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# Concreteness and Item-to-List Context Associations in the Free Recall of Items Differing in Context Variability

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*Context variability* can be defined as the number of preexperimental contexts in which a given concept appears. Following M. Steyvers and K. J. Malmberg's (2003) work, the authors have shown that concepts that are experienced in fewer preexperimental contexts generally are better remembered in episodic memory tasks than concepts that are experienced in a greater number of preexperimental contexts. The purpose of this article is to demonstrate that low context variability confers its memorial advantage because of stronger item-to-list context associations as compared with high context variability. Three experiments that use environmental context changes from study to test demonstrate that the low context variability advantage is eliminated when item-to-list context associations are not available because of environmental changes at test. In addition, the low context variability advantage is eliminated when inward processing at study prevents the formation of item-to-list context associations.

*Keywords:* free recall, context variability, environmental context

*Context variability* is defined as the number of different semantic contexts in which a particular concept is likely to be found (e.g., Dennis & Humphreys, 2001; Steyvers & Malmberg, 2003). For example, a high frequency word like *wool* is encountered in relatively few semantic contexts, such as those referring to clothing and perhaps the animals on which it grows. By contrast, the high frequency word *hour* is encountered in a multitude of different contexts, such as driving, cooking, sleeping, phone calls, lecturing, and so forth. Steyvers and Malmberg (2003) operationalized high versus low context variability as the number of different passages in which a particular concept appeared in the Touchstone Applied Science Associates corpus (i.e., K–12 reading material). The assumption was that the number of different passages that were associated with a concept would be highly correlated with the number of preexperimental contexts experienced by the average high school educated adult. We agree with their operationalization, and for the purposes of this article, we use their definition. Low context variability concepts tend to confer an advantage over high context variability concepts in several different memory measures, including explicit recollection in a recognition memory paradigm (Cook, Marsh, & Hicks, 2006), source memory (Marsh, Cook, & Hicks, in press), and free recall (Hicks, Marsh, & Cook, 2005).[1]

In this article, we concern ourselves only with the last measure in that list, that is, free recall performance. Previously we reported that context variability and word frequency were dissociated in a free recall task because low context variability conferred an advantage at both low and high word frequency, but high word frequency yielded its normal advantage in free recall (e.g., DeLosh & McDaniel, 1996; also see McDaniel, DeLosh, & Merritt, 2000). We asserted that low context variability items were better recalled because their item-to-list context associations were stronger as compared with high context variability items. Our simple theory went as follows. Whenever an item is studied for an episodic memory test, associations between that concept and spatiotemporal environmental information are recorded in memory (e.g., Anderson & Bower, 1972; Johnson, Hashtroudi, & Lindsay, 1993). We further asserted that low context variability items have fewer preexisting associations to contexts, which may allow more durable (i.e., stronger) item-to-environmental context associations to be formed during encoding. In essence, we based our theory on a variant of the fan effect in memory (Anderson & Reder, 1999;

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[1] Throughout this article, our use of the term *context variability* is a reference to preexperimental context variability. Rather than qualify context variability with the modifier preexperimental each time, we ask the reader to understand our intended meaning. In addition, some readers may disagree with Steyvers and Malmberg's (2003) use of the Touchstone Applied Science Associates corpus because such a definition would not be appropriate for those without a high school education. Although this is true, we argue that their measure should be highly correlated with any other definition because half of their norms include K–6 reading material.

Radvansky, 1999), whereby item-to-list context associations were stronger for low context variability items as compared with high context variability items. More explicitly, we argued that because low context variability items have a smaller fan, the item-to-list context associations that are formed are stronger and more useful when people cue themselves with context information during a free recall task. Unfortunately, we offered no unequivocal evidence for our theory in that previous report; therefore, the purpose of this article is to repay the intellectual promissory note that we borrowed on that former occasion.

