actions during encoding (e.g., *break a toothpick*; known as subject-performed tasks, SPTs) improves memory for those items compared to encoding the same phrases verbally (known as verbal tasks, VTs; for reviews, see Engelkamp, 1998; Nilsson, 2000; Zimmer et al., 2001). It is often argued in the action literature that while enactment improves memory for actions, it leads to poorer integration of actions with their context (Koriat, Ben-Zur, & Druch, 1991; Zimmer, 1994, 1996). Several findings are often discussed in support of this view. For example, the loci method, which is an effective mnemonic strategy for enhancing recall, is ineffective when used with SPTs (Cornoldi, Corti, & Helstrup, 1994; Helstrup, 1989). Also, memory for temporal order, which can be construed as one type of contextual information, is disrupted by enactment (Engelkamp & Dehn, 2000). Finally, in source-monitoring studies, enactment enhanced item memory but did not enhance (and even occasionally disrupted) memory for context. For example, memory for the physical environment was poorer when actions were performed than when they were only observed (Koriat et al., 1991). Some studies found impaired source

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I am grateful to Jean-Paul Azzi, Garin Narain, Holly Gershow, and Toshi Clarke for their assistance with data collection and scoring.

http://www.psypress.com/qjep
DOI:10.1080/17470210903414365

memory in the enactment condition (Koriat et al., 1991), whereas others found no effect of enactment on source (Conway & Dewhurst, 1995; Hornstein & Mulligan, 2004), and yet others found better source memory following enactment (Senkfor, Van Petten, & Kutas, 2002). Hornstein and Mulligan (2004) suggested that the conflicting findings across the studies could be driven by the methodological differences, which inflated or deflated source memory in the control conditions of the designs, making source discrimination in the SPT condition appear poorer (e.g., Koriat et al., 1991) or better (e.g., Senkfor et al., 2002). Using a methodology that circumvented some of the worrisome issues, Hornstein and Mulligan (2004) replicated better item memory in the SPT condition than in the control condition, but they obtained equivalent source memory in both groups of their standard condition, which more closely resembled previous studies. The paucity of findings showing that enactment impairs source memory casts doubts on the conclusions that SPTs are poorly integrated with their environmental context and suggests that such claims may be premature.

The current study was not designed to investigate source memory in SPTs, but rather whether SPTs benefit from the cueing property of context, which could be another indicator of whether they are integrated with their environmental context. Both source monitoring and the cueing property of context concern the relationship between items and their contexts, but they represent opposite problems. The cueing property of context is concerned with the likelihood of retrieving the event in the presence of certain context and can be construed as an implicit measure of context. In contrast, source monitoring relies in part on explicit retrieval of context in which the event occurred (e.g., Chalfonte & Johnson, 1996; Johnson, Hashtroudi, & Lindsay, 1993). Whether SPTs are considered "integrated" with their contexts may depend on whether one is interested in the cueing property of context or source monitoring, and earlier research suggests that the implicit and explicit context effects sometimes yield divergent results. For example, although older adults have worse source memory than younger adults, their item memory benefits at least as much as younger adults from the reinstatement of contextual cues during the test (e.g. Naveh-Benjamin & Craik, 1995). Older adults had difficulty explicitly retrieving contextual information that accompanied each item, but their memory nonetheless benefited implicitly from the match of those contextual cues between the study and the test.

SPTs might show a similar dissociation between implicit and explicit context effects. While some source-monitoring studies seem to suggest low integration of items with their context (Koriat et al., 1991; but see Hornstein & Mulligan, 2004), perhaps SPTs would still benefit from the presence of the context cues that were available during their performance. This would imply that SPTs are integrated with their context as far as implicit effects of context are concerned, even if explicit context effects as evidenced by source memory might occasionally suggest otherwise.

Changing the context between the study and test has negative consequences because it produces recall impairment (for a meta-analysis, see Smith & Vela, 2001). However, context change also has positive consequences, such that when several lists are learned in separate environments, they become more differentiated and interfere less with each other than when they are learned in the same environment (e.g., Dallett & Wilcox, 1968; Greenspoon & Ranyard, 1957; Jensen, Dibble, & Anderson, 1971; Smith, Glenberg, & Bjork, 1978; Strand, 1970).

