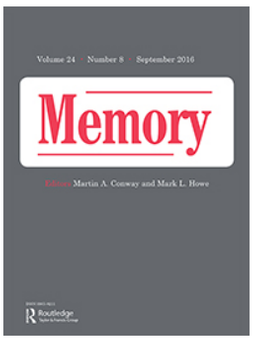

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The crutch of context-dependency: Effects of contextual support and constancy on acquisition and retention

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ABSTRACT

Paired associates (Tagalog–English word pairs) were studied and practiced with pairs superimposed over pictorial contexts, and tested with no context cues. On every retrieval practice (RP) incidental or conceptually supportive contexts were repeatedly shown with the same pair (constant context condition), or else new contexts were shown on every RP trial (varied context condition). Incidental contexts in the constant condition and supportive contexts in both constant and varied context conditions facilitated practice scores, but left learning susceptible to forgetting when context cues were not provided. In contrast, varying incidental contexts during practice resulted in slower acquisition, but greater retention in the absence of context cues. The results show that varying incidental contexts during practice can be a desirable difficulty.

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Memory is *context-dependent* if remembering suffers when encoding contexts are not provided. Studies where recall was better under context-reinstated conditions used various manipulations of environmental contexts, including underwater vs. on dry land (Godden & Baddeley, 1975), different laboratory rooms (McDaniel, Anderson, Einstein, & O'Halloran, 1988; Smith, 1979; Smith, Glenberg, & Bjork, 1978), and videos of environments (Smith, Handy, Angello, & Manzano, 2014; Smith & Manzano, 2010). Although Smith and Vela's meta-analysis (2001) showed that physical environmental manipulations have reliable effects on memory, the average effect size for such studies is modest ($d = 0.28$); in contrast, context reinstatement effect sizes for videos of environmental contexts are large ($d > 1.0$). Reviews of context-dependent memory have been done by Smith and Vela (2001) and Smith (2013). Is context-dependency a desirable outcome for learners?

Here, we consider memories accessed without contextual cues, such as material encountered in a class remembered in real-world contexts. A desired outcome of classroom learning is retention outside the classroom; there are desirable difficulties in learning, such as distributed practice, or diminishing the number of letter-cues over practice trials (Bjork, 1994; Finley, Benjamin, Hays, Bjork, & Kornell, 2011). We propose that material learned under less difficult conditions (in terms of context cues), involving meaningfully related contexts that remain constant over acquisition trials, will be forgotten more than material learned under more difficult conditions that include unrelated incidental contexts that are varied during acquisition. Our *contextual crutch* hypothesis (Smith & Handy, 2014) states that helpful context cues may benefit acquisition, but the overuse of context during practice maintains context-dependency, leading to forgetting when contextual crutches (i.e., context cues) are not provided.

The usefulness of contextual support depends upon many factors, such as the semantic or conceptual relation between contexts and material being learned. Bjork and Richardson-Klavehn (1989) distinguished between *incidental* contexts that randomly accompany material, and *influential* or *integrated* contexts that meaningfully connect to learned material. We refer to meaningfully related contexts as *supportive*.

If all experiences of an item include the same context, then memory of that item may remain context-dependent, susceptible to failure when context cues are not provided. If experiences with a repeated item include varied contexts, then memory should suffer less when context cues are not provided. Smith and Handy (2014) showed that face-name pairs were learned more slowly, but retained better (when tested without context cues) if incidental contexts had been varied on retrieval practice (RP) trials, relative to providing the same context on every trial. Varied contexts led to memories that were less susceptible to failure in the absence of contextual support.

Rather than the face-name pairs used by Smith and Handy (2014), the present experiments used Tagalog–English word pairs, semantically meaningful items that could be conceptually related to contexts (Figure 1). Therefore, we could examine effects of contextual variation for

