Forgetting the literal: The role of inhibition in metaphor comprehension

Tim George and Jennifer Wiley

University of Illinois at Chicago

Author Note

Tim George, Department of Psychology, University of Illinois at Chicago; Jennifer Wiley, Department of Psychology, University of Illinois at Chicago.

Correspondence concerning this article should be addressed to Tim George, University of Illinois at Chicago, 1007 West Harrison Street (M/C 285). Email: tgeorg7@uic.edu, Phone: 202-384-6225

Abstract

In order to comprehend metaphoric expressions do metaphor-irrelevant aspects of literal information need to be inhibited? Previous research using sentence-verification paradigms has found that literal associates take longer to process after reading metaphorical sentences; however it is problematic to infer inhibition from this research. Moreover, previous work has not distinguished between familiar and novel metaphor processing. To test more directly for when inhibition may be required during metaphor processing, three experiments were performed using a metaphor-induced lexical forgetting paradigm. Participants initially learned word pairs where the cues were potential metaphoric vehicles and the targets were literal associates (e.g., *SHARK-swim*). Then, participants read half the vehicles as part of metaphorical sentences which they interpreted (*The lawyer for the defense is a shark*). Subsequent forgetting of the literal associates was greater when vehicles had appeared in metaphorical sentences (Experiment 1), and was observed for both familiar and novel metaphors when participants were instructed to interpret the metaphors (Experiment 2), but was observed for *only* novel metaphors when participants were simply instructed to read the metaphors (Experiment 3). These results suggest that forgetting occurs as a result of inhibitory mechanisms that are engaged to alter activation of irrelevant literal information during metaphor processing, and that these mechanisms are most relevant for the processing demands associated with novel metaphors.

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

Forgetting the literal: The role of inhibition in metaphor comprehension

Many theories have suggested that figurative language can involve additional processing compared with literal language (Bowdle & Gentner, 2005; Searle, 1979). On one hand, it has also been shown that people can sometimes understand metaphors quite directly (Glucksberg, Gildea, & Bookin, 1982), as in highly conventional or familiar metaphors (Blakso & Connine, 1993) where the meaning may already be stored in memory. On the other hand, it has been assumed that when one encounters a novel figurative phrase, processing using literal meanings will first be attempted, while non-literal meanings may only be considered once a literal attempt has failed (Searle, 1979). When we encounter a novel metaphor we need to engage in creative cognition to appreciate its meaning (Rutter et al., 2012; Silvia & Beaty, 2012). For example, in the unconventional metaphor "Discipline is fertilizer", the vehicle (*fertilizer)* is used to illustrate one or more aspects of the topic concept (*discipline*). The words *discipline* and *fertilizer* each have strong associates with other concepts, but are weakly related as a pair. However, they share the semantic feature of promoting growth, which can be seen as a way to resolve the semantic anomaly presented by this sentence.

Theories of how metaphors are processed generally fall into two broad classes: comparison and categorization. Comparison accounts assume that metaphors are processed as similarity statements that highlight common properties between a topic and vehicle concept (Ortony, 1979), or that involve structural alignment between the two concepts, similar to analogy (Gentner, 1983). Categorization accounts suggest that the vehicle stands for a superordinate category of which the topic is a member (Glucksberg, McGlone, & Manfredi, 1997). However, the career of metaphor theory, an extension of the structure alignment view, suggests that these views are not mutually exclusive (Bowdle & Gentner, 2005). This theory suggests that

unfamiliar metaphors are processed as comparisons, but that as metaphors become conventionalized, there is a shift in processing toward categorization.

Each of these models involves excluding literal information from consideration, which suggests that inhibitory processes might be necessary to actively inhibit features of the vehicle that are not appropriate for the target. Previous research has indeed yielded findings consistent with inhibition of literal associates after reading metaphorical sentences (Gernsbacher, Keysar, Robertson, & Werner, 2001; Glucksberg, Newsome, & Goldvarg, 2001). In these experiments, participants judged the validity of prime sentences containing both literal and metaphorical uses of a metaphor vehicle (e.g., *That large hammerhead is a shark* vs. *That defense lawyer is a shark*) before judging the validity of target sentences that were either relevant or irrelevant to the metaphorical meaning (e.g., *Sharks are tenacious* vs. *Sharks are good swimmers*). Participants were slower to verify metaphor-irrelevant properties following metaphorical sentence primes than following literal sentence primes, suggesting that inhibition is a mechanism by which irrelevant literal information is filtered out during metaphor processing.