A two-list paradigm was designed to investigate both the negative and the positive effects of environmental context change on VT and SPT recall. Participants studied two lists of action phrases (containing a mixture of VTs and SPTs) in the same context or in two different contexts. Recall was always tested in the same context where the second list was studied. Therefore, recall impairment was predicted only for the first list when its study and test contexts mismatched, whereas no such effect was predicted for the second list, because its study and test contexts always matched. In addition to assessing the negative consequences of context change, the study also examined the positive consequences of context change by assessing the extent to which studying the lists in different contexts affected list discrimination errors. Based on prior research, studying the lists in different environments was predicted to reduce interference between them (e.g., Dallett & Wilcox, 1968; Greenspoon & Ranyard, 1957; Smith et al., 1978), and hence fewer intrusions across the lists were expected than when studying the lists in the same environment.

There is insufficient research to generate solid predictions regarding how context effects might vary across VTs and SPTs. On the one hand, enactment may lead to reduced storage of contextual information in the memory trace, thereby leading to smaller context effects for SPTs than VTs. This could happen if, in order to perform the actions, participants should disengage their attention from external environment and focus only on those aspects of context that are directly relevant for enactment (e.g., Zimmer & Engelkamp, 1989). Alternatively, one could also predict larger context effects for SPTs than VTs because SPT advantage is in part attributed to enhanced item-specific processing (Mohr, Engelkamp, & Zimmer, 1989; Zimmer & Engelkamp, 1985), and context effects are larger with item-specific than relational processing (Smith & Vela, 2001).

To date only a single study examined action recall when the environmental context changed between the study and the test (Phillips & Kausler, 1992). The study was aimed at comparing younger and older adults, and all study stimuli involved SPTs. There was no context-dependent forgetting either for younger or for older adults. However, because the design did not include a VT condition, it is hard to know whether the authors generally failed to obtain context-dependent forgetting, or whether SPT recall was indeed immune to contextual variations between the study and the test. The current study therefore included both conditions to allow comparisons across the item type.

Method

Participants

There were 64 university undergraduates who participated in exchange for course credit. They were tested individually.

Materials

Stimuli were 32 action phrases involving an external object that was not present in the experimental setting. The phrases were randomly assigned to two lists of 16 phrases each. Presentation order of the lists was counterbalanced across experimental conditions. Half of the action phrases on each list were accompanied by the "perform" prompt (SPTs), and the remaining half phrases were accompanied by the "study" prompt (VTs). Each phrase was assigned equally often to the "perform" or the "study" instruction, and no more than two prompts of the same type occurred in succession during presentation. The stimuli are shown in Appendix.

Two physical contexts were used in this experiment. The *indoors* context was a windowless basement laboratory room that contained a writing table with computer, two chairs, and empty bookshelves. Phrases were shown on the computer in the indoors context. The *outdoors* context was an isolated pavilion with a picnic table and two stone benches located outside of the building and surrounded by woods. To reduce pedestrian traffic, the area around the pavilion was roped off. Phrases were shown on a flipbook in the outdoors condition. There was a substantial difference in the temperatures between the cool indoors context and the hot and humid outdoors context. No testing was done outdoors on rainy days.

Procedure

During encoding, participants were told to memorize the action phrases for an unspecified memory test. Phrases were presented at a rate of 6 s. Participants were instructed to perform the action symbolically (pretending they had the objects they needed) if the phrase was accompanied by a "perform" prompt and to learn the phrase if it was accompanied by a "study" prompt. The experimenter monitored compliance with the instructions.

In the *same* context condition, participants studied both lists in the same context (indoors or outdoors), while in the *different* context condition, they studied one list in each context. To maximize contextual change, the sex and race of the experimenter changed between lists in the different context condition. Assignment of lists to contexts, participants to first context, and experimenter race and sex were counterbalanced.

In the different context condition, the new experimenter arrived after List 1 was studied and explained that she or he was taking the participant to the next location, where they would continue the experiment. Transit time was surreptitiously equated at 60 s by means of the experimenter's stopwatch. In the same context condition, participants were also interrupted after studying List 1 to control for the disruption between the two lists. They were told to get up and walk in the room (or outdoors pavilion) to determine the number of steps it took to get across the length, the width, and the diagonal of the room/pavilion. The experimenter used a stopwatch to ensure that participants engaged in this activity for no more than 60 s.

