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BRIEF REPORT

Improving memory after environmental context change: A strategy of "preinstatement"

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Abstract A change in environmental context between study and test can produce detrimental effects on memory. For instance, when a change in the environment occurs after an event, memory for the event declines. However, the negative effects of context change can be eliminated when participants are provided with contextual cues. Here, we report that, as predicted by the Lehman–Malmberg model (Lehman & Malmberg Journal of Experimental Psychology: Learning, Memory, and Cognition 35(4):970, 2009, Psychological Review, 2012), participants can overcome a change in the environment by recalling the future test environment while studying, a strategy referred to as *preinstatement*.

Keywords Preinstatement · Context dependent memory · Environmental reinstatement · Free recall

One encounters the same people, places, and things many times. Yet we are often able to remember specific events. The targets for memory are referred to as *items*, and different contexts distinguish the encounters. For instance, one might need to report a burglary of a garage to the police. The garage might contain items like a bike, a car, a lawnmower, and so forth before the burglary, and the episode-defining context is the garage the day prior to the burglary. In a typical experiment, each item on a study list is associated with the context representing the task performed, the time of day, the location, and so forth, and according to most theories of memory, to recall the items one must reinstate some aspects of the context stored during study; this aspect of retrieval is assumed to be facilitated when testing is done in a similar context to study (Anderson & Bower, 1973; Estes, 1955; Lehman & Malmberg, 2009; McGeogh, 1942; O'Keefe & Nadel 1979; Raaijmakers & Shiffrin, 1981; Tulving & Thomson, 1973). In fact, changes in context harm several episodic memory tasks throughout the life span (see Craik & Schloerscheidt, 2011; Hayne & Findlay, 1995; Smith & Vela, 2001), including free recall (Godden & Baddeley, 1975), recognition memory (Murnane, Phelps, & Malmberg, 1999), physical memory for performed tasks (Sahakyan, 2010), and even implicit memory (Brockmole, Castelhano, & Henderson, 2006). However, some items are retrieved despite the change in context, and one is quite able to retrieve from a specific list of items without significant levels of interference (Lehman & Malmberg, 2009; Shiffrin, 1970), which suggests that context cues are used to focus the retrieval processes on relevant memory traces even after a change in context occurs.

But how is context reinstated? Although this is perhaps the $64,000 question in our understanding of how we remember prior experiences, little is known about the reinstatement process or even what is being reinstated. With the present experiment, we test the predictions of a recently proposed model (Lehman & Malmberg, 2009, 2012) by manipulating whether anticipating the test context and actively encoding it during study benefits subsequent testing.

Context change and reinstatement

The Lehman–Malmberg model was originally developed to account for the mental context change associated with directed forgetting (Lehman & Malmberg, 2009) and later was extended to account for the effects of context change and reinstatement in a variety of tasks (Lehman & Malmberg,

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2011, 2012). The model assumes that context changes gradually within a list and more rapidly between lists and that changes in physical environment or intentional changes of mental context can increase the rate of context change. Furthermore, the model assumes that in free recall, features of the encoding context must be reinstated to serve as cues with which to probe memory for studied items. Performance in free recall will be high when the context cues used to probe memory match those stored with the encoded information. Thus, when context reinstatement is successful, free recall will be successful due to the match between the context used to probe memory and the encoding context.

The Lehman–Malmberg model predicts that recall will be more difficult after changes in physical environment due to the mismatch between the context used to probe memory at the time of test and the context in which studied items were encoded. For example, when participants study a list of words in one room and are tested in a different room, recall performance is lower than in a condition where study and test occur in the same room (Smith, 1979). To examine whether participants could overcome the negative consequences of a change in environmental context, Smith (1979) had some participants who had changed rooms mentally reinstate the study environment in order to create retrieval cues containing features of the study context. As predicted by the Lehman–Malmberg model, mental reinstatement of the study context eliminated the detrimental effects of context change (Smith, 1979).

Experiment: Preinstatement of context during encoding

According to the Lehman–Malmberg model, if we know what contextual cues will be available in the future, we should be able to enhance subsequent memory by encoding those cues with the items we anticipate needing to recall, even if the cues present in the future are not physically present during study. For instance, when studying for an exam, one might imagine the classroom in which the exam will be conducted. Under such conditions, the recallable features of the test environment should be associated with the studied information during encoding, and when the memory test occurs, the physical environment should then provide a good cue to retrieve those item representations that were associated with the environmental context information during study. That is, a strategy of contextual *preinstatement*, in which the test environment is recalled and imagined while to-be-remembered items are encoded during study, should buffer memory from harmful effects of a change in context (or perhaps even improve it). These predictions are shown in the right panel of Fig. 2, and we will discuss how they were generated in the Results section.