To do so, we appealed to the fact that in many situations, changing the environmental context from study to test reduces memory performance (for a review, see Smith & Vela, 2001). This outcome occurs for a variety of environmental contexts—such as changing the room, ambient temperatures, body positions, odors, and genre of music—as well as a variety of internal contexts—such as drug states (alcohol, nicotine, caffeine, marijuana) and states of pain. We reasoned that if our theory was correct for why free recall of low context variable items was better than for high context variability, then changing the environmental context from study to test would reduce access to the item-to-list context associations and thereby reduce the advantage enjoyed by low context variability items. Stated slightly differently, absent the original contextual cues that help recover low context variability items through the item-to-list context associations, there should no longer be any recall advantage for low context variability items after an environmental context change. Demonstrating the accuracy of the predictions from our theory was the main reason for conducting these experiments, although we also had a secondary motive that we describe next.

In our earlier report (Hicks et al., 2005), context variability was confounded with concreteness in the stimuli that we used from Steyvers and Malmberg's (2003) appendix. We argued that it was context variability that led to differences in concreteness ratings, and further, relying on an objective environmental statistic (context variability) is always better than using the subjective evaluation of people (concreteness ratings). Because our earlier claim represents only one (untested) possibility, we thought it prudent to explore concreteness further. Consequently, in the first experiment of this article, we orthogonally crossed low and high concreteness with low and high context variability. Our goal was to demonstrate within a single experiment that a low context variability advantage is obtained at both low and high levels of concreteness. In the General Discussion section, we relate our results to current theoretical models of memory.

## Experiment 1

The purpose of this first experiment was to test directly the predictions of Hicks et al.'s (2005) theory of the low context variability advantage to memory. That theory posits that low context variability items have a smaller preexperimental fan that in turn fosters better encoding of item-to-list context associations (i.e., those associations are stronger and more useful when context is used as a free recall cue). If this is so, then free recall of low context variability items should be disproportionately hurt by an environmental context change than would be the high context variability items whose recall is less dependent on those associations.

### Method

*Participants.* Undergraduate students from the University of Georgia volunteered in exchange for partial credit toward a research appreciation requirement. Each participant was tested individually or in dyads in sessions that lasted approximately 15 min. A total of 160 participants were tested in four between-subjects conditions ($n = 40$ in each) as defined by crossing low and high concreteness with testing in the same versus different environments as the encoding environment.

*Materials and procedure.* The materials were selected from Steyvers and Malmberg's (2003) appendix. Every participant studied 32 words, 16 of which were low context variability items, and 16 of which were high context variability items. Half the participants studied items of low concreteness, and the other half studied items that were highly concrete. Table 1 contains the average word frequencies, concreteness, and imagability ratings for the four classes of items that we selected from Steyvers and Malmberg's appendix. Word frequency was controlled for all four classes of items, and concreteness was controlled at low versus high context variability (i.e., at a given level of concreteness), as was imagability. During study, words were presented in the center of a computer monitor for 5 s each in an order randomized anew for each participant or dyad tested. Participants had only been informed to study the list for an unspecified memory test. When testing took place in dyads, the participants watched the computer monitor in chairs placed next to each other, but then they were separated for the distractor and recall activities. All instructions delivered on the computer monitor were also verbally reiterated by the experimenter.

Just as concreteness was manipulated between subjects, environmental context as the same versus different at test was also manipulated between subjects. Participants who were tested in the same environment were asked to work on arithmetic tasks for 3 min as a distractor activity after the study phase. At the conclusion of the distractor task, they were handed a blank piece of paper and a pencil and were asked to write down as many of the studied words as they could remember. The recall period lasted 4 min as timed with a hand-held stopwatch. For participants who were tested in a different environment, the experimenter walked with the participant(s) from one of our laboratory suites on the fifth floor of the psychology building (which had smaller carpeted rooms, normal height ceilings, and no windows) to the basement floor of the same building where they were tested in a starkly different environment (a very large room with a tall ceiling that contained only a table, two chairs, and a view of the front courtyard through a glass door). The experimenter had practiced his trip from the fifth to the first floor many times and carried with him a hand-held stopwatch to ensure that the retention interval was exactly 3 min before administering the recall test to participants who were tested in the different environmental condition. Although we could not have the participants who changed rooms engage in arithmetic tasks, the experimenter tried to engage