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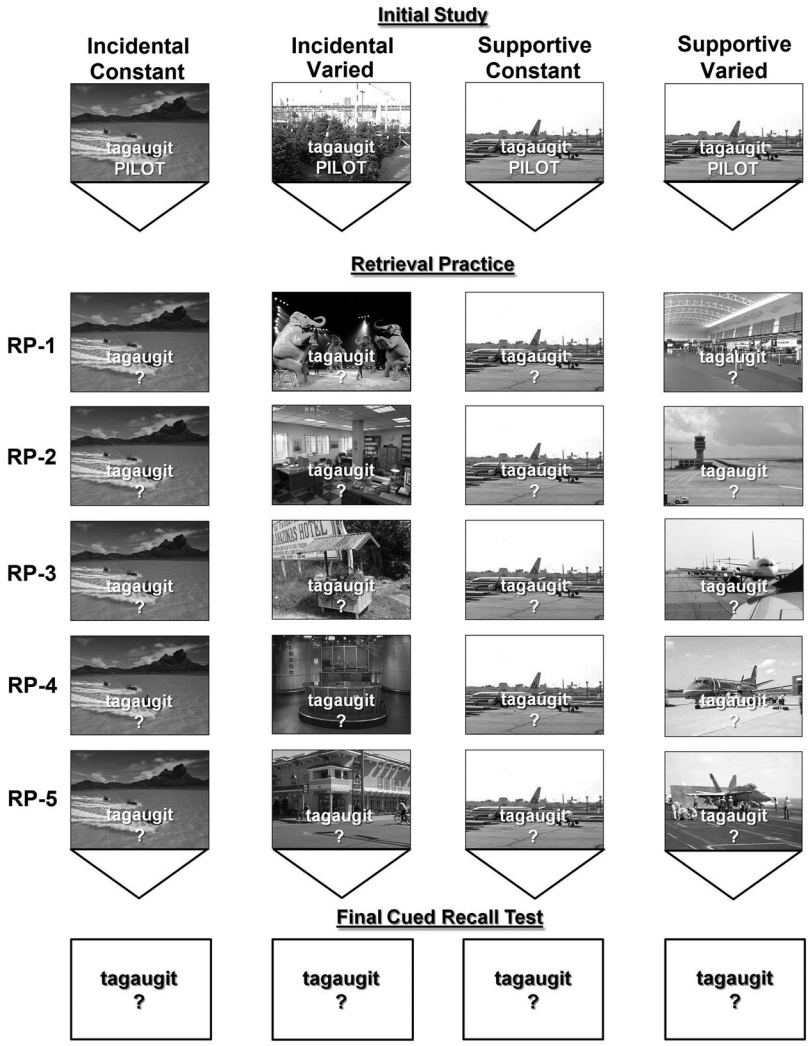

Figure 1. Example pictorial contexts for RP. Shown from the leftmost column to the right are stimuli for the constant incidental context, varied incidental, constant supportive context, and varied supportive context conditions. No contexts were presented on the final recall test.

contexts unrelated to Tagalog–English pairs and for supportive contexts. Another difference between Smith and Handy's experiments and the present one was that Tagalog–English word pairs were shown superimposed over photos of environments in the present experiment, whereas Smith and Handy (2014) used context videos, which also have motion and sound. Whether context reinstatement is as effective with photos as with multimodal videos was also in question.

Our experiment examined constant vs. variable contexts during RP, using incidental environmental contexts vs. supportive contexts. We predicted that contextual constancy would lead to better recall on practice trials, but more forgetting on a final recall test with no context cues. We also predicted that supportive contexts would aid acquisition, but lead to more context-dependent forgetting.

Finally, we examined recall on the first practice trial; for the constant context condition, this first recall was cued in its reinstated encoding context, whereas the varied condition had a new context. Therefore, we tested reinstatement effects for both incidental and supportive contexts.

Method

Participants

Participants were undergraduates fulfilling part of a course requirement. Enrollment was voluntary, with each session conducted in groups of 10–15 participants. Because participants could randomly enroll in experiment sessions, the number of participants in each condition was not equal (see Figure 3). A total of 337 volunteers participated in the experiment.

Design and materials

The experiment used a $2 \times 2 \times 5$ factorial design, with context type (incidental or supportive contexts), context

variation (constant or varied contexts), and number of RP trials (1, 2, 3, 4, or 5 RPs) manipulated between-subjects. The proportions of study items correctly recalled on RP trials and on the final cued recall test were used as dependent measures.