However, since these studies relied on probe paradigms that used sentence verification times as the dependent measure, it is not clear whether these findings truly reflect the active suppression of metaphor-irrelevant information during processing. For example, in the Gernsbacher et al. (2001) study, it may be that once a prime is understood to contain a metaphorical meaning, it is more difficult to then integrate a conflicting literal-relevant target with the preceding meaning than when the literal target is preceded by a literal prime or other baseline prime. Such post-reading probe measures make it difficult to conclude that inhibition must be recruited during the act of processing a metaphor. Additionally, these studies do not explicitly distinguish between familiar and novel metaphors, which is an important distinction as

indicated by the career of metaphor theory. If familiar metaphors simply point to a stored figurative representation, this suggests that their meaning can be accessed without the need to inhibit literal associates. However, for less familiar metaphors that one has not previously encountered, literal information may initially interfere with resolving the metaphor. Consequently, one might expect novel metaphors to require more inhibition of literal information than for familiar metaphors.

This distinction between familiar and novel metaphor processing is highlighted in a series of lexical decision experiments by Blasko and Connine (1993). They found similar response times for both literal and metaphorical target words immediately after reading familiar metaphorical sentences, but longer response times for unrelated words, suggesting activation of both literal and figurative meanings versus unrelated control targets. This pattern was different for unfamiliar metaphors. For unfamiliar metaphorical sentences, there was only evidence of activation of the literal meaning immediately after reading. People were slower to respond to metaphorical targets than unrelated control targets at short SOAs. It was not until after a longer SOA that activation for metaphorical targets was found (Blasko & Connine, 1993). This pattern is consistent with the suggestion that familiar metaphors may have figurative meanings stored in memory that can be accessed along with the literal sense, while for novel metaphors figurative meanings may not be accessed until an initial literal-level processing attempt results in comprehension failure.

Thus, the goal of the present study was to test whether competition from and inhibition of literal associates during metaphor processing might be particularly important for novel metaphoric expressions, or whether they are involved for both familiar and novel metaphors. Instead of using response times on post-reading recognition probes that are literal associates of a

metaphorical vehicle, the current studies adapt the retrieval-induced forgetting (RIF) framework (Anderson, Bjork & Bjork, 1994; Storm & Levy, 2012) to study metaphor processing. In RIF, as a consequence of attempting to retrieve target information in memory, subsequent recall of other related information is impaired, and this likely reflects inhibitory mechanisms. Analogously, in metaphor processing, any previously-encountered irrelevant literal information that is activated upon presentation of a metaphor may have to be inhibited in order to effectively arrive at the figurative meaning, resulting in reduced recall for literal information. Based on prior work that has made a distinction in the processes recruited by familiar and novel metaphors, it is predicted that forgetting should be more likely to occur or will be stronger in its effect when metaphors are novel rather than familiar.

Experiment 1

Experiment 1 developed and tested a new paradigm for exploring processes underlying metaphor comprehension by extending the established RIF paradigm (Anderson, Bjork & Bjork, 1994; Storm & Levy, 2012). If inhibition of literal meaning occurs during the processing of metaphoric meaning, then recall for previously-learned literal associates of metaphors should be reduced as a result of metaphor processing. In RIF experiments, subjects typically study a list of category exemplar pairs (e.g., *FRUIT-banana, FRUIT-lemon, TOOLS-hammer, TOOLS-saw*), followed by a period of retrieval practice for half the exemplars from half the categories (e.g., *FRUIT-banana*). On a test of final recall for all of the word pairs, recall for responses associated with unpracticed categories (e.g., *TOOLS*) is at baseline, and recall for practiced responses from practiced categories (e.g., *FRUIT-banana*) is enhanced. Critically, recall of unpracticed responses from practiced categories (e.g., *FRUIT-lemon*) is inhibited (i.e., below baseline). This effect is assumed to be a consequence of competition arising from similar but irrelevant items in

memory during retrieval practice, which in turn causes inhibition to be directed toward the competing information. Metaphor processing can be viewed as a form of selective retrieval from memory during which information competes for access. To the extent that competing or dominant responses such as literal associates are automatically brought to mind during metaphor processing, inhibitory mechanisms may be recruited to reduce these responses.