Following the study session, participants completed a filler task involving counting backwards (out loud) by threes from a prespecified number for 60 s. Finally, they were told to recall both lists, with recall order of the lists counterbalanced across participants. Recall was carried out on blank sheets of papers with 90 s designated for recall of each list. Recall time was determined based on pilot testing, which showed that participants seldom utilized the entire time.

Results

The first analysis in this section evaluates context-dependent forgetting, which is the negative consequence of changing the context between the study and the test. The second analysis evaluates the positive consequence of changing the context between the two lists, which is expected to reduce list discrimination errors compared to when the lists are studied in the same context.

Context-dependent forgetting

Recall was analysed using Item Type (VT vs. SPT) × Lists (List 1 vs. List 2) × List 1 Context (indoors vs. outdoors) × List 2 Context (indoors vs. outdoors) mixed factorial analysis of variance (ANOVA), with the first two factors varied within subjects, and the last two factors varied between subjects. There was a main effect of item type, $F(1, 60) = 9.81$, $MSE = 0.042$, $p < .001$, confirming a recall advantage for SPTs (.36) over VTs (.22). However, it did not interact with other variables in the study (Fs < 1). Importantly, there was a significant three-way interaction of List 1 Context × List 2 Context × Lists, $F(1, 60) = 7.75$, $MSE = 0.017$, $p < .01$. The remaining main effects and two-way interactions are not reported because they were all modified by the three-way interaction. To follow up the interaction, the recall of each list was separately evaluated with List 1 Context × List 2 Context ANOVA.

List 2 analyses are reported first, because List 2 was always tested in the same context in which it was studied; hence there was no reason to suspect context-dependent forgetting. Indeed, there was only a marginal main effect of List 2 context, $F(1, 60) = 2.65$, $MSE = 0.010$, $p = .11$, indicating that recall was higher when List 2 was encoded indoors (.32) than outdoors (.28). However, there was neither an effect of List 1 context ($F < 1$), nor an interaction between the two variables, $F < 1$ (see Figure 1, top panel). In other words, as predicted there was no context-dependent forgetting. Item type was not included in this analysis because it was not significant in the higher order interactions in the overall ANOVA. However, if item type is analysed along with the List 1 context and List 2 context, it produces only a main effect, $F(1, 60) = 27.16$, $MSE = 0.037$, $p < .001$, and does not interact with any of the variables (Fs < 1). Figure 2 shows List 2 VT and SPT recall as a function of whether the two lists were studied in the same or in different contexts.

Unlike List 2, List 1 was sometimes tested in the context that matched its encoding context and sometimes in the context that mismatched its

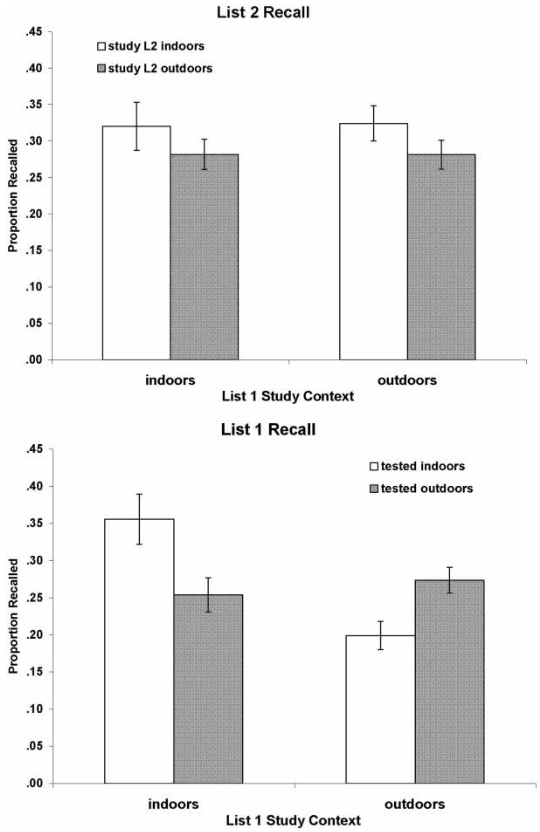

Figure 1. *Proportion of List 2 recall (top panel) and List 1 recall (bottom panel) by List 1 context and List 2 context. Error bars represent standard errors of the means.*