Twenty Tagalog words with English translations were selected from a Tagalog–English dictionary for study items. Tagalog words were pronounceable nouns that were 2–4 syllables. None were obvious English or Spanish cognates. Each Tagalog–English word pair was presented in red boldface type superimposed over photographs of environments, which served as background contexts. Two hundred pictures from Internet sources served as environmental contexts; none were famous or likely to be recognised by participants. These pictures depicted everyday locations (e.g., an office, an amusement park, and a restaurant). For the 100 incidental contexts, we avoided obvious relationships between pictures and corresponding words. The 100 supportive contexts were places where target word referents are likely to be found. For example, for the Tagalog–English word pair *TAGAUGIT-PILOT*, a picture of an airplane tarmac served as a supportive context. None of the objects referenced by target words appeared in the background contexts. For the *TAGAUGIT-PILOT* study pair, for example, a pilot never appeared in the background picture. The supportive-varied context condition contained multiple unique pictures all relating to the same word pair. Stimuli were presented using *PowerPoint*.

Procedure

Participants studied Tagalog–English pairs for a memory test. Participants were cautioned that pictures would not appear at the final test, so they should focus on Tagalog–English word pairs. For each study trial, participants saw a background image for one second before the corresponding Tagalog–English word pair appeared in the centre of the image. The Tagalog–English pair and corresponding context remained on the screen for five seconds before the next trial. This procedure was repeated for all 20 pairs.

Following study, participants were given RP packets and tested for memory of Tagalog–English pairs in a random order. For each practice trial, participants were told that the pictures might help them think of the English translation. Background pictures were either the same pictures paired with the Tagalog words during study, or new, never-before-seen pictures. Participants had five seconds to write down the English translation for each practice trial, with encouragement to guess if they were unsure. Immediate feedback was given on all RP trials in the form of the correct Tagalog–English word pair with the background context that had just appeared on the practice trial; these correct answers remained on the screen for five seconds. Participants indicated on their response form during this feedback period if they had not written the correct English translation. This test-feedback procedure continued until all 20 pairs were tested, thus comprising one block of RP trials. Participants had up to five blocks of RP, depending on their random assignment to treatment conditions.

Final cued recall test forms were passed out, which took approximately one minute. For the final test, participants wrote English translations for Tagalog words. Tagalog words appeared five seconds each in red boldfaced type over a white background in a random order.

Results

Context-dependent recall

On the first RP trial, the constant context condition reinstated the original study context, whereas the varied context condition tested memory with a context changed from the original one. Therefore, to assess the effectiveness of our context cues in terms of a context reinstatement effect, we computed a 2×2 analysis of variance (ANOVA) with context type (incidental or supportive contexts) and context variation (constant or varied) as between-subjects variables, collapsing across all five number-of-retrieval-practice groups, using *performance on the first RP trial* as the dependent measure. There was a significant effect of context variation, F (1, 331) = 35.18, $p < .001$, $d = 0.65$, 95% CI[1] [0.43, 0.87]; overall, those in the context-reinstated condition (i.e., constant context condition) recalled 61% of the English words paired with Tagalog cues, as compared with 50% recall in the varied context condition, a mean difference of 11% (Figure 2).

The context type × context variation interaction did not reach significance, F (1, 331) = 3.01, $p = .084$, although, numerically, the mean difference between reinstated and changed context conditions was greater for incidental contexts, relative to supportive contexts. For participants in the incidental context condition, those in the context-reinstated condition (constant context) recalled 45% of the English words paired with Tagalog cues, as compared with 31% recall in the varied context condition, a mean difference of 14%, and with supportive contexts, participants in the context-reinstated condition recalled 78% of the English words paired with Tagalog cues, as compared with 70% recall in the varied context condition, a mean difference of 8%. The simple effect of context reinstatement was significant for both the incidental (t (169) = 5.36, $p < .001$, $d = 0.82$, 95% CI [0.51, 1.13]) and supportive context conditions (t (162) = 3.01, $p < .003$, $d = 0.47$, 95% CI [0.16, 0.78]).

There was also a main effect of context type, F (1, 331) = 358.30, $p < .001$, $d = 2.06$, 95% CI [1.80, 2.33]; recall was considerably better (nearly double) for supportive contexts

[1]The 95% confidence intervals for Cohen's d are reported.

