When is literal meaning inhibited? Evidence from nonsense in the metaphor-induced lexical forgetting paradigm

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Conflict of Interest Statement

There are no conflicts of interest to declare.

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Abstract

A common feature of metaphoric language processing is a conflict between literal and figurative aspects of meaning. A consequence of this is the need to select the most appropriate meaning amongst competing associates when we encounter such phrases. The goal of the present experiments was to adapt the "impossible" retrieval approach of previous retrieval-induced and problem-solving-induced forgetting (RIF; PSIF) studies in order to test for the use of inhibitory mechanisms during metaphor comprehension. To achieve this goal, a series of three studies assessed forgetting following the processing of *nonsense* metaphors which were unlikely to lead to viable interpretations within a short period of time (*Jealousy is a barn).* In the first two experiments, processing nonsense metaphors led to reduced recall for previously studied literal associates. In a third study, processing nonsense metaphors led to longer recognition latencies for literal associates on a cue-independent task. In contrast, no evidence of forgetting was seen due to the processing of familiar metaphors in any study. Because participants are unlikely to reach a viable interpretation of these nonsense metaphors, and because results were similar using recall and cue-independent recognition measures, these results provide novel support for an inhibitory account for this forgetting effect over a blocking or cue-based interference account.

Keywords: metaphor, retrieval-induced forgetting, inhibition, figurative language processing

When is literal meaning inhibited? Evidence from nonsense in the metaphor-induced lexical forgetting paradigm

Language is often used to extend the meanings of words and phrases in creative ways beyond what is typical or conventional. For example, in the nominal metaphor *discipline is fertilizer,* the meaning underlying this phrase differs from what is literally expressed. Because metaphors can convey a rich set of meanings in an interesting and relatively brief manner, the use of metaphors is pervasive (Lakoff & Johnson, 1980). Further, despite the apparent semantic anomaly that they present, they can sometimes be understood quite directly, such as in very familiar metaphors (Glucksberg, Gildea, & Bookin, 1982). Indeed, sometimes a word's metaphorical meaning is as strong as or stronger than the literal meaning, as expressions become more familiar or conventional with repeated usage (Bowdle & Gentner, 2005; Giora, 1997). However, other times the appropriate meaning may not be initially obvious, and some additional effort may be required in order to override activation of irrelevant literal senses and arrive at an understanding of how the metaphor vehicle (i.e., *fertilizer*) relates to the topic (i.e., *discipline*). It is at precisely these times when literal meanings may need to be inhibited.

There are a number of sources of evidence that motivate this hypothesis. For instance, overcoming competing literal meanings when a figurative meaning is required seems to require cognitive resources. Research has found a relationship between measures of executive function and metaphor comprehension (Carriedo et al., 2016; Chiappe & Chiappe, 2007; Columbus et al., 2015). One way in which the use of executive control may facilitate metaphor processing is through inhibitory processing that helps filter out inappropriate associates of the metaphor vehicle, just as with resolving lexical ambiguity (Gunter, Wagner, & Friederici, 2003).

Similarly, it has been found that novel metaphors tend to be associated with a greater processing cost than more familiar or conventional metaphors (Blasko & Briihl, 1997; Blakso & Connine, 1993; Bowdle & Gentner, 2005; Columbus et al., 2015; Gentner & Wolff, 1997; Jones & Estes, 2005; Lai & Curran, 2013; Lai, Curran, & Menn, 2009), and that frontal brain regions associated with more effortful semantic processing are recruited in novel metaphor processing (Mashal, Faust, Hendler, & Jung-Beeman, 2007; Rutter et al., 2012a), and novel idiom processing (Häuser, Titone, & Baum, 2016).

Part of this cost may be due to competition arising from activation of irrelevant literal information. McGlone and Manfredi (2001) found that priming people with irrelevant literal-related properties of metaphors impaired their subsequent comprehension. Blakso and Connine's (1993) series of lexical decision experiments demonstrated facilitation of literal-related target words following novel metaphors, but no facilitation of metaphor-related words, suggesting that these metaphors failed to initially activate a figurative meaning and instead activated a literal meaning. Studies using ERP methods have also documented that sentences ending with novel metaphors, compared to familiar metaphors, elicit a more temporally-extended N400 effect (Lai et al., 2009), and larger N400 amplitudes (Arzouan, Goldstein, & Faust, 2007). The N400 partly indexes difficulties associated with semantic access (Kutas & Federmeier, 2011), and such effects likely indicate a conflict between the word's typical literal meaning and the metaphorical context in which it appears. More recently Weiland, Bambini, and Schumacher (2014) presented people with a masked prime word related to a metaphor's literal meaning just prior to viewing the metaphor vehicle of the sentence. Compared to an unprimed condition, this literal prime reduced the N400 elicited by the vehicle and also produced a more delayed late positive component, perhaps suggesting that the literal prime facilitated initial access to the literal meaning of the vehicle word itself which then interfered with processing the overall meaning of the metaphor.

Taken together, it appears that a common feature of processing novel metaphors is a conflict between literal and figurative aspects of meaning, and a consequence of this is the need to select the most appropriate meaning amongst competing associates. Several previous studies have found results consistent with metaphor comprehension requiring the inhibition of literal meanings, but each study has limitations that prevent it from providing evidence consistent *only* with an inhibitory account (George & Wiley, 2016; Gernsbacher, Keysar, Robertson, & Werner, 2001; Glucksberg, Newsome, & Goldvarg, 2001). For instance in the Gernsbacher et al. and Glucksberg et al. experiments, participants read and judged prime sentences that used a word in either a metaphorical or literal sense (e.g., *The lawyer for the defense is a shark / That large hammerhead is a shark*), and then judged the validity of target sentences that were relevant or irrelevant to the metaphoric meaning (e.g., *Sharks are tenacious / Sharks are good swimmers*). Reaction times to metaphor-irrelevant sentences were slowed following metaphor primes compared to literal primes. These results were argued to demonstrate that irrelevant literal-level properties were inhibited during metaphor processing. However, an alternative possibility is that the slow-down in reaction time may have been the result of a post-comprehension incompatibility between the literal target sentence and the preceding metaphorical prime, rather than the result of inhibition or suppression (Potts, Keenan, & Golding, 1988; Tipper, 2001; Wiley, Mason, & Myers, 2001).