Table 1
*Average Word Frequency and Average Concreteness for the Four Classes of Items Crossing Concreteness With Context Variability*

| Variability | Low concreteness | High concreteness |
|---|---|---|
| Low context | | |
| Average word frequency | 48.69 | 51.19 |
| Average concreteness | 358.63 | 521.63 |
| Average imagability | 422.44 | 520.31 |
| High context | | |
| Average word frequency | 49.06 | 49.81 |
| Average concreteness | 357.88 | 521.56 |
| Average imagability | 428.44 | 538.25 |

the participant(s) continuously in small talk to prevent rehearsal. He claimed that he was successful at doing so. The experimenter who collected the data also scored the free recall protocols against master lists of items without regard to minor spelling mistakes.

### Results and Discussion

Unless otherwise specified with an explicit $p$ value, no statistical test in this experiment or those that follow has a probability of a Type I error greater than the conventional 5%. We do not report intrusions because of their rarity in free recall that precludes their meaningful analysis (Bower & Mann, 1992). The data are summarized in Figure 1, in which the first set of bars represents participants tested with high concrete items, and the middle set of bars reflects performance for participants tested with low concrete items. The last set of bars simply averages over concreteness as a visual aid for readers to see the overall pattern of results without regard to concreteness. We conducted a 2 (high vs. low concreteness) $\times$ 2 (high vs. low context variability) $\times$ 2 (same vs. different test environment) mixed model analysis of variance (ANOVA) on the proportion of items recalled in each of the high versus low context variability classes of items. As we have known for quite some time (Paivio, 1969), free recall was better for high than low concrete words, $F(1, 156) = 23.55$, $MSE = .034$, $\eta_p^2 = .131$. Replicating our prior work, recall was better for low context variability items than high context variability items, $F(1, 156) = 16.05$, $MSE = .017$, $\eta_p^2 = .093$, and that result was qualified by an interaction between context variability and the environmental context factor, $F(1, 156) = 5.94$, $\eta_p^2 = .037$. No other terms in the model approached conventional levels of significance.

Regarding the interaction, performance is reflected in the last set of bars that averages over concreteness. The first two bars in that last set represent being tested in the same environment, whereas the second two bars depict performance when tested in a different environment. Consistent with the predictions that were set forth here, the largest effect of an environmental context change was to eliminate the low context variability advantage. When tested in the same environment, there was a significant effect of context variability favoring low context variability, $t(79) = 4.75$, but changing the room eliminated that difference, $t(70) = 1.06$, *ns*. The careful reader will notice that the attenuation effect is numerically larger at low concreteness than high concreteness, but the concreteness factor did not interact with any other factor, so we have no statistical evidence for concreteness mediating this effect, even with the relatively large sample sizes that we used (i.e., 40/condition).[2] In brief, we conclude that changing the environment at test reduced access to item-to-list contextual associations and reduced the low context variability advantage.

To address our secondary question about whether concreteness confounds context variability, we conducted a reduced ANOVA model on just the same environmental data that map directly to Hicks et al.'s (2005) original report (i.e., the first two bars from each of the first two sets of bars). There was a main effect of concreteness, $F(1, 78) = 11.10$, $MSE = .020$, $\eta_p^2 = .130$, and a main effect of context variability, $F(1, 78) = 22.37$, $\eta_p^2 = .220$, but no interaction, $F(1, 78) < 1.00$. Because there was no interaction, we found no evidence that the effects of context variability and concreteness were somehow confounded with one another. Rather, each factor appears to exert its own independent contribution to free recall performance. Consequently, although concreteness and context variability may be naturally confounded in a statistical sense in Steyvers and Malmberg's (2003) word list, this represents no impediment to using that list to explore the important effects that context variability has on memory performance.