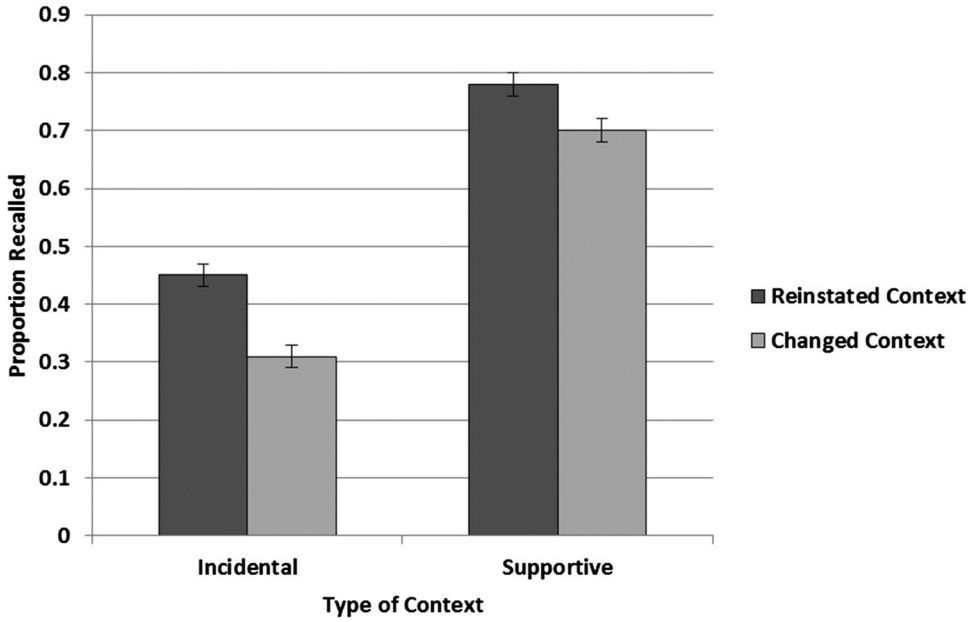

Figure 2. Mean proportion correct on the first RP trial for incidental and supportive contexts as a function of context reinstatement and context change.

($M = 0.74$, SD = 0.17), relative to unrelated incidental contexts ($M = 0.38$, SD = 0.19) on the first RP trial.

Acquisition

To examine the effects of context manipulations on acquisition we computed five analyses, one for each level of number of RP trials. For the 1-RP condition, the effects of context type (incidental or supportive contexts, a between-subjects variable) and context variation (constant or varied contexts, a between-subjects variable) on RP performance were analysed with 2 × 2 ANOVA. For each of the other four RP conditions (2-RP, 3-RP, 4-RP, and 5-RP), we computed ANOVAs that analysed context type (incidental or supportive contexts, a between-subjects variable), context variation (constant or varied, a between-subjects variable), and practice trial number (a repeated measure) on RP performance. The effect of context type was significant for all five ANOVAs. Supportive contexts produced better acquisition performance than did incidental contexts for the 1-RP condition, F (1, 56) = 103.82, $p < .001$, d = 2.71, 95% CI [2.01, 3.41], the 2-RP condition, F (1, 66) = 120.18, $p < .001$, $d = 3.00$, 95% CI [2.32, 3.68], the 3-RP condition, F (1, 67) = 67.94, $p < .001$, $d = 1.90$, 95% CI [1.34, 2.46], the 4-RP condition, F (1, 64) = 110.26, $p < .001$, d = 2.52, 95% CI [1.89, 3.16], and the 5-RP condition, F (1, 63) = 38.71, $p < .001$, $d = 1.31$, 95% CI [0.79, 1.84].

The effect of context variation was significant for all five levels of number of RP trials; in every case, recall was better in the constant context condition than in the varied context condition (Figure 3). The effect was significant for the 1-RP condition, F (1, 56) = 6.18, $p = .016$, $d = 0.68$, 95% CI [0.16, 1.20], the 2-RP condition, F (1, 66) = 28.20, $p < .001$, $d = 1.45$, 95% CI [0.92, 1.98], the 3-RP condition, F (1, 67) = 24.02, $p < .001$, $d = 1.15$, 95% CI [0.65, 1.66], the 4-RP condition, F (1, 64) = 12.34, $p = .001$, $d = 0.87$, 95% CI [0.37, 1.37], and the 5-RP condition, F (1, 63) = 15.88, $p < .001$, $d = 0.88$, 95% CI [0.37, 1.38].