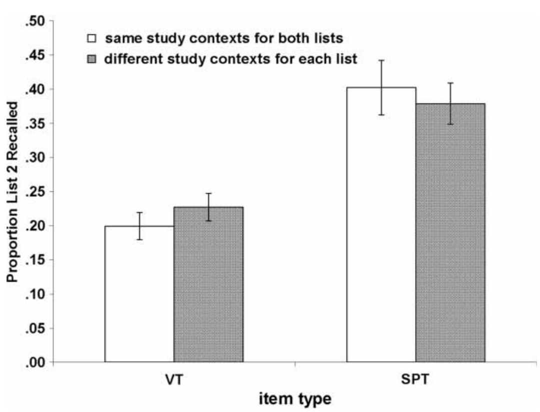

Figure 2. *Proportion of List 2 recall as a function of item type (verbal task, VT; subject-performed task, SPT) and contextual similarity between the List 1 and List 2 study contexts. Error bars represent standard errors of the means.*

encoding context. Hence, there should be context-dependent forgetting in List 1 recall when the study and the test contexts mismatch. For simplicity of exposition, in this analysis, List 2 context will be renamed *testing context* because it represents the same variable. When List 1 recall was analysed with List 1 context (indoors vs. outdoors) and testing context (indoors vs. outdoors), there was a main effect of List 1 context, $F(1, 60) = 8.04$, $MSE = 0.009$, $p < .01$, indicating higher recall when List 1 was studied indoors (.31) than when it was studied outdoors (.24). In addition, there was a List 1 Context × Testing Context interaction, $F(1, 60) = 13.33$, $MSE = 0.009$, $p < .001$ (see Figure 1, bottom panel). When List 1 was studied indoors, it was remembered better when it was tested indoors than outdoors, $t(30) = 2.49$, $p < .05$. Likewise, when List 1 was studied outdoors, it was remembered better when tested outdoors than indoors, $t(30) = 2.90$, $p < .01$. In other words, when List 1 study and test contexts mismatched, recall suffered, demonstrating context-dependent forgetting.

Item type was not included in the above analysis because it was not significant in the higher order interactions in the overall ANOVA. However, even when List 1 analyses were rerun by including the item type variable, there were no interactions of item type with other variables (Fs < 1), suggesting that the magnitude of context-dependent forgetting was the same across VTs and SPTs (see Figure 3). Thus, when context changed between the study and test, SPTs suffered as much as VTs, suggesting that SPTs were associated with their environmental context and were benefiting from the presence of context cues at the time of test.

List discrimination errors

During the recall of each list, participants occasionally intruded items from the wrong list. The proportion of intrusion errors were analysed using Lists (List 1 vs. List 2) × Item Type (VT vs. SPT) × List 1 Context (indoors vs. outdoors) × List 2 Context (same vs. different from List 1) mixed factorial ANOVA.

There were more SPT intrusions (.029) than VT errors (.018), as evidenced by the significant

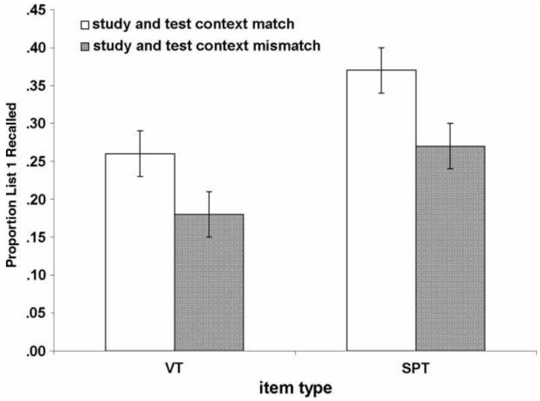

Figure 3. *Proportion of List 1 recall as a function of item type (verbal task, VT; subject-performed task, SPT) and contextual match between the study and the test. Error bars represent standard errors of the means.*

main effect of item type, $F(1, 60) = 4.02$, $MSE = 0.117$, $p < .05$. There was also a main effect of lists, $F(1, 60) = 7.70$, $MSE = 0.183$, $p < .01$, revealing more intrusions from List 1 during List 2 recall (.016) than from List 2 intrusions during List 1 recall (.007). There was also a significant main effect of List 2 context, $F(1, 60) = 12.89$, $MSE = 0.255$, $p < .001$, demonstrating higher intrusions when the lists were studied in the same context (.019) than when they were studied in the different contexts (.004). There was no main effect of List 1 context and also no interaction of List 1 context and List 2 context (both Fs < 1). Thus, the intrusion rate was independent of the environment in which List 1 was encoded; what mattered more was whether the second list was studied in the same or in the different context.