To provide an alternative to these priming studies, George and Wiley (2016) recently adapted a forgetting paradigm (based in prior work on retrieval-induced forgetting, RIF, Anderson, Bjork, & Bjork, 1994; and problem-solving-induced-forgetting, PSIF, Storm &

Koppel, 2012) to metaphor processing. In their experiments, participants initially learned cue-response pairs (e.g., *fertilizer-odor*) where the cue word was paired with an associate that was relevant to its literal meaning, and irrelevant for the metaphoric meaning. Half of these cue words then appeared as the vehicle in metaphor sentences (e.g., *Discipline is fertilizer*). Half of the metaphors were familiar and half were novel. Finally, recall of all of the cue-response pairs was assessed. Across three experiments, participants demonstrated reduced recall of associates for cue words that had appeared in metaphors compared to cue words that had not appeared in metaphors. In the first two experiments this forgetting effect was observed when people explicitly interpreted the metaphors, and it occurred for both familiar and novel metaphors. A third experiment required only reading of the metaphors (without typing in an interpretation). In this third experiment, forgetting was observed *only* for novel metaphors, and *not* for familiar metaphors. The fact that forgetting was seen only when comprehending novel metaphors was interpreted as being due to the need for greater inhibition of competing literal meanings when figurative meanings are less salient. In contrast, for familiar metaphors, which have a salient figurative meaning stored in memory, less competition is experienced when comprehending these statements and inhibition may be less necessary. Thus, these results suggested that literal meanings may need to be inhibited specifically during the resolution of novel or unfamiliar metaphoric expressions.

Although these “forgetting” results are consistent with an inhibitory account, the George and Wiley (2016) studies cannot rule out other potential alternate explanations that are frequently given for RIF. A compelling range of evidence exists supporting inhibitory accounts (Anderson, 2003; Chan, Erdman, & Davis, 2015; Murayama, Miyatsu, Buchli, & Storm, 2014; Storm & Levy, 2012). However, certainly not all RIF effects are due to inhibition, and alternative explanations for forgetting include blocking and interference accounts (Jonker, Seli, & MacLeod, 2013; MacLeod, 2007; Raaijmakers & Jakab, 2013a; 2013b). There are several kinds of "blocking" accounts that may provide plausible alternative explanations for the forgetting effects seen in George and Wiley (2016). Because the novel metaphors could be resolved, it is possible that resolving the novel metaphors strengthened the association between the vehicle and newly-learned topic term (*fertilizer – discipline*) more than resolving the familiar metaphors. Such a differential change in association strength may have "blocked" access to the previously learned associates for novel metaphors more than for familiar metaphors. Or, the sense of the word that was relevant for the generated resolution could have blocked access to the initial associate. To help to isolate the effects of inhibitory processing on forgetting, other studies in the RIF (and PSIF) literatures have eliminated blocking as a plausible explanation by creating a context in which retrieval or resolution is *impossible*.

Generally, RIF is the finding that retrieval of target information in memory causes temporary forgetting of other related information. In the prototypical version of RIF experiments, participants initially learn category-exemplar pairs such as *FRUIT-banana, FRUIT-lemon, TOOLS-hammer, TOOLS-axe*, before selectively retrieving half of the items from half of the categories (e.g., *FRUIT - b*____). These items that receive retrieval practice are conventionally referred to as *Rp+* items. In contrast, unpracticed items from practiced categories (e.g. *FRUIT-lemon*) are referred to as *Rp- items,* and items from unpracticed categories are referred to as *Nrp*. On a final test of recall of all items, recall of *Rp-* items is impaired relative to *Nrp* items. This direct test between *Rp-* to *Nrp* recall rates is the key comparison that has been used to demonstrate the RIF effect. To adapt this into a task that precludes successful retrieval, retrieval success is made to be impossible during the retrieval practice phase by presenting participants with category-plus-stem cues that cannot be completed using the exemplars they were shown (e.g., *WEAPONS – wo*____). Yet, even though no retrieval success is possible (i.e. there are no *Rp+* items), memory for the *Rp-* items is still impaired compared to *Nrp*. This suggests that subsequent forgetting results from the *attempt* to selectively retrieve (Storm, Bjork, Bjork, & Nestojko, 2006; Storm & Nestojko, 2010), and not from a generated response that blocks access to the original associate.

A similar effect has been observed for PSIF using a Remote Associates Task (RAT), a creative problem solving task which involves finding a fourth word that makes a meaningful phrase with each of the three problem words (e.g., *playing, credit, report;* ANSWER: *card*). In the PSIF version of this task, participants initially learn word-associate pairs for each of the RAT problem words (e.g., *playing*–fun*; credit*–union*; report*-paper; Storm, Angello, & Bjork, 2011; Storm & Koppel, 2012). These associates were "misleading" because none offered the solution to the problem. Then, instead of retrieval practice, participants engaged in solution attempts for half the problems. These attempts led to forgetting of previously-studied misleading associates only for the problems that were attempted. To create an *impossible* version of this PSIF task, RAT problems were made to be impossible to solve by listing three words that did not have a fourth common associate (e.g., *globe, narrow, purse*) (Storm et al., 2011). In this context, the attempt to find a common associate represents an impossible *Rp+* item, while the originally studied misleading associates represent *Rp-* items. Associates of problems that were not attempted serve as the *Nrp* items. Even though no solution could be found, participants nonetheless showed forgetting of misleading associates of these impossible problems following their attempts to solve them (Storm et al., 2011). That is, the key comparison revealed that *Rp-* associates were recalled less well than the *Nrp* associates. Because these findings indicate that successful retrieval or successful problem solving is not necessary for forgetting to occur, this more strongly places the locus of the forgetting effect within attempts to retrieve or solve, removes the possibility that forgetting is due to blocking from a generated response, and suggests that inhibitory processing is utilized during such attempts to help overcome competition.