Method

Participants

Participants were 180 undergraduate psychology students from the University of South Florida (USF), who participated in exchange for course credit. Participants were divided into one of three conditions, *same-context* (SC), *different-context* (DC), and *different-context–preinstatement* (DC–P), with 60 participants in each condition. Participation excluded anyone who had been inside the laboratory within the last 7 days.

Materials

Two word lists were created consisting of 12 one- or two-syllable nouns between three and ten letters in length, with frequencies between 20 and 50 per million (Francis & Kučera, 1982), balanced on word length (M = 5.63 letters). Two distinct physical environments were used: a participant-testing laboratory cubicle and an outdoor setting. The cubicle was located inside a laboratory at USF and was set up to appear like a general office setting, which included books, writing utensils, and other office decorations. The outdoor setting was a bench outside of the psychology building at USF, which was surrounded by sidewalks and palm trees (pictures of the environments are shown in Fig. 1). Ten questions about personality traits were used as a filler task during exposure to the cubicle. To orient the participants to the physical environment of the cubicle, a digital camera was used by participants to photograph three specific objects in the cubicle, and other objects were present that participants were asked to point out. Pertinent objects in the indoor environment included a coffee cup, an orange highlighter, a music encyclopedia, a paper cup, a leopard jigsaw puzzle, and a glue stick. In the outdoor environment, a similar procedure was used, and participants were asked to point out a yellow newspaper box, a stairway, and a green sign (these tasks will be described in the Procedure section). For the indoor stages of the experiment, a desktop computer was used for word presentation and participant responses; an Apple iPad was used for list presentation in the outdoor conditions. For additional differentiation between the environmental contexts, two different researchers were used in the DC conditions: One researcher was a middle-aged female, and the other was a college-aged male.

Procedure

All participants participated in three stages of the experiment. Because participants in the DC–P condition would be required to recall the test environment prior to the test, while studying in a different environment, it was necessary that

Fig. 1 Pictures of the indoor (top panel) and outdoor (bottom panel) environments used in the experiment

they become familiar with this environment prior to studying; thus, all participants began at the main laboratory inside the psychology building. Participants were accompanied to the cubicle, where researcher 1 gave them an overview of the experiment. Participants completed a personality survey (which was used as a filler task to expose participants to the cubicle environment), after which researcher 1 asked the participants to find and photograph a coffee cup with sailboats on it, then to find and photograph an orange highlighter, then the music encyclopedia. Participants were given 75 s to find the three objects. If the last item was not found within the time frame, researcher 1 pointed out the object and had the participant photograph it.

For the second phase of the experiment, procedures differed across conditions. The novel DC–P condition will be described first, since the procedures described in the other conditions consisted of various experimental controls for consistency with this condition. After the first phase, participants in the DC–P condition were escorted by researcher 2 to a bench in the outdoor area. Participants were given 30 s and were instructed to look around the outdoor area until the researcher asked them to stop. Participants were then asked to find and point out first a yellow newspaper box, then a staircase, and lastly a green sign. They were also given 75 s to locate the outdoor objects. Next, participants were told to remember the cubicle where they first started the experiment and to imagine that they were actually studying the words there instead of outside. Participants were instructed to recall the beginning of the experiment, what the first researcher looked like, any sounds or smells that they noticed, and the tasks that they performed. Participants were shown a picture of the cubicle on the iPad for 30 s to help them to remember the room. Participants then viewed list 1 (L_1). The list was shown three times in the same order, in order to increase the amount of exposure each item received in the given environment (a spaced presentation was used because it presumably leads to more encoding of contextual information than does massed presentation; Malmberg & Shiffrin, 2005). Each word appeared on the iPad screen, one at a time for 4 s. After each list presentation, the picture of the cubicle was shown for 8 s while an on-screen instruction reminded participants to focus on the room while studying. After studying L_1, participants walked back to the laboratory and were instructed to count aloud the steps taken (to prevent rehearsal). Upon returning to the lab, researcher 1 directed the participants back to the original cubicle, where they studied list 2 (L_2).[1]

The procedure for the DC condition was identical to that for the DC–P condition, except for the preinstatement instruction. Participants were instead asked to remember when they first came outside, any thoughts that they may have had and sights or smells that they may have noticed. They were told to think about these things as they studied the list of words. An outdoor picture was interspersed between list presentations, instead of the picture of the cubicle.