A variant of this paradigm called "problem-solving-induced forgetting" (PSIF) has already been extended into the domain of creative problem-solving. PSIF has been demonstrated during the generation of solutions in creative tasks where subordinate meanings of words or unusual uses for objects are required, such as the remote associates test (RAT) or the alternate uses test (AUT) (Storm, Angello, & Bjork, 2011; Storm & Patel, 2014). These results are thought to demonstrate that inhibition is an adaptive mechanism that is engaged in order to deal with competition from less creative solutions during creative problem solving attempts.

In the context of metaphor processing, we expect that the same mechanisms that underlie both RIF and PSIF would be recruited when a previously-learned literal associate of a metaphor vehicle interferes with the successful comprehension of the metaphor's figurative meaning. If readers engage in inhibition during the processing of metaphoric expressions, then participants should also show forgetting in this context which would result in reduced recall for word pairs consisting of vehicles and their literal associates. To test this hypothesis, an initial experiment was conducted in which participants studied metaphor-irrelevant literal associates of metaphor vehicles (e.g., *SHARK–swim)* before generating interpretations of metaphors that used half of these vehicles (*The lawyer for the defense is a shark*). This initial study relied on the materials of Gernsbacher et al. (2001) so as to demonstrate that an inhibitory effect could be replicated using this methodology. As in Gernsbacher et al. (2001), no distinction was made between novel and

familiar metaphors in this first experiment. It was predicted that more forgetting would be observed for associates of the vehicles for which participants were shown and asked to interpret metaphoric expressions.

Method

Participants

Participants were 22 fluent English-speaking undergraduates from the University of Illinois at Chicago subject pool. All participants provided agreement to participate and they received course credit for participation.

Materials

The stimuli consisted of 40 metaphorical sentences taken from a previous study on metaphor comprehension (Gernsbacher et al., 2001). A set of 40 cue-response word pairs was created using these stimuli, in which the cue was the metaphor vehicle of the sentence, and the response was a literal associate of the vehicle that did not relate to the figurative meaning (e.g., *SHARK-swim* for the sentence *The lawyer for the defense is a shark*). The single-word literal associates used in the word pairs for this study were based on the Gernsbacher et al. (2001) literal-meaning probes.

To assess base-rate recall of these word pairs, a norming experiment was conducted with ten participants. Participants studied the cue-response pairs on a sheet of paper for 3.5 m, followed by cue-plus letter stem recall on a sheet of paper for 3.5 m. Average percent recall was 95% (*SD* = 6%). For each individual item, the average percent recall was calculated across subjects. These stimuli were then split into two lists of 20 items that matched the target responses on base-rate of recall, written frequency, number of letters, and number of syllables. The cue words were also matched for the number of living things. The two lists were used to

counterbalance materials across the two conditions, with equal numbers of participants in each condition.

Procedure

After collecting agreement to participate, there were four phases to the main experiment: Study, Initial Recall, Metaphor Interpretation, and Final Recall. First participants studied the word pairs. Participants were given the 40 cue-response word pairs on a sheet of paper and instructed that they should study each word pair so that when given the cue word, they could recall the response word. The order of items was randomized for each participant. They had 3.5 m to study this list before it was collected.

Immediately following the study period, participants were given a list of the 40 cue words along with the first letter of the response word on a sheet of paper in a new random order. They had 3.5 m to write down the correct response to each cue before it was collected. This procedure ensured strengthening of the cue-response pairs in memory.

Following the initial recall, participants completed a metaphor interpretation task via E-Prime. Participants were presented with one of the two lists of 20 metaphorical sentences in which the vehicle was a cue from the previously studied word pairs (metaphor condition). The other half of the cue words did not appear in any sentences (no-metaphor condition). The sentences were presented in random order one at a time. For each sentence, participants had up to 20 s to read and think of the metaphorical interpretation, which they indicated by pressing the space bar. The computer logged the response time for this space bar press. After pressing the space bar, they had up to 20 s to type the interpretation in a response box, before automatically being presented with the next sentence.

Following the metaphor interpretation task, participants received a surprise final recall test of all 40 cue-response pairs via E-Prime. The order of items was randomized across participants. Each trial began with the presentation of a fixation cross for 500 ms, followed by the presentation of the cue word along with a blank response box for 5 s. Participants were instructed to type the correct response into the response box. After 5 s, the next trial began.