In addition to these main effects, there were two significant two-way interactions. There was an interaction of List 2 Context × Lists, $F(1, 60) = 4.12$, $MSE = 0.183$, $p < .05$, and an interaction of List 2 Context × Item Type, $F(1, 60) = 5.62$, $MSE = 0.117$, $p < .05$. The remaining effects were not significant.

Figure 4 summarizes the List 2 Context × Lists interaction. When both lists were studied in the same context, there were more List 1 intrusions during List 2 recall than List 2 intrusions

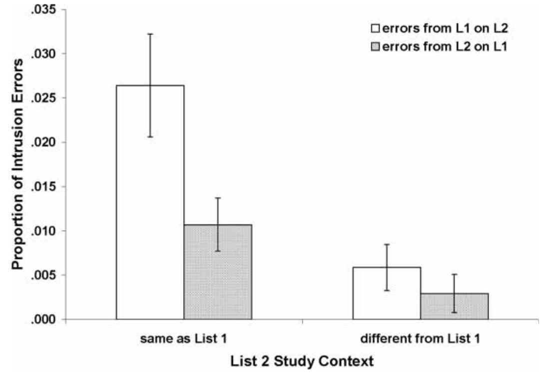

Figure 4. *Proportion of intrusion errors as a function of study list and List 2 context. Error bars represent standard errors of the means.*

during List 1 recall, $t(31) = 2.49$, $p < .05$. However, when the lists were studied in different contexts, both types of intrusions were significantly reduced—from List 1, $t(62) = 3.22$, $p < .01$; from List 2, $t(62) = 2.11$, $p < .05$—and were not different from each other, $t = 1.00$. This analysis confirms that encoding the lists in different environments improves list discriminability, and in the current study it eliminated the errors.

Figure 5 summarizes the List 2 Context × Item Type interaction. When both lists were encoded in the same context, there were more SPT intrusions than VT intrusions, $t(31) = 2.44$,

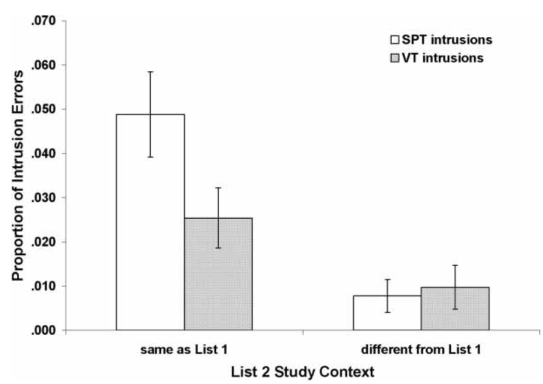

Figure 5. *Proportion of intrusion errors as a function of item type (verbal task, VT; subject-performed task, SPT) and List 2 context. Error bars represent standard errors of the means.*

$p < .05$; however, when the lists were encoded in different contexts, both types of intrusions were reduced and were no longer different from each other, $t < 1$. Studying the lists in different contexts reduced both SPT intrusions, $t(62) = 3.98$, $p < .001$, and VT intrusions, $t(62) = 1.86$, $p = .07$. There was no three-way interaction with lists suggesting that reduction of SPT and VT intrusions was found both with List 1 items intruding during List 2 recall and with List 2 items intruding during List 1 recall.