## Experiment 2

The main outcome from Experiment 1 provided support for the idea that low context variability items have stronger item-to-list context associations. However, we believed that we would be on firmer ground for this claim if we could replicate the reduction in recall of low context variability items with a different sort of environmental context change. In this next experiment, we had all participants study under quiet conditions with normal ambient noise from adjacent laboratory rooms. Half of these were tested under the same conditions, but the other half recalled while Mozart's *Eine Kleine Nachtmusik* played in the background. On the basis of Eich and Metcalfe's (1989) demonstration that changing from this music to a different piece of music (or vice versa) affects free recall, we hypothesized that the change from silence at study to music at test would be sufficient to create an environmental context change that should reduce access to the item-to-list context associations that aid in recalling low context variability items.

### Method

*Participants.* Undergraduates from the University of Georgia volunteered in exchange for partial credit toward a research appreciation requirement. Each participant was tested individually (or in dyads) in sessions that lasted approximately 15 min. Two groups of 40 people (80 in total) were tested with the only difference between them being whether music was played at test.

*Materials and procedure.* The procedure was virtually identical to the one used in Experiment 1. We used only the low concreteness set of stimuli from Experiment 1 because we did not want to carry the concreteness issue through with the remaining two experiments (doubling the size of the experiments), and this class of stimuli responded in virtually the same manner to the manipulation of context variability as the high concreteness items. Thus, all participants studied 16 low context variability items and 16 high context variability items that were randomly intermixed anew for each participant (or dyad) tested. Following the study and distractor phases, the instructions for the free recall test were given in written form on the computer monitor and reiterated by the experimenter. For half of the participants, they wrote down as many words as they could remember with no music playing in the background. The other half of the participants were handed a blank piece of paper, and then the experimenter started a CD player approximately 4 feet (1.22 m) behind the participant that was cued to the beginning of Mozart's *Eine Kleine Nachtmusik*, which played continuously throughout the entire free recall period.

### Results and Discussion

The results are displayed in Figure 2. The left set of bars depicts performance with silence at encoding and test, and the right set of

[2] In reduced 2 $\times$ 2 ANOVA models analyzing the data separately for high versus low concreteness, the interaction term is significant for low concrete items but not high. This pattern is consistent with an attenuation at high concreteness and an elimination of the effect at low concreteness.

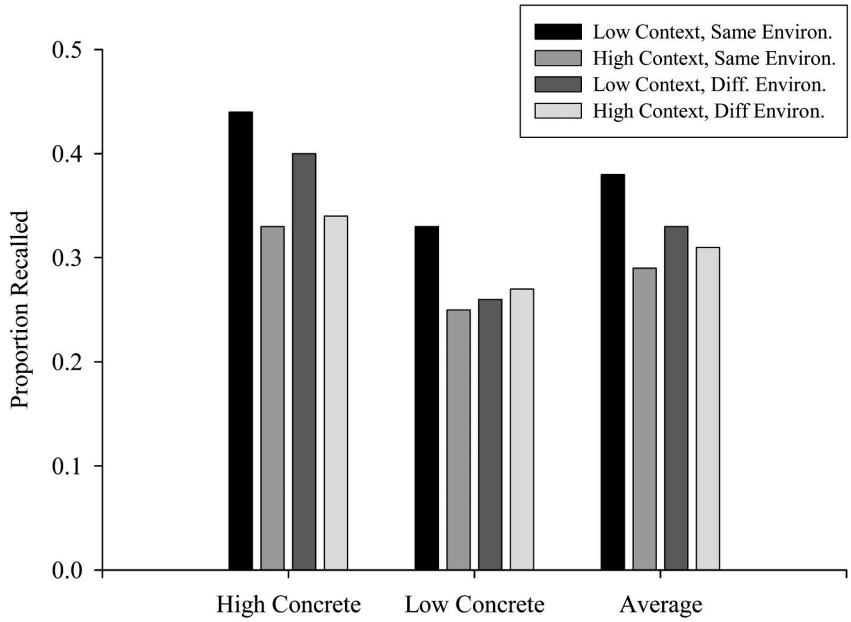


*Figure 1.* Proportion recalled as a function of context variability, concreteness, and environmental context change in Experiment 1. Environ. = environment.