Thus, one main goal of the present experiments was to adapt the *impossible* retrieval approach of previous RIF and PSIF studies in order to provide a critical test for inhibitory mechanisms during novel metaphor comprehension that could rule out alternative explanations for forgetting that were possible in earlier studies. Closely following the *impossible* PSIF design, the current study involved initially presenting misleading (literal) associates of target words, manipulating whether participants were exposed to metaphors using those target words, and testing for forgetting using key comparisons between associates of words that appeared in metaphors versus those that did not. If irrelevant associates of a metaphor vehicle compete for access during comprehension attempts, and inhibition of such associates is utilized to reduce this competition, then metaphor-induced lexical forgetting should be observed even when a metaphor has no clear resolution. To achieve this goal, these studies used nonsense metaphors such as *Jealousy is a barn*, which were unlikely to lead to viable interpretations within a short period of time. Much like novel metaphors, these nonsense metaphors were unfamiliar pairings that presented an anomaly. However, unlike novel metaphors these statements were not readily interpretable. If forgetting of literal associates (e.g., *BARN – hay*) were to occur after processing these nonsense-metaphoric statements, then post-comprehension interference at final recall would not be a plausible explanation of forgetting because resolution is unlikely to have occurred. Instead, this would place the locus of the forgetting effect within attempts to resolve the metaphor’s meaning, and suggest that inhibitory processing is utilized during such attempts to help overcome competition. As people attempt to align the topic and vehicle to determine the meaning of a nonsense metaphor, some activation of the previously-learned associate of the vehicle is likely to occur, which will not offer a useful resolution. If inhibitory mechanisms are used to reduce competition from these associates, forgetting will occur after processing these nonsense metaphors and the memory for the misleading associates of words used in metaphors will be lower than memory for associates of words that did not appear in metaphors. On the other hand, no forgetting is expected to result from the processing of familiar metaphors because no competition is expected. When the metaphoric meaning is salient in memory, there is less competition from literal meaning, no need for inhibition, and therefore no differences should be seen in memory for associates as a function of whether familiar metaphors were read. In other words, for familiar metaphors (*the lawyer for the defense is a shark*), no differences are expected in recall of literal associates (*SHARK* - *swim*).

In addition, to rule out a cue-based interference account, another goal was to the for forgetting using a cue-independent recognition task (Aslan & Bäuml, 2011; Rupprecht & Bäuml, 2016; Veling & van Knippenberg, 2004, Verde & Perfect, 2011). When recall tasks employ a cue to evoke memories of response words, then forgetting effects may be explained by cue-based interference. In contrast, when recognition tests directly re-present response words to participants for a decision without presenting the cue, this helps to eliminate cue-dependent interference as a possible explanation and instead suggests that inhibition acts directly on the response word representation (Storm & Levy, 2012). Using a cue-independent recognition task, evidence for inhibitory processing is garnered when participants are slower to recognize *Rp*- items than *Nrp* items (Veling & van Knippenberg, 2004; Verde & Perfect, 2011).

This paper reports three experiments in which nonsense metaphors were used to test for the role of inhibitory processes in novel metaphor comprehension. The first two experiments used cued-recall measures to test for forgetting of literal associates due to novel metaphor processing, whereas the third experiment employed a cue-independent recognition measure. The critical comparison for all three studies was testing for differences in forgetting for the studied associates between the metaphor-processing and no-metaphor-processing conditions.

Experiment 1

In the first experiment, participants were presented with metaphors after first studying literal associates of the metaphor vehicles. This experiment included familiar and novel metaphors, as well as nonsense metaphors. (For simplicity, we also refer to associates of nonsense metaphor vehicle words as "literal"). If subsequent forgetting of literal associates is a result of inhibitory mechanisms used during comprehension attempts, then it is expected that forgetting should be observed for novel and nonsense metaphors where the need to overcome irrelevant literal meaning is greatest. For familiar metaphors, no significant forgetting is predicted because the metaphoric meaning should be highly salient, and should involve little competition from literal information during comprehension.

Methods

Participants. Participants consisted of 76 undergraduates from the University of Illinois at Chicago psychology subject pool. All participants were fluent in English and provided agreement to participate.

Materials.

Sentences. The 20 familiar and 20 novel metaphoric sentences from George and Wiley (2016) were used, along with 20 new nonsense metaphors created for this purpose of this experiment. The vehicle words for the nonsense metaphor sentences were chosen such that they were unlikely to refer to a previously existing metaphoric category, or share a salient feature with the topic. In *That boy's indecision is a rooster*, it is difficult to identify points of overlap between *indecision* and *rooster*.

To norm these materials, the set of 20 nonsense metaphors (included in the Appendix) was presented along with the 40 meaningful metaphors (20 familiar; 20 novel) to an independent sample of participants ($N = 15$) to test whether the three kinds of metaphors differed as intended with the familiar, novel and nonsense metaphors representing a continuum of resolution difficulty. Each metaphor was presented to participants for interpretation and participants were allowed up to 5 s to think of an interpretation, which they indicated via button press, after which they typed their interpretation. The computer recorded the button press time. If participants failed to think of an interpretation within the 5 s deadline, they advanced to the next sentence. If participants did think of an interpretation, they were also asked to judge the quality of their interpretation on a 1 – 5 scale (1 = *not good at all*, 5 = *very good*). Additionally, interpretations were coded by two independent coders for a) whether the participant typed any response (number of complete responses), and b) whether they meaningfully related the two concepts to each other (number of viable responses). For example, for the nonsense metaphor *That science museum is a muffin* the response "it has lots of displays" was not considered a viable response because displays are not relevant for muffins. Reliability between the two coders was high (Krippendorf's Alpha > .85).