Discussion

The results of the current study demonstrate that the recall of VTs and SPTs was impaired when the environmental context between the study and test changed. The degree of forgetting was equivalent across item types, suggesting that SPTs are as sensitive to contextual variations as VTs. Thus, people stored contextual information regardless of whether they learned the phrases verbally or whether they physically performed the actions, and context served as a retrieval cue during the test. If enactment diminished the storage of contextual information in the memory trace, then SPTs should have suffered less than VTs when context changed between the study and test. However, the same magnitude of recall impairment was observed from SPTs and VTs suggesting that both types of items are integrated with their environmental context as far as the cueing property of context is concerned. Furthermore, these findings imply that the lack of forgetting for SPTs in a related environmental context change study by Phillips and Kausler (1992) was most likely due to a failure to obtain a context effect rather than the insensitivity of SPTs to contextual factors. Their study may have been less successful in finding an overall context-dependent forgetting because the environmental context manipulation involved two different laboratory rooms. The meta-analysis of the context literature suggests that the magnitude of the context effect is much smaller when different laboratory environments are used than with more dramatic environmental manipulations (Smith & Vela, 2001). The current study employed simultaneous manipulation of several variables known to maximize the context effect, such as the change of the experimenter, presentation modality, and the combination of outdoors and indoors physical contexts. In addition to these factors, the study involved a second-order paradigm rather than a first-order paradigm (Bjork & Richardson-Klavehn, 1988). The latter involves studying a list in one context and receiving a test in another context, and thus context cues from the previous environment can be mentally reinstated during the test and reduce the impact of context change in recall. However, the use of the second-order paradigm in the current study (e.g., multiple lists) could have made it harder to mentally reinstate the context because of potential interference with two sets of context cues. Furthermore, mental reinstatement in the second-order paradigms typically does not yield a memory advantage (Smith, 1979, 1984). A combination of these factors could have contributed to a more sizeable context effect obtained in the current study.

In addition to the negative consequence of context change, there was also a positive consequence of context change as evidenced by reduced cross-list intrusions when the lists were encoded in different environments compared to the same environment. Both SPT and VT intrusions were reduced as a result of contextual differentiation. One cannot conclude that SPTs benefited more from the context change than VTs because although there were more SPT errors when the lists were studied in the same context (note that greater accessibility of SPTs during recall could lead to potentially more errors), in this study, changing the study context between the lists almost completely eliminated the errors for both types of items. The floor effect complicates the interpretation of the relative magnitude of the positive context effect across VTs and SPTs. However, the more unambiguous result is that SPTs clearly benefited from contextual differentiation.

An interesting observation that emerged from this study concerns the reduction of cross-list intrusions when the lists were encoded in two different environments. These findings imply that spatial cues may be more effective in differentiating the lists than temporal cues because when both lists were encoded in the same environmental context, they could be differentiated mostly along the temporal dimensions, whereas studying them in different environments provided additional spatial cues. Note that errors from both lists were reduced as a result of environmental differentiation. Although one might suggest that when List 1 items were retrieved in a mismatching context, fewer of them could come to mind and intrude during List 2 recall (which could explain why List 1 intrusions were reduced), the same argument cannot be used to explain the reduction of List 2 intrusions during List 1 recall. This is because List 2 was always tested in the same context in which it was studied, and hence item accessibility was not an issue. Therefore, the reduction of errors from both lists suggests that the results were not driven by the item accessibility.

To summarize, SPTs were sensitive to the cueing property of context: They showed both the positive and the negative consequences of environmental context change. As far as implicit measures of context are concerned, SPTs appear to be integrated with their environmental context. Furthermore, there is only a single study that found impaired source memory for SPTs (Koriat et al., 1991); no other studies using explicit retrieval of context suggested that SPTs are poorly integrated with their environmental context. Together the evidence suggests that the claims about poor integration of SPTs with their environmental context were premature.

Original manuscript received 8 December 2008
Accepted revision received 9 August 2009
First published online 1 December 2009

REFERENCES

Bjork, R. A., & Richardson-Klavehn, A. (1988). On the puzzling relationship between environmental context and human memory. In C. Izawa (Ed.), *Current issues in cognitive processes: The Tulane Flowerree Symposium on Cognition* (pp. 313–344). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chalfonte, B. L., & Johnson, M. K. (1996). Feature memory and binding in young and older adults. *Memory & Cognition*, *24,* 403–416.

Conway, M. A., & Dewhurst, S. A. (1995). Remembering, familiarity, and source monitoring. *Quarterly Journal of Experimental Psychology*, *48A,* 125–140.

Cornoldi, C., Corti, M., & Helstrup, T. (1994). Do you remember what you imagined you would do in that place? The motor encoding cue-failure effect in sighted and blind people. *The Quarterly Journal of Experimental Psychology, 47A*, 311–329.

Dallett, K., & Wilcox, S. G. (1968). Contextual stimuli and proactive inhibition. *Journal of Experimental Psychology*, *78,* 475–480.

Englekamp, J. (1998). *Memory for actions*. Hove, UK: Psychology Press.