bars depicts performance with an environmental context change that came from playing music at test. We conducted a 2 (low vs. high context variability) × 2 (same vs. different environment at test) mixed model ANOVA with context variability tested within subjects and environmental context change tested between subjects. As is obvious from Figure 2, we obtained a significant interaction, $F(1, 78) = 9.77$, $MSE = .013$, $\eta_p^2 = .110$. With no change in the environment from study to test, low context variability items were recalled more frequently, $t(39) = 3.71$, but when the item-to-list context associations were disturbed by a context change, the low context variability advantage disappeared, $t(39) < 1.00$, *ns*. Given that no advantage was obtained for half of the participants, the main effect of context variability being in the marginal range was not surprising, $F(1, 78) = 3.33$, $MSE = .013$, $p = .07$. The important point is that a change in environmental context eliminated the low context variability advantage that was observed in Experiment 1 (and thrice over by Hicks et al., 2005).

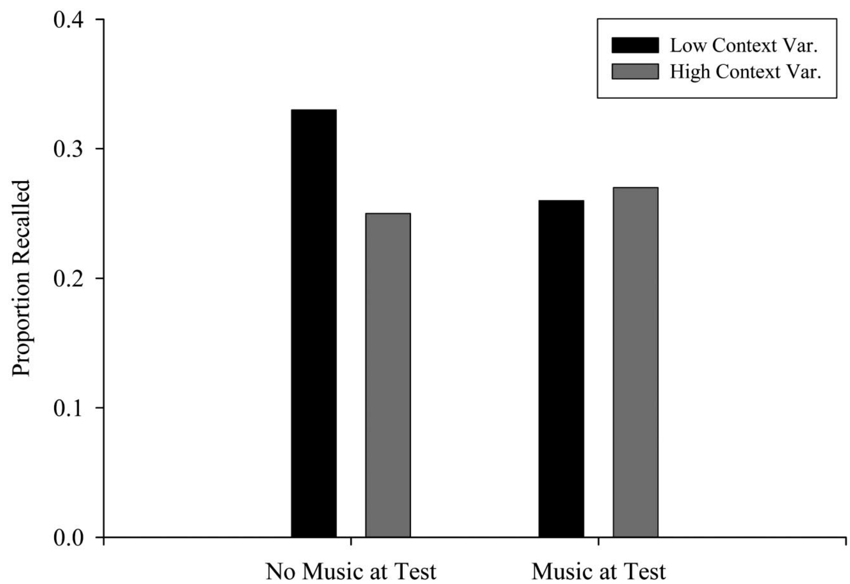


*Figure 2.* Proportion recalled as a function of context variability and environmental context change in Experiment 2.

## Experiment 3

This third and final experiment was designed to show that our theory about item-to-list context associations applies more generally. In the environmental context literature, one can *overshadow* item-to-list context associations by having participants engage in conceptual processing during learning (e.g., Glenberg, 1997; Glenberg, Schroeder, & Robertson, 1998; Matzel, Schachtman, & Miller, 1985). By having participants focus their efforts during learning toward forming interitem associations, they will fail to bind item-to-list context associations into memory in the first place. In the environmental context literature, this means that a context change does not affect recall performance because the item-to-list context associations were never acquired in the first place. In the present case, having participants engage in relational processing between word pairs during study should eliminate the low context variability advantage, and if the environment is changed it should have no effect on the low context variability items.

### Method

*Participants.* Eighty University of Georgia undergraduates volunteered in exchange for partial credit toward a research appreciation requirement. Each participant was tested individually (not in dyads) in sessions that lasted approximately 15 min. Half were tested in the same room, and half were tested in a different room.

*Materials and procedure.* We returned to the room change manipulation that was used in Experiment 1. The procedures associated with testing in the same versus different rooms were identical to that described in Experiment 1. The only difference was that all participants engaged in an encoding manipulation designed to increase the strength of the interitem associations formed at encoding. For every word except the first, the participants had to call aloud to the experimenter one similarity between the current word and the word that occurred on the previous study trial. Participants knew that they had only 5 s to do so, and occasionally they did not utter a similarity. During the instructions for the study phase, they had been instructed to get back on track as quickly as possible if this happened. The experimenter was sitting behind the participant ostensibly recording these, but in actual fact, he did not record the similarities that they called out. The parameters of the distractor task and testing were identical to those used previously.