As seen in Table 1, the norming study showed that the three metaphor types differed as intended. The number of complete responses decreased from familiar to novel to nonsense, $F(2, 28) = 66.07$, $p < .01$, $\eta_p^2 = .83$, the number of viable responses decreased, $F(2, 28) = 146.60$, $p <$

.01, $\eta_p^2 = .91$, and judgments of interpretation quality decreased, $F(2, 24) = 127.00$, $p < .01$, $\eta_p^2 = .90$. All of these contrasts were significant ($p < .01$). There was also an effect on mean interpretation time, $F(2, 24) = 5.48$, $p < .05$, $\eta_p^2 = .31$, such that familiar metaphors were interpreted faster than both novel metaphors ($p < .01$) and nonsense metaphors ($p < .05$). Interpretation times for novel and nonsense metaphors did not differ. This lack of a difference is likely an artifact of many participants failing to generate any interpretation of nonsense metaphors within the 5 s deadline, resulting in few trials with interpretation times for those metaphors. Overall, this initial study indicates that people are unlikely to think of meaningful interpretations of the nonsense metaphors within a short period of time.

Cue-response pairs. Literal associates of each metaphor's vehicle word were used as part of the cue-response pairs that were studied at the outset of the experiment. The original literal associates from George and Wiley (2016) were used for the familiar and novel metaphors. For the nonsense metaphors, literal associates were chosen such that there was no overlap with any potential figurative meaning. The full set consisted of 60 cue-response word pairs (included in the Appendix), in which the cue word is the metaphor vehicle of the sentence, and the response word is a strong literal associate of the vehicle.

A norming study for these materials assessed base-rate cued-recall for the response words with another independent sample of participants ($N = 14$). Participants had 5 minutes to initially study the word pairs, followed by a practice cued-recall phase (5 min) where they were provided with cue word plus first letter of the response word. This was followed by a final recall phase in which only the cue words were presented, sequentially, and participants had 5 s to type in the response word. Using the recall rates from the final recall phase, the metaphor sentences were split into two lists for counterbalancing, each containing 10 familiar, 10 novel, and 10 nonsense metaphors. The mean base rates for recall of the literal associates between the two lists were identical (81.4%). Additionally, base-rate recall levels, word frequency, and number of letters in the response words were similar across the lists for each level of familiarity (all *t*s < 1).

Procedure. The procedure closely followed that of George and Wiley (2016, Experiment 3). The procedure consisted of four phases: initial study, initial recall, metaphor processing, and final recall. During initial study phase, participants were provided a list of the 60 cue-response word pairs on sheets of paper, in a randomized order for each participant. Participants were given 5 min to study these word pairs. This was followed by an initial recall phase in which participants were provided with new sheets of paper listing the cue words along with the first letter of the associated response word, in a new randomized order. They were provided 5 min to write down as many response words as they could recall.

During the metaphor-processing phase, half of the cue words appeared in the metaphoric sentences (counterbalanced across participants). Participants were first instructed that they would be reading metaphoric sentences and that they should read the sentences carefully to themselves. They were then presented with 30 metaphors (10 for each level of familiarity) in random order via computer presentation. To control for potential differences in processing time, each metaphor was presented for 5 s.

In the final recall phase, participants were then instructed that they would need to recall all the original response words. Participants were presented with all 60 original cue words via computer presentation along with a response box for typing in the response word (they were not provided with the first letter of the response at final recall). Participants were provided 5 s to recall each word before advancing to the next trial. The trials were presented in a random order.

All experiments reported in this paper were run under an approved Institutional Review Board protocol.

Results

For both initial and final recall, the proportion of correct responses was calculated. For initial recall, there were no significant differences across conditions (*F*s < 1), and mean initial recall was 83.3% (*SD* = 14.8%). At final recall, the overall average was 72.8% (*SD* = 19.2%).

Planned comparisons on final recall between the metaphor and no-metaphor conditions for each level of familiarity were carried out to test the prediction that forgetting would be associated with processing novel and nonsense metaphors. These comparisons were performed using both subjects (*t1*) and items (*t2*) as the random effect. As shown in Table 2, for both novel and nonsense metaphors, forgetting was observed – recall of response words in the metaphor condition was lower than recall in the no-metaphor condition for both novel metaphors ($t1(75) = 2.09$, $p < .05$, $d = .20$; $t2(19) = 2.28$, $p < .05$, $d = .44$) and nonsense metaphors ($t1(75) = 3.02$, $p < .01$, $d = .31$; $t2(19) = 2.80$, $p < .05$, $d = .60$). However, for familiar metaphors, no significant difference in forgetting was observed due to metaphor processing, $t1(75) = 1.31$, $p = .19$; $t2(19) = .93$, $p = .36$.

Discussion

The results of Experiment 1 demonstrate that a consequence of reading novel metaphoric sentences is forgetting of literal associates that had been studied prior to encountering the metaphors. While no significant forgetting resulted from reading familiar metaphors, forgetting did occur for novel (meaningful) metaphors. Most importantly, forgetting also occurred for nonsense metaphors which are also novel and take the form of a metaphorical statement with no readily resolvable meaning. This pattern suggests that inhibition of literal information plays some role in metaphor processing. The reduced recall of literal information as a result of processing nonsense metaphors helps support such an inhibitory account of this forgetting over a blocking account because participants are unlikely to reach an interpretation of these metaphors within a short amount of time. While post-comprehension interference may explain part of the forgetting effect for novel metaphors, it is unlikely to explain forgetting associated with nonsense metaphors and suggests that the impaired recall of literal associates resulted from processes occurring during comprehension attempts.

Although this pattern of results provides support for an inhibitory account, one peculiarity is that the magnitude of the forgetting effect for novel metaphors in this study appears to be less robust than in that of the novel metaphor condition of George and Wiley (2016; Experiment 3). The overall forgetting effect was only around 5%. One consideration is that the present experiment used a larger list size (60 words compared to 40 word pairs). This larger list size may have diluted the metaphor-induced forgetting effect, perhaps by creating an overload that decreased initial learning or by increasing the amount of intra-list interference which may have weakened any effects of inhibitory-based forgetting associated with metaphor processing.