Results

The pattern of final recall is shown in Table 1. The percentage of correct responses on the final recall test was computed separately for the metaphor interpretation and no-metaphor interpretation conditions to create recall accuracy scores for each condition. Misspellings and pluralizations were accepted as correct. These values were entered into a repeated-measures analysis of variance (ANOVA). More forgetting of the literal associates was seen in the metaphor-interpretation condition than in the no-metaphor condition, $F1(1, 21) = 12.05$, $p < .01$; $\eta_p^2 = .37$; $F2(1, 39) = 20.74$, $p < .01$, $\eta_p^2 = .35$, suggesting metaphor-induced forgetting. There were no differences in initial recall for either subject or item analyses, $F1 < 1$; $F2 < 1$, ($M = 91\%$, $SD = 9\%$).

Discussion

Recall of literal associates of metaphor vehicle words was reduced following metaphor interpretation, compared to when those words did not appear in metaphors. The finding that there is forgetting of literal associates of metaphoric vehicles as a result of generating their figurative interpretations is consistent with the notion that inhibition of irrelevant literal information is involved in metaphor processing (Gernsbacher et al., 2001; Glucksberg et al., 2001).

Experiment 2

The results of Experiment 1 suggest that inhibition of irrelevant literal associations may occur as part of metaphor processing. However, a great deal of research has suggested that there may be an important distinction between the processing of familiar and novel metaphors (Blasko & Connine, 1993; Bowdle & Gentner, 2005). Familiar metaphors may be processed more like categorical statements (e.g., "A bear is a mammal"), while novel metaphors may require an initial comparison process in order to arrive at an appropriate metaphorical meaning

The Gernsbacher et al. (2001) and Glucksberg et al. (2001) studies do not make such a distinction. A novel metaphor vehicle is not as likely to have a stored figurative representation or associated metaphorical category as a familiar metaphor vehicle. This should make processing more challenging, and may require more inhibitory processing in order to overcome the irrelevant literal meaning. This may result in even more forgetting of literal associates for novel metaphors. To test this hypothesis, for this experiment participants studied literal associates of both familiar and novel metaphor vehicles before generating interpretations of metaphors that used half of these vehicles of each type (familiar and novel). If readers engage in inhibition particularly during the processing of novel metaphoric expressions, it is predicted that more forgetting would be observed for associates of the vehicles for which participants were asked to interpret novel metaphoric expressions, than for familiar metaphoric expressions.

Method

Participants

Participants consisted of 30 fluent English-speaking undergraduates from the University of Illinois at Chicago subject pool. Participants provided agreement to participate and were given course credit for participation.

Materials

The original 40 metaphorical sentences from Gernsbacher et al. (2001) stimuli along with 30 new metaphorical sentences were rated on familiarity by seven raters along a 1 - 7 scale (1 = *not all familiar*, 7 = *highly familiar*). From this sample we selected 20 metaphors with the lowest familiarity ratings (M = 2.23, SD = 0.62) to serve as stimuli for the novel metaphor condition (e.g., *My mother says envy is rust*), and 20 metaphors with the highest familiarity ratings (M = 5.89, SD = 0.64) to serve as stimuli for the familiar metaphor condition (e.g., *Her husband is a gem*). This difference in ratings was significant $t(38)= 18.40$, $p < .01$. Additionally, latent semantic analysis (LSA) was used to provide a measure of semantic similarity between each metaphor's vehicle and topic terms. Similarity was higher for the familiar metaphors (M = .12, SD = .10) compared with the novel metaphors (M = .04, SD = .05), $t(38) = 2.23$, $p < .01$. The sentences used similar syntactic structures; were similar in word count between the familiar (M = 6.0, SD = 1.3) and novel conditions (M = 6.6, SD = 1.2) $t(38) = -1.57$, $p > .05$; and similar in syllable count between the familiar (M = 9.0, SD = 2.7) and novel conditions (M = 10.2, SD = 2.2) t(38) = -1.59, p > .05. Adjusting response time measures for sentence length did not change the pattern of results for either Experiments 2 or 3.[1]

A set of 40 cue-response word pairs were created using these stimuli, in which the cue was the metaphor vehicle of the sentence, and the response was a literal associate of the vehicle unrelated to the figurative meaning (e.g., *RUST-red*). The assessment of base-rate recall for the target responses was tested in a norming study with ten participants, following the same base-rate assessment procedure as the norming study used for Experiment 1, with the addition of a second recall phase administered via E-prime, which was identical to the final recall procedure of Experiment 1. This ensured that words appearing in the different conditions were matched according to recall rate on the second test without any intervening task. Average percent recall

was 94% (SD = 10%) for the familiar vehicles, and 94% (SD = 9%) for the novel vehicles. The stimuli were split into two lists of 20 items, each list containing 10 items associated with novel metaphors and 10 items associated with familiar metaphors. The two lists were used to counterbalance materials across the two conditions, with equal numbers of participants in each condition. Each of the 4 subsets of 10 items were matched for rate of recall on the second test, written frequency, number of letters, and number of syllables. The cue words were matched on the number of living things.