### Results and Discussion

The results are summarized in Figure 3 in a manner consistent with the previous two experiments. The left pair of bars denotes being tested in the same room, and the right pair denotes being tested in a different room. The reader will notice that free recall performance is slightly better than in the two previous experiments, which we expected because of the relational processing that participants performed at encoding. In the 2 (low vs. high context variability) × 2 (same vs. different room at test) mixed-model ANOVA, none of the three terms in the model was statistically significant, $Fs(1, 78) < 1.00$. Given that the sample sizes were the same as the previous experiments, as were the stimuli and the procedures, the reader cannot claim that we did not have enough power to detect differences that were easily detectable in the previous two experiments. Rather, the results are exactly as they should be according to the overshadowing hypothesis: the advantage usually conferred to low context variability items was absent because cognitive processing during study was turned inward toward generating interitem associations. The absence of an environmental context change arose because fewer (or weaker) item-to-list context associations were acquired during learning, and they were less important during the retrieval phase because of strong

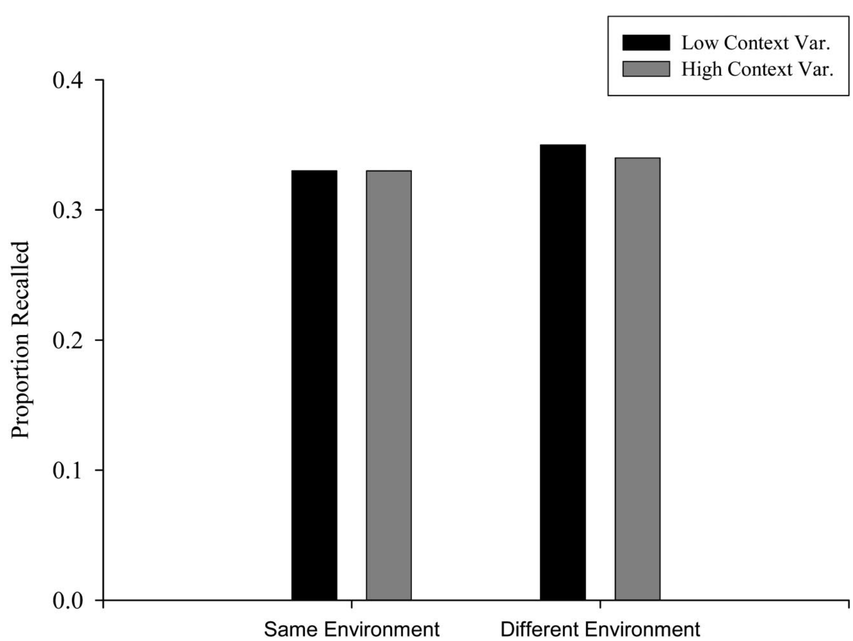


*Figure 3.* Proportion recalled as a function of context variability and environmental context change in Experiment 3.

interitem associations. We turn now to placing the results from all three experiments more broadly into the existing literature.

## General Discussion

We embarked on the experiments reported here because context information is becoming increasingly important to recent efforts to model human memory processes. As several examples of this, Howard and Kahana (1999, 2002) have proposed the temporal context model in which a candidate memory evokes retrieval of its temporal context in the study list. They have argued further that this retrieved context information can serve as a retrieval cue for other list items. Moreover, in that theory, the time-of-test context also plays a role in the ability of a rememberer to gain access to memories of the original context. In a similar vein, Dennis and Humphreys (2001) have argued that in the bind, cue, and decide model, interference to memory does not accrue from other list items as has been posited in most theories of memory heretofore, but rather, interference arises from contextual elements stored at the time of encoding and those from a concept's preexisting exposures. When evaluating a candidate memory, the retrieved contextual information is compared with a composite vector representing the entire list context. Even though this model has not been formally extended to free recall, our point is that the model is consistent with the increasing role of context information in models of memory. In an extension of the generalized context model, the item, context, and ensemble model of memory proposes that the ensemble of item and context information can be used to explain very subtle changes in memory performance (e.g., Murnane, Phelps, & Malmberg, 1999). Our goal is not to review these theories here but rather to point out to readers that context information is becoming increasingly prominent and central to many newer models of memory. Thus, understanding the conditions in which context information changes memory performance is also becoming an increasingly important endeavor.