The interaction of context type with context variation was significant for the 2-RP, F (1, 66) = 10.18, $p = .002$, 3-RP, F (1, 67) = 22.98, $p < .001$, and 5-RP conditions, F (1, 63) = 5.87, $p = .018$, and the interaction was of marginal significance in the 4-RP condition, F (1, 64) = 3.25, p = .076. In each of these cases, constant contexts (relative to varied contexts) led to more improved performance during acquisition for incidental contexts than for supportive contexts (Figure 3). These interactions clearly were due to the fact that maximal performance after only one or two trials was seen for the supportive context conditions, leaving no room for measureable improvement due to constant context RP. The context type × context variation interaction was not significant for the 1-RP condition, F (1, 56) < 1.0, in which performance was not at ceiling.

The effect of RP trial number on practice scores was significant for the 2-RP condition, F (1, 66) = 305.32, $p < .001$, $d = 2.95$, 95% CI [2.48, 3.43], the 3-RP condition, F (2, 134) = 208.58, $p < .001$, $d = 2.42$, 95% CI [1.99, 2.86], the 4-RP condition, F (3, 192) = 263.35, $p = .001$, $d = 2.78$, 95% CI [2.31, 3.26], and the 5-RP condition, F (4, 252) = 197.64, $p < .001$, $d = 2.36$, 95% CI [1.93, 2.79]; more practice produced better practice scores. The interaction of RP trial number × context type on practice scores was significant for the 3-RP, F (2, 134) = 16.60, $p < .001$, the 4-RP, F (3, 192) = 45.24, $p < .001$, and 5-RP conditions, F (4, 252) = 19.93, $p < .001$; ceiling effects on practice scores occurred in the supportive context conditions, but not the incidental context conditions. The interaction of RP trial