Experiment 2

The main goal for Experiment 2 was to test whether employing to a shorter cue-response list length of 40 items as used in prior work might allow for a more robust forgetting effect. To achieve this, Experiment 2 included only familiar and nonsense metaphor stimuli. Consistent with the previous hypotheses, it was predicted that processing nonsense metaphors should produce significant forgetting of literal associates. Processing familiar metaphors was expected to produce little or no forgetting.

Methods

Participants. Participants were 26 undergraduates from the University of Illinois at Chicago psychology subject pool. All participants were fluent in English and provided agreement to participate.

Materials. The 20 familiar and 20 nonsense metaphor sentences and cue-response pairs from Experiment 1 were used.

Procedure. The procedure was similar to that of Experiment 1, except that participants were given 3.5 minutes for the study and initial recall phases (to adjust for the change in list length).

Results

For initial recall, there were no significant differences across conditions (*F*s < 1) and mean initial recall proportion was 92.0% (*SD* = 8.5%). This initial recall average was higher than that of Experiment 1, $t(100) = 2.84$, $p < .01$, $d = .72$ At final recall, the overall average was 79.7% (*SD* = 15.8%), which was also higher than that of Experiment 1, although this difference was not significant, $t(100) = 1.65$, $p = .10$, $d = .39$. There also appeared to be greater variability in initial recall scores in Experiment 1 than 2, as indicated by Levene's test for equality of variances ($F = 13.54$, $p < .001$), and a trend in final recall ($F = 3.29$, $p = .07$).

Planned comparisons were carried out between the metaphor and no-metaphor conditions to test the prediction that forgetting would be associated with processing nonsense metaphors. As shown in Table 3, for nonsense metaphors, recall of response words in the metaphor condition was lower than recall in the no-metaphor condition, $t1(26) = 3.47$, $p < .01$, $d = .64$; $t2(19) = 3.83$, $p < .01$, $d = .90$. The effect size for this comparison was also larger than that of Experiment 1 ($d1 = .31$; $d2 = .60$). However, for familiar metaphors, no significant difference in forgetting was observed due to metaphor processing, $t1(25) = .47$, $p = .64$; $t2(19) = .32$, $p = .75$.

Discussion

In Experiment 2, in which only familiar and nonsense metaphors were used in the metaphor processing task, subsequent forgetting of literal associates was only observed for nonsense metaphors but not familiar metaphors. This replicates the pattern observed for Experiment 1, providing additional evidence for inhibitory mechanisms used during the attempt to comprehend novel metaphors – even nonsense ones. Further, presenting only 40 items rather than 60 increased initial learning of the associates, decreased variability in the initial learning of associates, and resulted in a more robust forgetting effect.

Although the reduced recall associated with reading nonsense metaphors (but not familiar metaphors) in the first two experiments is consistent with an inhibitory account, one common alternate explanation of this forgetting effect involves associative interference during final recall. Such "blocking" accounts have been offered as an explanation of RIF, wherein the act of selective retrieval practice (e.g., *FRUIT–ba____*) strengthens the association between a cue and response, thereby making it more difficult to later retrieve other responses associated with the cue (e.g., *FRUIT–lemon*) (Jonker et al. 2013; Raaijmakers & Jakab, 2013a; 2013b). In the current experiments, there was no retrieval practice phase, however there are a couple of ways that blocking could still play a role.

For example, interference could come from the unsuccessful resolution attempts. Upon encountering a nonsense metaphor (*Jealousy is a barn*), people might activate a broad array of potential ideas about its meaning. Thus many attributes of the vehicle may become weakly activated by this process. While one could argue that this might cause interference, prior work suggests that activation of weak associates during retrieval practice does not lead to significant forgetting (Anderson et al., 1994).

A second possibility consistent with a blocking account is that the pairing in a nonsense metaphor (*jealousy* - *barn*) may be so unusual as to interfere with the original pairing (*barn* – *hay*). Under this perspective, during the processing of a nonsense metaphor, the cue word (*barn*) may simply become more strongly associated with the topic (e.g., *jealousy*). The strengthening of the association between *barn* and *jealousy* may interfere with one's ability to retrieve *hay* at the final test. Thus, even without a successful resolution of the nonsense metaphor's meaning, some form of cue-dependent, associative interference may still provide an explanation of the forgetting effect. This cue-dependent account stands in contrast to the inhibitory explanation which suggests that inhibition acts on the target item representation (in this case, *hay*, the literal associate) directly to produce forgetting (Anderson, 2003).

Cue-independent measures of forgetting are necessary to provide stronger support for an inhibitory explanation of RIF (Storm & Levy, 2012). Instead of using cued recall, which by definition is a cue-dependent measure, several prior studies have tested for RIF using recognition paradigms (Aslan & Bäuml, 2011; Rupprecht & Bäuml, 2016; Veling & van Knippenberg, 2004, Verde & Perfect, 2011). In these recognition paradigms, participants view only the response words (not the cue words) from the initial study phase and make a decision about whether or not they appeared during study. By directly presenting the original response word, separate from its cue, this eliminates the possibility of forgetting effects being due to cue-dependent associative interference. Thus, a cue-independent measure of forgetting was employed in Experiment 3.

Experiment 3

The goal of Experiment 3 was to test whether the forgetting effect associated with reading nonsense metaphors would generalize to a cue-independent recognition measure. The RIF paradigm used here was based on Veling and van Knippenberg (2004) and Verde and

Perfect (2011) who have used longer recognition times on correct trials for *Rp-* items than for *NRP* items to provide evidence for an inhibitory account of forgetting. In the present context, if inhibitory processes act on the level of the representation of the literal associate during attempts to understand nonsense metaphors, then recognition of literal associates for words that appeared in the nonsense metaphors should take longer than recognition of associates of words that did not appear in nonsense metaphors. For familiar metaphors, no differences in recognition latencies were expected.