For participants in the SC condition, phase two also began with an escorted walk out of the lab, half the distance to the outdoor environment, and back to the cubicle for the study stage of the experiment. This activity was intended to simulate the interval in which the participants in the other conditions traveled between the indoor and outdoor areas. Upon returning to the cubicle, participants were asked to look around the cubicle until they were told to stop (30 s). Participants were asked to locate and point out three additional items in the room (a paper cup, a leopard jigsaw puzzle, and a glue stick). They were next shown a photograph of the same area displayed on the desktop computer monitor and were asked to confirm that the photograph represented the same room. Participants then viewed L_1 in the same manner as in the other two conditions, but on the

[1] Due to the nature of the computerized tasks and indoor/outdoor environments involved in the experiment, the physical environments were not counterbalanced, but we have no reason to believe that this would interact with the effects in the experiment.

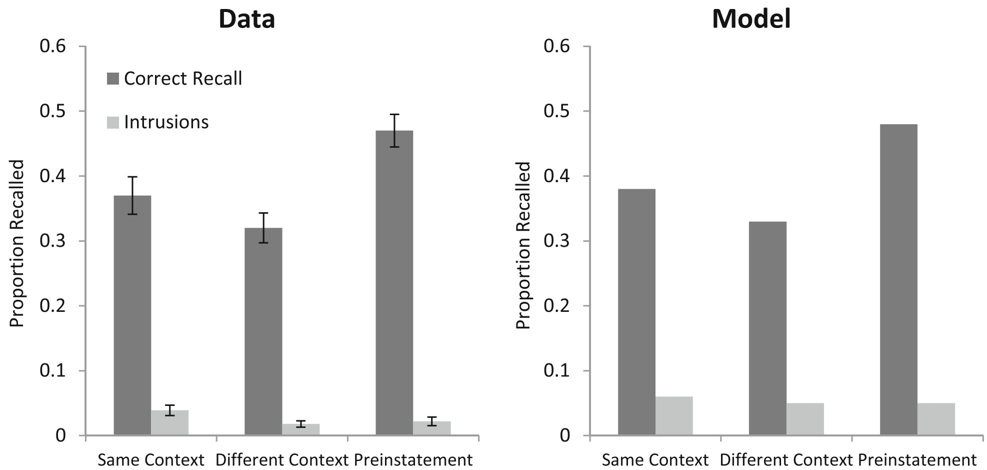

Fig. 2 The left panel shows the proportion of list 1 words correctly recalled during the list 1 test and intrusions from list 1 output during the list 2 test. The right panel shows the model's predictions. Error bars represent standard errors

desktop computer in the cubicle. After each list presentation, an on-screen instruction reminded participants to focus on the room while the picture of the cubicle was displayed. After viewing L_1, participants were once again escorted out of the lab and walked half the distance to the outdoor area and back before beginning the third phase. They were also instructed to count aloud the steps they took as they walked.

In the third phase of the experiment, after returning to the cubicle, all participants studied a second list of words (L_2), following the same procedure as that for L_1. A picture of the cubicle was presented between list presentations. L_2 served to increase the amount of activity occurring in this environment (Sahakyan, 2010) and to provide a measure of list discrimination via intrusion analyses. A 60-s distractor task requiring participants to count backward aloud by threes from a specified three-digit number preceded the individual recall tests. Participants first recalled words from L_1 and then L_2, with a 60-s recall period for each test.[2]

Results

An alpha level of .05 was used for all analyses, which were confined to the data obtained from L_1. A one-way ANOVA revealed a significant effect of context condition on the percentage of words recalled, $F(2, 177) = 4.69$, $MSE = .190$, $p = .01$. Figure 2 shows that participants who preinstated the cubicle context while studying the words outdoors recalled more words than did those participants who did not preinstate the cubicle context (Tukey HSD, $p = .007$). The proportion of words correctly recalled in the SC condition did not significantly differ from that in the DC condition ($p = .324$) or the DC–P condition ($p = .238$).

[2] There were no significant differences between groups on list 2 performance; these data are not discussed further.

The context change in the DC condition may have aided L_1 memory by reducing output interference if fewer L_2 intrusion errors were made (Tulving & Arbuckle, 1963). If the context change manipulation was effective, it should have differentiated the lists in memory (Lehman & Malmberg, 2009). When memory is probed with the context features that differentiate the lists, it should be less likely that an item from L_2 should be output when recalling from L_1, because fewer irrelevant L_2 traces should be activated by the probe with the context cue. Additionally, once retrieved from memory, fewer L_2 items should be output, since it would be more likely that the participant would notice that the item was studied on the wrong list. The probabilities of producing a word from L_1 during recall of L_2 are shown in the left panel of Fig. 2. Planned comparisons revealed significantly fewer intrusions in the DC condition than in the SC condition, $t(118) = 2.214$, $p = .029$.