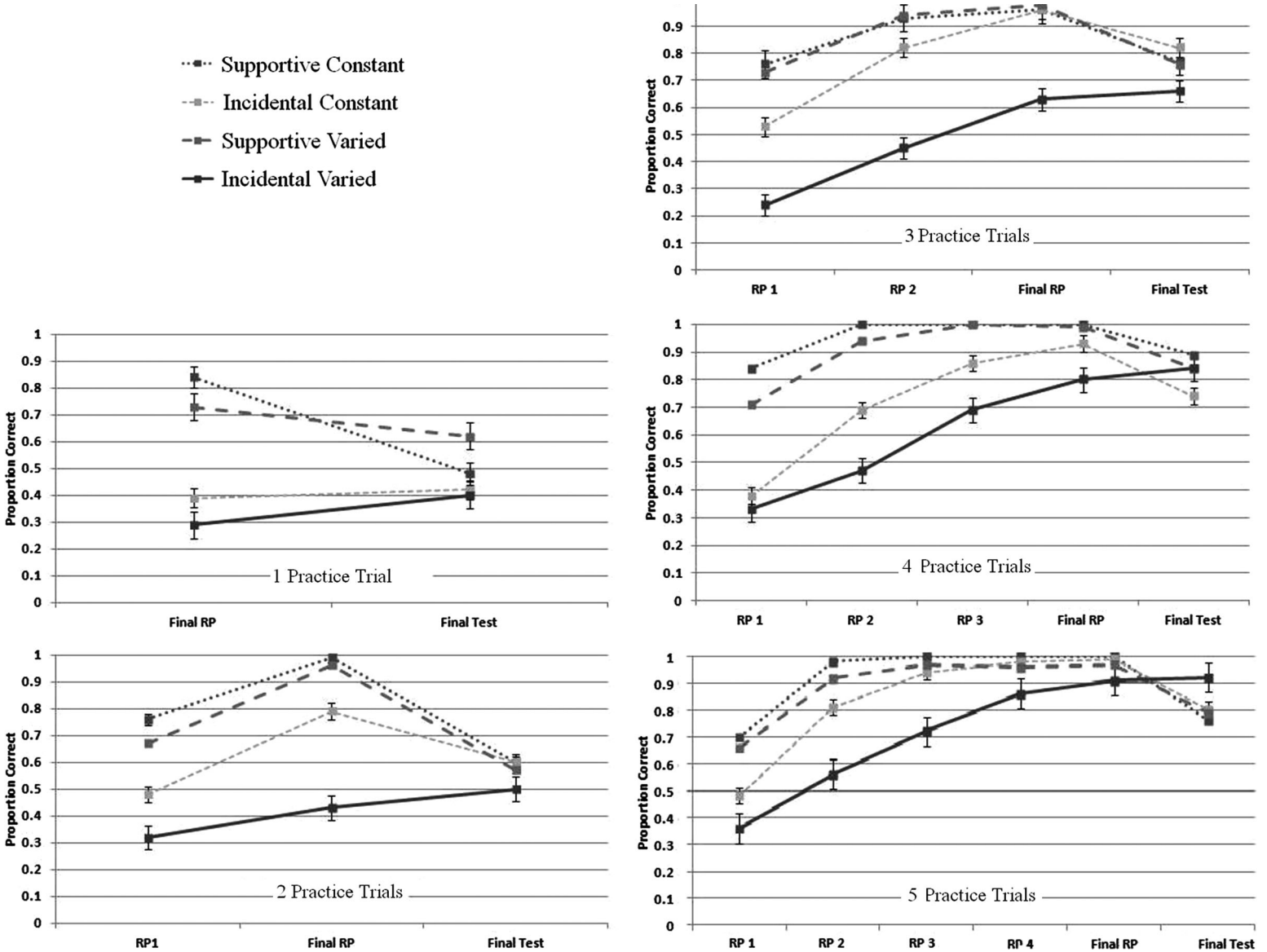

Figure 3. Mean proportion correct for RP trials and final recall with incidental and supportive contexts as a function of context variation and number of RP trials. The numbers of participants in the unrelated-constant condition were as follows: 1-RP (17 participants), 2-RP (18 participants), 3-RP (16 participants), 4-RP (18 participants), and 5-RP (20 participants). The numbers of participants in the unrelated-varied condition were as follows: 1-RP (16 participants), 2-RP (17 participants), 3-RP (18 participants), 4-RP (17 participants), and 5-RP (15 participants). The numbers of participants in the supportive-constant condition were as follows: 1-RP (15 participants), 2-RP (20 participants), 3-RP (18 participants), 4-RP (17 participants), and 5-RP (16 participants). The numbers of participants in the supportive-varied condition were as follows: 1-RP (12 participants), 2-RP (15 participants), 3-RP (19 participants), 4-RP (16 participants), and 5-RP (20 participants).

number × context variation on practice scores was significant for the 2-RP, F (1, 66) = 6.80, p = .011, and 5-RP conditions, F (4, 252) = 2.80, p = .027. Finally, the three-way interaction of RP trial number × context type × context variation on practice scores was significant for the 2-RP, F (1, 66) = 23.15, p < .001, and the 4-RP conditions, F (3, 192) = 8.33, p < .001.

Retention and forgetting

A 2 (context type: supportive or incidental, a between-subjects variable) × 2 (context variation: constant or varied, a between-subjects variable) × 5 (number of RP trials: 1, 2, 3, 4, or 5, a between-subjects variable) ANOVA was computed using recall performance on the final (context-free) retention test as the dependent measure. There was a main effect of the number of RP trials, F (4, 315) = 29.24, p < .001, d = 1.11, 95% CI [0.82, 1.40]; performance on the retention test was better following more practice trials. No other main effects or interactions were significant.

A 2 (context type: supportive or incidental, a between-subjects variable) × 2 (context variation: constant or varied, a between-subjects variable) × 5 (number of RP trials: 1, 2, 3, 4, or 5, a between-subjects variable) ANOVA was computed using *forgetting*, defined as performance on the final practice trial minus performance on the final retention test, as the dependent measure (Figure 4). There was a main effect of context type, F (1, 315) = 109.65, p < .001, d = 0.99, 95% CI [0.77, 1.23]; forgetting was greater if supportive contexts were given during acquisition, relative to incidental contexts. There was also a main effect of context variation, F (1, 315) = 51.03, p < .001, d = 0.63, 95% CI [0.41, 0.85]; forgetting was less if contexts were varied during acquisition, relative to constant, unchanging contexts. Finally, there was a main effect of the number of RP trials, F (4, 315) = 6.45, p < .001, d = 0.52, 95% CI [0.23, 0.80]; forgetting varied among the five levels of number of practice trials. Because the interaction of context type × context variation × number of practice trials was significant, F (4, 315) = 2.78, p = .027, we computed five additional analyses of forgetting effects, one for each level of practice.