Of course, we are not saying that older models of memory have ignored the importance of context. For example, search of associative memory (SAM) argues that the word frequency effect in free recall is due to a greater number of interitem associations for high frequency words (e.g., Gillund & Shiffrin, 1984). SAM assumes that on some number of sampling trials, memory is probed with context information only, and this is especially true in order to retrieve the first item. Consequently, that theory predicts that more low context variability items should be the first items retrieved in the same environmental conditions, whereas this will not occur as often when the environmental context is changed during testing. We analyzed the data from Experiments 1 and 2 for evidence of this prediction. In Experiment 1, of the items that came out of memory first, 58% were low context variability items in the same environmental condition, whereas 55% were low context variability items in the different room condition. Although the effect is in the correct direction, it is very far from conventional statistical significance, $\chi^2(1, N = 80) < 1.00$, *ns*. By contrast, in Experiment 2, 70% of the first recalled items were low context variability in the same environmental condition, whereas only 50% were in the different environmental condition, $\chi^2(1, N = 80) = 3.33$, $p = .06$. At best, this is mixed evidence for SAM's predictions, as well as our own theory, but the outcome does represent important evidence about context variability. Namely, low context variability items are occurring early in the output protocols for everybody tested, not just the same environmental conditions. As we argued earlier, we anticipated that changing the environmental conditions would reduce the importance of context variability, not render it entirely unimportant to the whole free recall process.

The three experiments that we reported here were intended to converge on the notion that item-to-list context associations play an important role when concepts differ in their preexperimental context variability. The first two experiments were designed to show that when the test context was changed, then access to item-to-list context associations uniquely affected low context variability items and left memory for high context variability items intact. The third experiment was designed to show that the same effect could be achieved by making item-to-list context associations relatively unavailable by an encoding manipulation that focused participants on forming interitem associations. Our second two experiments used only low concrete items, which does somewhat reduce the generality of our findings to many studies on environmental context changes. However, most memory theorists would report that such changes are unreliable, which is Smith and Vela's (2001) point to the contrary that they are robust. Another message that can be taken away from this article is that all of the previous work on environmental context changes was done without regard to Steyvers and Malmberg's (2003) unconfounding of the naturally high correlation between context variability and word frequency. Context variability was probably not considered a factor in stimulus selection in any of the 80 or so studies contained in Smith and Vela's (2001) meta-analytic review. Thus, an unlucky choice by an experimenter of selecting high context variability items (or high word frequency) would affect his or her ability to detect an environmental context change.

More generally, as context information becomes increasingly prominent in theories of memory, all researchers studying memory need to be even more mindful of how stimulus selection can affect the outcomes of their independent variables of interest. As demonstrated here, the number of preexperimental contexts in which a concept appears can affect memory performance differently depending on the parameters of either the encoding or test procedures. One may be able to use the high correlation between word frequency and context variability as a means of controlling the number of preexperimental contexts in which concepts appear, but the current experiments that held word frequency constant across item classes show the sheer folly in doing so. After all, we obtained large differences in recollection at essentially the same level of word frequency. Context variability exerts its control, in a free recall task anyway, by means of the item-to-list context associations, and those associations are not mediated by the degree of concreteness of different concepts. Given the range of episodic memory tasks affected by context variability of the stimuli to be learned (as mentioned in the introduction), researchers interested in memory should be asking themselves how context variability affects their own work, or perhaps how it already has.

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