Procedure

The procedure and scoring of the final recall test was identical to that of Experiment 1.

Results

Analysis of response times revealed that participants spent longer thinking of interpretations of novel metaphors (M = 7.6 s, SD = 2.6 s) than familiar metaphors (M = 4.9 s, SD = 1.6 s), $F1(1, 29) = 72.26$, $p < .01$, $\eta_p^2 = .71$, suggesting greater processing difficulty for novel metaphors.

An examination of average initial recall for all items revealed one outlier that was more than 3 SDs below the mean, so this item was dropped from analyses. The percentage of correct responses on the initial and final recall test were computed separately for the familiar and novel metaphor conditions, and the two no-metaphor conditions, to create four recall accuracy scores for each subject for both initial and final tests. When the initial recall scores (M = 97%, SD = 4%) were entered into a two-way repeated measures ANOVA, no differences were seen due to either metaphor condition, $F1 < 1$; $F2 < 1$, or familiarity, $F1 < 1$; $F2 < 1$.

As shown in Table 2, when the final recall scores were entered into a two-way repeated measures ANOVA, there was a main effect of metaphor condition, $F1(1, 29) = 11.33$, $p < .05$,

$\eta_p^2 = .28$; *F2*(1, 37) = 7.53, $p < .05$, $\eta_p^2 = .17$, such that recall for items appearing in metaphors was lower than recall for items not appearing in metaphors. There was also a main effect of familiarity, *F1*(1, 29) = 13.67, $p < .05$, $\eta_p^2 = .32$; *F2*(1, 37) = 4.51, $p < .05$, $\eta_p^2 = .11$, such that recall for response words associated with novel vehicles was lower than for words associated with familiar vehicles, regardless of whether they appeared in metaphor sentences. The interaction was not significant, *F1* < 1; *F2* < 1.

Discussion

The results of Experiment 2 replicate the metaphor-induced forgetting effect seen in Experiment 1. When participants read and were prompted to generate an interpretation for a metaphoric expression, they were less able to retrieve the associate they had learned previously for the vehicle. The results also indicated a main effect for familiarity condition such that the words associated with the novel vehicles were recalled less at final recall regardless of whether or not they appeared in metaphor sentences. This result was unexpected because the norming study had suggested that the recall rates would be more similar in the no-metaphor condition, and because recall rates were matched at initial recall. Further, contrary to the strong prediction that more forgetting would be seen for novel expressions, a forgetting effect was found even for familiar metaphors.

One explanation for this general forgetting effect might be the methodology that was used in the first two studies. Requiring participants to explicitly type in an interpretation of a familiar metaphor might serve as a source of interference that blocks access to the initially learned associates. In contrast to forgetting via an inhibitory route, the blocking account serves as a common alternative explanation for many RIF results (MacLeod, Dodd, Sheard, Wilson & Bibi, 2003). In an attempt to reduce the likelihood of blocking or interference as a source of

forgetting, in Experiment 3 participants were only asked to read the metaphoric statements, and not to interpret them. Removing the instruction to generate an explicit interpretation was intended to eliminate a potential source of interference, thereby providing a closer measure of inhibitory-based forgetting as a result of normal reading processes.

Experiment 3

Because instructing participants to produce a written interpretation for each metaphor may have been partly responsible for the forgetting effects seen in the previous experiments, Experiment 3 attempted to demonstrate forgetting effects when participants were simply instructed to read metaphors. Experiment 3 tested whether forgetting depends on forcing participants to generate a written interpretation, or whether it is the result of the attempt to process a metaphor. To test this hypothesis, participants were simply instructed to read metaphors in a reading-only condition.