The effect of context type on forgetting was significant or marginally significant for the 1-RP condition, F (1, 56) = 61.12, p < .001, d = 1.81, 95% CI [1.21, 2.41], the 2-RP condition, F (1, 65) = 60.58, p < .001, d = 1.59, 95% CI [1.05, 2.14], the 3-RP condition, F (1, 67) = 12.83, p = .001, d = 0.85, 95% CI [0.36, 1.34], the 4-RP condition, F (1, 64) = 3.88, p = .053, d = 0.43, 95% CI [−0.05, 0.91], and the 5-RP condition, F (1, 63) = 5.45, p = .023, d = 0.46, 95% CI [−0.02, 0.95]. In each case, forgetting was greater for supportive contexts than for incidental contexts.

The effect of context variation on forgetting was significant or marginally significant for the 1-RP condition, F (1, 56) = 24.00, p < .001, d = 0.91, 95% CI [0.37, 1.45], the 2-RP condition, F (1, 65) = 13.63, p < .001, d = 0.74, 95% CI [0.25, 1.23], the 3-RP condition, F (1, 67) = 3.94, p = .051, d = 0.39, 95% CI [0.08, 0.86], the 4-RP condition, F (1, 64) = 8.72, p = .004, d = 0.67, 95% CI [0.18, 1.15], and the 5-RP condition, F (1, 63) = 7.10, p = .01, d = 0.60, 95% CI [0.11, 1.09]. In each case, forgetting was greater for constant contexts than for varied contexts.

The interaction of context type × context variation on forgetting was not significant for the 1-RP condition, F (1,56) < 1.0, or the 5-RP condition, F (1, 63) = 2.07, p = .155, but it was significant for the 2-RP condition, F (1, 65) = 12.46, p = .001, the 3-RP condition, F (1, 67) = 6.14, p = .016, and the 4-RP condition, F (1, 64) = 16.18, p < .001. In the significant interactions, forgetting was greater for constant contexts than for varied contexts in the incidental contexts condition, but not for supportive contexts.

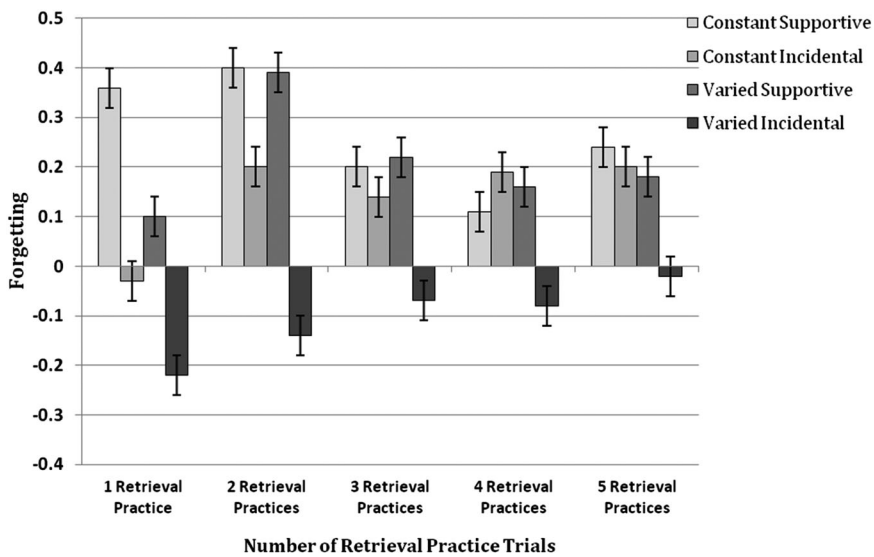

Figure 4. Mean forgetting (recall performance on the final RP trial minus recall performance on the final retention test) with incidental and supportive contexts as a function of context variation and number of RP trials.

Discussion

Contextual aids, including contexts constantly present during practice, and contexts meaningfully supportive of learned material, facilitated recall during acquisition, but left material susceptible to forgetting when context cues were not provided. Practicing retrieval in a constant, unchanging context, as compared with practice in varied contexts, produced better recall on practice trials. Considerable context-dependent forgetting, however, was found on a final context-free test of retention if RP trials had been conducted with constant contexts, supportive contexts, or both. These results show that withholding contextual support (i.e., varying practice contexts and using contexts unrelated to learning material) during practice is a desirable difficulty that leads to better retention.