Methods

Participants. Participants consisted of 40 undergraduate participants from the University of Illinois at Chicago psychology subject pool, who provided agreement to participate.

Materials. The 20 familiar and 20 nonsense metaphor sentences and cue-response pairs from Experiment 2 were used. For the final recognition task, a set of 40 lure words were created (listed in the Appendix). To make lures as similar as possible to the response words, all lure words were also nouns. The two sets of stimuli were matched overall for number of letters (M = 4.9) and for frequency (lure words M = 52.29; response words M = 45.53, $t < 1$).

Procedure. The initial study, recall, and metaphor processing phases were the same as in Experiment 2. However, the final recall phase was replaced with a recognition task (based on Veling & van Knippenberg, 2004). Participants were presented with words in the center of the screen. The words consisted of the target words (literal associates) from the initial phase of the experiment and lure words. Participants were instructed to press the “1” key with their left index finger when a word was recognized (old), and the “0” with their right index finger when a word was not recognized (new). Participants were instructed to make their decision as quickly and as accurately as possible. Each trial started with the presentation of a fixation cross (+) for 1 sec, which was then replaced by a word. After making their decision, the word disappeared during an inter-trial interval of 1 sec. The words were presented in a random order, with the constraint that no more than two trials of the same type (old/new) be presented in succession.

Results

For initial recall, the mean initial recall proportion was 86.1% (*SD* = 16.1%). There were no significant differences across conditions (*Fs* < 1.18). At final recognition, the overall average recognition accuracy was 86.4% (*SD* = 10.2%). There were no significant differences across conditions (*F*s < 1.13).

Following Veling and van Knippenberg (2004) and Verde and Perfect (2011), the primary dependent measure was mean recognition time on correct response-word trials. Planned comparisons were carried out between the metaphor and no-metaphor conditions to test the prediction that processing nonsense metaphors would result in slower recognition times. As shown in Table 4, for nonsense metaphors, recognition times on correct trials for response words in the metaphor condition were significantly slower than in the no-metaphor condition, $t1(39) = 2.53$, $p < .05$, $d = .44$; $t2(19) = 2.85$, $p < .05$, $d = .66$. However, for familiar metaphors this contrast in recognition times was not significant, $t1(39) = .33$, $p = .74$; $t2(19) = .28$, $p = .78$.

Discussion

The third experiment replaced the final cued-recall task used in the first two experiments with a cue-independent-recognition task. Consistent with predictions and with the results of the first two experiments, reading nonsense metaphors resulted in longer recognition latencies for previously-studied literal associates, while reading familiar metaphors did not affect recognition latencies for the literal associates. The extension of the previous findings to a cue-independent recognition paradigm provides additional support for an inhibitory account of the forgetting effect rather than an associative interference account.

General Discussion

Across three studies, similar patterns were observed demonstrating reduced access to literal information as a consequence of processing of novel metaphors that were difficult to clearly resolve within a short time frame. The norming study done as part of Experiment 1 demonstrated that the novel and nonsense metaphors, compared to the familiar metaphors used in these studies, were associated with more processing effort. These results suggest that part of this effort may stem from the need to inhibit a competing literal meaning, as these metaphors resulted in the most forgetting of information related to literal meaning.

The first two experiments demonstrated forgetting using a cued-recall paradigm. In Experiment 1, the forgetting effect was weaker as compared to Experiment 2 as indicated by the different effect sizes. One salient difference between the first two studies was in the length of the lists of cue-response pairs. In Experiment 1, with 60 word pairs, this list was harder to learn than the list of 40 word pairs in Experiment 2, as evidenced by the lower initial recall proportion in Experiment 1 and greater variability in performance. This difference in initial learning could affect the ability to find effects of inhibitory-based forgetting. For example, the larger list size in Experiment 1 may have caused participants to develop a weaker representation of the cue-response pairs, which could mean there was reduced competition from the associates during the metaphor processing task (and consequently, less forgetting). Alternatively, the lower initial recall proportion in Experiment 1 may have left less room for forgetting to occur.

Another salient difference between the first two experiments was that the second experiment used only nonsense metaphors and familiar metaphors as stimuli. By using only the two extremes of metaphor types (very familiar, easily understood metaphors vs. very novel, incomprehensible nonsense metaphors), this may have created a sharp contrast between the two types of metaphor for participants, such that the somewhat bizarre pairings presented by the nonsense metaphors were more distinctive, and therefore more memorable, relative to the familiar metaphors. This distinctiveness may have caused the new pairing of vehicle and topic to simply interfere with the old pairing (of vehicle and response word), regardless of the comprehension processes. This may partially explain why the forgetting effect was quite large in Experiment 2. However, forgetting effects were also observed in Experiment 1, wherein novel metaphors (which represent a midpoint of difficulty) were also included, which likely reduced the distinctiveness of the nonsense metaphors. Thus, this explanation is unlikely to account for all of the forgetting seen in Experiment 2.

More importantly, the results of Experiment 3, which used a cue-independent recognition measure, help to rule out a cue-based associative interference account of the forgetting effect. The original response words were presented independent of their cues on the final recognition test, and slower recognition times were observed for items associated with reading nonsense metaphors, but not familiar metaphors. If the reduced recall for nonsense metaphors in the first two experiments were purely a result of the strengthening of the association between a cue word and its nonsense metaphor (effectively "stealing" activation strength from the original cue-response pairing), one would not expect recognition times for the response words alone to also show such differential impairment.

Taken together, the results of these three experiments provide evidence that inhibition of literal meaning plays some role in novel metaphor comprehension. First, the use of nonsense metaphors helps to rule out a post-comprehension blocking explanation of impaired recall at final test. Because these nonsense metaphors are unlikely to result in a meaningful interpretation, blocking at final test cannot easily explain these findings. Second, the same results were found using a cue-independent measure of forgetting, which means that cue-dependent associative interference accounts also cannot easily explain these findings. Instead, the results suggest that the impaired recall is the result of forgetting due to inhibitory mechanisms that are used during the *attempt* to select an appropriate meaning. Thus, these results are consistent with other work using impossible retrieval practice and impossible problem solving paradigms, wherein the retrieval of target information involves inhibition of competing information – even when such retrieval is made to be impossible (Storm et al., 2006; Storm & Nestojko, 2010; Storm et al., 2011). The present findings suggest that when meaning competition takes place, it is the act of *attempting* to resolve competition that involves inhibitory processing – even when resolution is unsuccessful.