Englekamp, J., & Dehn, D. M. (2000). Item and order information in subject-performed tasks and experimenter-performed tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26,* 671–682.

Greenspoon, J., & Ranyard, R. (1957). Stimulus conditions and retroactive inhibition. *Journal of Experimental Psychology*, *53,* 55–59.

Helstrup, T. (1989). Loci for act recall: Contextual influence on the processing of action events. *Psychological Research*, *51,* 168–175.

Hornstein, S. L., & Mulligan, N. W. (2004). Memory for actions: Enactment and source memory. *Psychonomic Bulletin and Review*, *11,* 367–372.

Jensen, L. C., Dibble, J., & Anderson, D. C. (1971). Effects of a contextual change upon retroactive inhibition. *Psychological Reports*, *29,* 39–46.

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin*, *114,* 3–28.

Koriat, A., Ben-Zur, H., & Druch, A. (1991). The contextualization of input and output events in memory. *Psychological Research*, *53,* 260–270.

Mohr, G., Engelkamp, J., & Zimmer, H. D. (1989). Recall and recognition of self-performed tasks. *Psychological Research*, *51,* 181–187.

Naveh-Benjamin, M., & Craik, F.I. M. (1995). Memory for context and its use in item memory: Comparisons of younger and older persons. *Psychology and Aging*, *10,* 284–293.

Nilsson, L. G. (2000). Remembering actions and words. In F. I. M. Craik & E. Tulving (Eds.), *Oxford handbook of memory* (pp. 137–148). Oxford, UK: Oxford University Press.

Phillips, P. L., & Kausler, D. H. (1992). Variation in external context and adult age differences in action memory. *Experimental Aging Research*, *18*, 41–44.

Senkfor, A. J., Van Petten, C., & Kutas, M. (2002). Episodic action memory for real objects: An ERP investigation with perform, watch, and imagine action encoding tasks versus a non-action encoding task. *Journal of Cognitive Neuroscience*, *14*, 402–419.

Smith, S. M. (1979). Remembering in and out of context. *Journal of Experimental Psychology: Human Learning & Memory*, *5*, 460–471.

Smith, S. M. (1984). A comparison of two techniques for reducing context-dependent forgetting. *Memory & Cognition*, *12*, 477–482.

Smith, S. M., Glenberg, A. M., & Bjork, R. A. (1978). Environmental context and human memory. *Memory & Cognition*, *6*, 342–353.

Smith, S. M., & Vela, E. (2001). Environmental context-dependent memory: A review and meta-analysis. *Psychonomic Bulletin & Review*, *8*, 203–220.

Strand, B. Z. (1970). Change of context and retroactive inhibition. *Journal of Verbal Learning & Verbal Behavior*, *9*, 202–206.

Zimmer, H. D. (1994). Representation and processing of the spatial layout of objects with verbal and non-verbal input. In W. Schnotz & R. W. Kulhavy (Eds.), *Comprehension of graphics* (pp. 97–112). Amsterdam: Elsevier, North Holland.

Zimmer, H. D. (1996). Memory for spatial location and enactment. *Psychologische Beiträge*, *38*, 404–418.

Zimmer, H. D., Cohen, R. L., Guynn, M. J., Englekamp, J., Kormi-Nouri, R., & Foley, M. A. (2001). *Memory for action: A distinct form of episodic memory?* Oxford, UK: Oxford University Press.

Zimmer, H. D., & Engelkamp, J. (1985). An attempt to distinguish between kinematic and motor memory components. *Acta Psychologica*, *58*, 81–106.

Zimmer, H. D., & Engelkamp, J. (1989). Does motor encoding enhance relational information? *Psychological Research*, *51*, 158–167.

APPENDIX

Stimulus materials

Change the light bulb	Put on the hat	Seal the envelope	Lock the safe
Smoke a cigarette	Inflate the balloon	Throw the dice	Break a toothpick
Iron the shirt	Clip the nails	Open the umbrella	Smell the flower
Aim the bow	Flip the coin	Cool yourself with a fan	Peel the potatoes
Pet the cat	Hammer the nail	Draw a circle	Throw the ball
Light the candle	Crush the bug	Close the book	Blow the whistle
Drive a car	Make a snowball	Drink from a cup	Remove the ring
Chop the onions	Talk on the phone	Cut the fabric	Shake the bottle