Decreased forgetting was found for the varied incidental context condition, relative to constant contexts. Little (if any) forgetting occurred from the last practice trial to the final recall test for the varied incidental context condition.[2] The constant incidental context condition, however, showed sizeable forgetting effects, on the average, a 14% drop from the context-assisted final practice trial to the context-free final test. Constant supportive contexts yielded better acquisition scores than varied supportive contexts, but both conditions showed considerable forgetting at every level of RP. These forgetting effects occurred in all conditions (except the varied incidental context condition) in spite of explicit instructions that the final test would occur without context cues.

On the first practice trial recall in the constant context condition significantly exceeded that of the varied context condition, indicating a robust context reinstatement effect. The effect size of reinstatement was somewhat smaller in the present study, relative to effects found with video contexts (Smith & Manzano, 2010), suggesting that richer contexts, such as those that include sound and motion, may evoke greater context-dependency than we found with still photos of contexts. The context reinstatement effect was marginally greater for incidental contexts than for supportive contexts. With incidental contexts the mean difference between reinstated and changed context conditions was 14%, as compared with an 8% difference with supportive contexts, and the reinstatement effect size for incidental contexts was $d = 0.82$ (a large effect according to Cohen, 1988, 1992), as compared with $d = 0.42$ (a moderate effect) when supportive contexts were used. It would be misleading, however, to attribute this trend to differences between incidental and supportive contexts, because the test context in the varied/supportive context condition was *conceptually similar* to the encoding context. Smith, Handy, Angello, and Manzano (2014) showed that contexts *similar* to encoding contexts cue recall better than new contexts, but not as well as original encoding contexts. The weaker reinstatement effect with supportive contexts could also explain why the effect of varied supportive contexts was weaker than the effect of varying incidental contexts, because the varied supportive contexts were all conceptually similar to each other.

In the constant incidental context condition, context-dependent forgetting was negligible for the 1-RP condition,[2] but was greater in the other four conditions. This result was consistent with findings by Isarida (2005), who found greater reinstatement effects when study time in a context was increased. This suggests that more practice in a constant context may increase contextualisation. With supportive contexts, however, contextualisation in the constant context condition was evident from the start, and did not increase with increasing practice trials. Overall, evidence from our experiment was not conclusive in terms of showing that additional practice in a constant context makes that material more susceptible to context-dependent forgetting.

It is interesting to note that although the benefits of varied incidental contexts were evident in (smaller) forgetting scores, benefits were not seen in final recall following one, two, three, or four RP trials. After five practice trials, however, final recall in the varied incidental context condition (i.e., the contextually unsupported practice condition) exceeded that of all three contextually helpful conditions (i.e., the contextually constant and supportive conditions), consistent with Smith and Handy's (2014) findings. A *t*-test comparing final recall of the incidental-varied (i.e., no contextual support) condition with the other three treatment conditions (all three of the contextually supported conditions combined) of the RP-5 group found a significant difference, $t\ (65) = 2.14$, $p = .036$. Thus, the disadvantage of losing contextual crutches may be seen in absolute retention only for high levels of learning.

It is also interesting to note that in some treatment conditions, items that had been recalled perfectly—in some cases, for four consecutive practice trials—nonetheless, showed substantial forgetting when context cues were withheld. Continued reliance on supportive and constant contexts during RP undermined the strengthening of Tagalog–English word associations. The ceiling effect in acquisition with supportive contexts also may have led participants to think they had finished their learning, which may have led to deficit processing or inattention on subsequent practice trials. However, the forgetting effects for supportive context conditions, and the absence of forgetting for varied incidental context conditions, could be seen after one and two practice trials, before performance had reached a ceiling for supportive context conditions, showing that the interaction occurred even before participants might have concluded that their learning was

[2]Feedback (the correct English response) was given at the end of each retrieval practice trial. Therefore, our measure of forgetting is diminished by any learning that occurred after measuring the last retrieval practice, during the feedback presentation.

complete. Thus, the hazards of contextual crutches may remain hidden until those crutches are taken away.

Disclosure statement

No potential conflict of interest was reported by the authors.

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