These results converge with several other findings in work on metaphoric sentence processing. For instance, ERP studies have shown that novel metaphors and anomalous sentences produce relatively similar waveform patterns (Lai et al., 2009; Rutter et al., 2012b). In fMRI work, Stringaris, Medford, Giampietro, Brammer, and David (2007) also found that metaphoric sentences and non-meaningful sentences both involved additional activation of left inferior frontal gyrus relative to literal sentences, a region suggested to be involved in controlled semantic selection (Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997). Schmidt and Seger (2009) also found that metaphors that were more difficult tended to recruit this region. Perhaps not coincidentally, this is a region that has also been associated with RIF (Wimber et al., 2008). In contrast, some other studies do not indicate that metaphoric and nonsense sentences involve overlapping processes (Rutter et al., 2012a; Gernsbacher et al., 2001, Experiment 2). However, in those studies, participants were tasked with discriminating nonsense and meaningful sentences, and thus may have more readily dismissed nonsense sentences without further processing.

Because this study explored only metaphoric phrases of the nominal “X is a Y” format, which only represents one form of metaphoric language, future work is needed to understand how broadly these results could generalize to other forms of metaphoric and figurative language. Additionally, factors related to the topic of the metaphors were not controlled for, such as topic constraint (Glucksberg, McGlone, & Manfredi, 1997). Some metaphor topics (e.g., *my brother*) are low in constraint (i.e., many properties can be attributed to them), compared to other more high-constraint topics (e. g., *a football player*), which have a more narrow range of relevant properties. This is likely to influence processing demands, and may be relevant for inhibition. Another goal for future work is to find a way to study this phenomenon using methods less tied to episodic memory, and more clearly based in semantic processing. In the present studies, the recall and recognition tasks were closely tied to episodic processing by testing for memory of a set of presented associates. Future work is needed to demonstrate whether similar memory dynamics can be demonstrated simply as a function of attempting to comprehend and resolve novel metaphorical expressions (without prior exposure to associates). It is also important to note that these results do not necessarily suggest that literal meaning is always inhibited as part of novel metaphor comprehension. Perhaps there are cases where some aspects of literal meaning could be easily integrated with the figurative meaning, and therefore aid comprehension (Chiappe & Kennedy, 2001). In such cases, literal and figurative meaning would not compete, and facilitation of literal meaning might be expected.

The current findings add to a growing body of work that is using RIF-inspired paradigms to study creative cognition. Several studies using the RAT have suggested that inhibitory mechanisms are needed in contexts wherein highly available or easily accessed information must be overcome in order to reach a solution (Storm, Angello, & Bjork, 2011; Storm & Koppel, 2012). In an interesting variation on this approach, Gómez-Ariza et al. (2017) recently used the RIF procedure to first reduce the accessibility of words in an initial phase of the experiment, before presenting RAT items whose solutions were the words that had been selected against during retrieval practice. This resulted in fewer correct solutions on RAT items. Thus, forgetting can be either beneficial or detrimental to creative problem solving, depending on the target of forgetting. Other RIF-inspired work on creative cognition has explored the role of forgetting in divergent thinking tasks such as the alternate uses task (AUT) – thinking of creative uses for everyday objects (e.g., *newspaper*) resulted in forgetting of common uses (*starting a fire*) at final recall (Storm & Patel, 2014), as well as participants' own initially generated ideas (Ditta & Storm, 2017). The current experiments in novel metaphor comprehension are similar to these studies, and they lend further support for the role of inhibitory processing in creative cognition as processing novel metaphors requires readers to come up with non-routine and non-obvious interpretations. These studies also further demonstrate the usefulness of memory-based paradigms in exploring higher-order cognitive processes related to language, problem-solving, and creativity. At a broader level, these findings have implications for creative cognition more generally. Making novel and creative connections ideas sometimes requires controlled processing (Beaty, Christensen, Benedek, Silvia, & Schacter 2017; Green 2016), wherein more directed activation of information in memory can aid in filtering out irrelevant, obvious, or unoriginal ideas while facilitating access to more novel ideas. While ramping up general memory retrieval can support some aspects of creative thinking (Madore, Jing, Schachter 2016), in situations where the contents of those memories impede the creation of more novel connections, then more controlled aspects of retrieval may facilitate these creative connections.

Finally, these results have implications for the ongoing debate about the role of inhibition in forgetting effects. A compelling range of evidence exists supporting an inhibitory account (Anderson, 2003; Chan, Erdman, & Davis, 2015; Murayama, Miyatsu, Buchli, & Storm, 2014; Storm & Levy, 2012). Certainly not all RIF or PSIF effects are due to inhibition, and the debate concerning whether forgetting effects are actually due to blocking rather than inhibition continues. However, several features of the present study help rule out these alternative explanations, and consistent with a review of the available evidence, these results suggest that non-inhibitory explanations are insufficient to account for all instances of RIF (Murayama et al., 2014).

To summarize, these results add to the body of research findings indicating that attempting to understand metaphors sometimes involves overriding activation of literal information. As readers attempt to extract figurative meaning from novel metaphoric phrases, competition arises from the activation of literal information. Consequently, inhibitory mechanisms may be used during comprehension attempts to reduce this competition. By adapting the RIF/PSIF framework, particularly “impossible” paradigms that preclude retrieval success, these experiments isolate the forgetting effect as being due to attempts to resolve the metaphor’s meaning. Because these novel, nonsense metaphors were not readily interpretable this rendered post-comprehension interference at final recall (or blocking) an implausible explanation of poor recall because comprehension was unlikely to have occurred. Across three studies, processing nonsense metaphors led to reduced recall or slower recognition of previously studied literal associates. This same pattern did not emerge for familiar metaphors. The selective memory impairment associated with nonsense metaphors places the locus of the forgetting effect within attempts to resolve a novel metaphor's meaning, and suggests that inhibitory processing is utilized during such attempts to help overcome competition.