Did the change in context also reduce intrusion errors in the preinstatement condition? Under preinstatement conditions, it is likely that a representation of the physical environment during study was encoded, as well as the preinstated test context. If so, even though the preinstated test context was similar to the context encoded during the study of L_2, L_2 intrusions could be avoided by using the retrieved study context to edit output. In fact, intrusion rates in the DC and DC–P conditions were not significantly different, $t(118) = 0.511$, $p = .610$. Thus, preinstating the test environment enhanced correct recall and helped limit intrusion errors.

Model predictions

The right panel of Fig. 2 shows model predictions from the Lehman–Malmberg model. These predictions were generated using the same model for all conditions (details about the model and parameter values can be found in Lehman & Malmberg, 2012), with the exception of two parameters related to context change and reinstatement. First, we assumed that the rate at which context changed between lists, β_b, was greater in the DC and DC–P conditions (β_b = .5) than in the SC condition (β_b = .2). Next, we assumed that proportion of L_1 context features reinstated during recall (γ_I) was greater in the SC condition (γ_I = .3) than in the DC condition (γ_I = .1), and greater yet in the DC–P condition (γ_I = .5). Consistent with the data, the model predicted higher recall and lower intrusion rates in the DC–P condition than in the other two conditions.

Discussion

Participants who preinstated the test environment recalled more studied items than did participants who did not, suggesting that preinstatement is an effective strategy for overcoming the negative memorial effects of environmental context change. The proportions of items recalled in the SC condition and in the DC condition were not significantly different; however, the analysis of intrusion errors confirmed significant effects of context change. In addition, the intrusion analyses revealed more successful list discrimination in both of the DC conditions, regardless of whether the test context was preinstated or not. Thus, preinstating the test context enhanced free recall by increasing the number of target items recalled and by reducing interference from irrelevant memory traces.

While performance in the SC condition was numerically greater than performance in the DC condition, this difference was not statistically significant, and it is important to address this small effect, given that others have demonstrated larger effects of context change (Sahakyan, 2010; Smith, 1979). First, when referring to differences in performance, we need to consider both the items that were correctly recalled and intrusions. In fact, we used two study lists so that we could measure intrusion rates to provide a measure of list discrimination because it is possible that, in the SC condition, the addition of the second study list in the same environment produced interference during the L_1 test, decreasing performance in the SC condition (Strand, 1970). Thus, while individuals in the SC condition may have benefitted from the match in context between study and test, performance may have suffered due to interference from L_2, which is in fact predicted by our model, and the reduction in intrusion errors when a change of context occurs between lists is consistent with prior work (Lehman & Malmberg, 2009; Sahakyan, 2010). While list discrimination may have been difficult for participants in the SC condition, reflected by higher intrusion rates, participants in the DC and DC–P conditions studied one list in an outdoor setting and one list in an indoor setting, providing more differentiation between lists. The preinstatement of test context allows these overlapping features to be stored, which would increase the confusion between L_1 and L_2 if it were not for the fact that the change in physical environment also occurred. Hence, the intrusion rates are not higher in the DC–P condition than in the DC condition.

The benefits of preinstatement on later memory are consistent with research showing that visualizing or imagining an anticipated action improves performance in sports (Martin, Moritz, & Hall, 1999; Schmidt & Wrisberg, 2004) and in brain injury rehabilitation work (Lui, Chan, Lee, & Hui-Chan, 2004). Future work may also examine how preinstatement affects other psychological phenomena in which environmental context may play an important role, such as phobias. For example, in the treatment of arachnophobia, Mystkowski, Craske, Echiverri, and Labus (2006) found that anxiety returned when an individual with a spider phobia encountered a spider in a different environment than the one in which he had received treatment, but if he or she encountered a spider in the same environment, anxiety did not increase. Context also plays a role in drug addiction. For example, individuals with positive expectations about alcohol, who are more likely to develop alcohol-use disorders (Goldman, Darkes, Reich, & Brandon, 2006), more easily access these positive expectancies when in an environmental context that matches the context in which alcohol is consumed (such as a bar), as compared with a neutral environment (such as an office; Wall, Hinson, McKee, & Goldstein, 2001). Although treatment might appear successful in an office environment, relapse may be more likely when individuals return to the alcohol-related context. Findings from the present study suggest that a strategy of preinstatement, involving visualization of an environment in which a stimulus might be encountered, may lead to better treatment outcomes for phobias and addictions than standard treatment methods.

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