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Table 1.

Mean interpretation times, mean number of complete responses, mean number of viable responses, and mean quality rating for familiar, novel and nonsense metaphors from the norming study.

	Interpretation time (s)	# Complete interpretations	# Viable interpretations	Quality rating
Metaphor familiarity	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Familiar	2.47 (.54)	16.27 (2.91)	16.20 (3.00)	3.53 (.57)
Novel	3.13 (.57)	9.93 (6.31)	8.33 (5.65)	2.14 (.27)
Nonsense	3.18 (1.10)	5.07 (5.79)	1.33 (1.88)	1.27 (.76)

Table 2

Final recall of response words for the metaphor and no-metaphor conditions for familiar, novel, and nonsense metaphors in Experiment 1.

	Metaphor		No-metaphor	
Metaphor familiarity	*M*	*SD*	*M*	*SD*
Familiar	73.6%	23.9%	76.6%	19.8%
Novel	66.7%	27.3%	71.7%	23.7%
Nonsense	70.8%	23.7%	77.6%	19.2%

Table 3

Final recall of response words for the metaphor and no-metaphor conditions for familiar and nonsense metaphors in Experiment 2.

	Metaphor		No-metaphor	
Metaphor familiarity	*M*	*SD*	*M*	*SD*
Familiar	80.4%	21.2%	81.9%	17.9%
Nonsense	71.9%	21.5%	84.6%	17.3%

Table 4

Recognition latencies (ms) for response words on correct trials in the metaphor and no-metaphor conditions for familiar and nonsense metaphors in Experiment 3.

Metaphor familiarity	Metaphor		No-metaphor	
	M	*SD*	*M*	*SD*
Familiar	1008.41	386.74	989.65	286.83
Nonsense	1069.90	410.97	958.22	280.71

Appendix

Metaphoric sentences and cue-response pairs. All three levels of familiarity were used in Experiment 1; only familiar and nonsense metaphors were used in Experiments 2 and 3. Lures and response words were used in the recognition task in Experiment 3.

Familiar Metaphors	**Lure**	**Cue-Response Pair**
My uncle's surgeon is a butcher	step	BUTCHER : meat
My grandmother is a peach	lamp	PEACH : tree
That baby's cheeks are roses	wheel	ROSE : thorn
His kindergarten class is a zoo	neck	ZOO : cage
My history teacher is an encyclopedia	dive	ENCYCLOPEDIA : page
The senator is a fossil	mop	FOSSIL : dig
In the winter, my studio is a refrigerator	furniture	REFRIGERATOR : appliance
That twelve speed bicycle is a rocket	fork	ROCKET : fuel
Jalapeño peppers are fire	officer	FIRE : oxygen
When she is upset, her voice is a siren	crack	SIREN : truck
Her husband is a gem	bloom	GEM : stone
My sister says that happiness is gold	turkey	GOLD : yellow
The cheering crowd was thunder	steam	THUNDER : storm
My young cousin is a shrimp	pillow	SHRIMP : lobster
My boyfriend's arms are steel	tower	STEEL : iron
My brother says that soothing music is medicine	island	MEDICINE : doctor
The lawyer for the defense is a shark	bean	SHARK : swim
My daughter's smile is sunshine	bird	SUNSHINE : burn
My cat's fur is silk	file	SILK : worm
Her unflinching gaze is ice	wood	ICE : slip
Novel Metaphors		
The news media is an octopus		OCTOPUS : ink
My mother says that envy is rust		RUST : red
Their lifelong friendship was wine		WINE : glass
That lightweight boxer is a wasp		WASP : nest
The teacher’s passion was a battery		BATTERY : car
That pregnant woman is a duck		DUCK : feather
That groupie for the band is a satellite		SATELLITE : moon
Some dreams are rivers		RIVER : bank
My professor says that science is a glacier		GLACIER : arctic
The forest on the summer day was a harmonica		HARMONICA : guitar
The artist said that imagination is a cave		CAVE : man
That daily newspaper is a telescope		TELESCOPE : lens
The billboards along the highway were warts		WART : skin

My mother said that discipline is fertilizer		FERTILIZER : odor
That philanthropist is a fountain		FOUNTAIN park
The goalie tending the net was a spider		SPIDER : venom
For the writer, creativity was a toaster		TOASTER bread
That baby monkey is a vine		VINE : plant
My gossiping office mate is a radio		RADIO : antenna
My friend says strong communities are soil		SOIL : grass

Nonsense Metaphors

My friend says jealousy is a barn	cup	BARN : hay
The chirping canary was a desk	pasta	DESK : paper
Homelessness is a towel	oak	TOWEL : dry
That sermon was a toe	farmer	TOE : finger
That widow is a canoe	hat	CANOE : oar
My brother's memory is a moustache	sleep	MOUSTACHE : shave
The small farm was a sled	mask	SLED : hill
That breakfast was a sidewalk	college	SIDEWALK : cement
That science museum is a muffin	oil	MUFFIN : oven
That dancer is a helmet	library	HELMET : soldier
The ambulance was a skirt	beetle	SKIRT : blouse
The fisherman was a mushroom	clean	MUSHROOM : pizza
My new office is rice	sit	RICE : bowl
That boy's indecision is a rooster	candle	ROOSTER : chicken
The woman's impulse was a rug	trash	RUG : wool
My regular mechanic is a bath	road	BATH : soap
My sister's coach is a patio	lime	PATIO : lawn
The gnats in the air were a frame	shoulder	FRAME : gallery
Beaches can be flagpoles	carbon	FLAGPOLE : school
Some people think justice is a banana	glove	BANANA : split