Instead of generating written interpretations of the metaphoric sentences, participants in the reading-only condition were told to press a key when they were done reading the sentences. This condition allows us to see metaphor-induced lexical forgetting patterns in a more natural reading context (without the explicit requirement of typing in an interpretation). If inhibition is utilized during the course of simply reading novel metaphors, then forgetting of literal associates of novel metaphor vehicles should be still observed, as it was in Experiment 2. However, if inhibition is not as necessary during the course of simply reading *familiar* metaphors, then no such forgetting should be observed, in contrast to the findings of Experiment 2. This would suggest that the forgetting that did result from interpreting familiar metaphors in Experiment 2 was due to interference arising from participants' explicitly generated interpretation.

Method

Participants

Participants consisted of 26 fluent English-speaking undergraduates from the University of Illinois at Chicago subject pool. Participants provided agreement to participate and were given course credit for participation.

Design

Experiment 3 used a 2 x 2 design with metaphor processing condition (read metaphor vs. no-metaphor) and familiarity condition (familiar vs. novel metaphors) fully crossed within subjects.

Materials

The same materials were used as in Experiment 2.

Procedure

The procedure was similar to that of Experiment 2 except that participants were instructed to simply carefully read each sentence, and to press a key after doing so.

Results

Examination of reading times revealed that one participant's reading time (18.1 s) was over 3 SDs above the mean. After excluding this participant, participants took 3.9 s (*SD* = 1.6) to read familiar metaphors and 4.7 s (*SD* = 1.7) to read the novel metaphors $F1(1, 25) = 24.22$, $p < .01$, $\eta_p^2 = .50$, indicating that metaphor novelty still impacted processing time, despite the lack of a requirement to generate an interpretation. Initial recall scores were entered into an ANOVA crossing metaphor condition and familiarity. There were no effects of metaphor condition, $F1 < 1$; $F2 < 1$, familiarity $F1(1, 24) = 2.41$, $p = .13$, $\eta_p^2 = .09$; $F2(1, 38) = 1.90$, $p = .18$, $\eta_p^2 = .05$, nor an interaction, $F1(1, 24) = 1.70$, $p = .20$, $\eta_p^2 = .06$; $F2(1, 38) = 2.26$, $p = .14$, $\eta_p^2 = .06$.

For the final recall data, the ANOVA revealed a main effect of metaphor condition, $F1(1, 24) = 7.19$, $p < .05$, $\eta_p^2 = .23$; $F2(1, 38) = 3.45$, $p = .07$, $\eta_p^2 = .08$, with more forgetting in the metaphor condition than the no-metaphor condition, and a marginal effect of familiarity, $F1(1, 24) = 3.69$, $p = .07$, $\eta_p^2 = .13$; $F2(1, 38) = .83$, $p = .38$, $\eta_p^2 = .02$, with greater forgetting associated with novel than familiar metaphors. The interaction of metaphor condition and novelty was also significant, $F1(1, 24) = 4.81$, $p < .05$, $\eta_p^2 = .17$; $F2(1, 38) = 4.58$, $p < .05$, $\eta_p^2 = .11$. As shown in Table 3, there was more forgetting of literal associates from having read novel metaphors, compared with the no metaphor condition, $F1(1, 24) = 10.00$, $p < .01$, $\eta_p^2 = .29$, $F2(1, 19) = 6.12$, $p < .05$, $\eta_p^2 = .24$, but no forgetting was observed for reading familiar metaphors compared with the no metaphor condition $F1 < 1$; $F2 < 1$.

Discussion

In Experiment 3, forgetting was still observed under reading-only instructions, which supports the hypothesis that forgetting did not depend on forcing participants to generate a written response. Critically, the interaction between familiarity and metaphor exposure was significant, as the forgetting effect was only observed for novel metaphors, and not for familiar metaphors.

General Discussion

Across all three experiments, following the processing of metaphoric sentences, recall of literal associates of metaphor vehicles that were irrelevant to the metaphoric meaning of the sentences was impaired. However, differences in patterns between Experiments 2 and 3 suggest that there may be two different sources of forgetting in these studies. In Experiment 2, forgetting may have resulted from post-comprehension interference from the metaphor interpretation which

prevented access to the initially learned item. This resulted in forgetting associated with both types of metaphors.

However, in Experiment 3, a different pattern emerged. Forgetting was observed under reading-only instructions, in which no such explicit interpretation had to be articulated by the reader. Moreover, this forgetting effect was *only* observed for novel metaphors, and not for familiar metaphors. If forgetting resulted purely from interference arising from the metaphoric meaning, or from the formation of a new associative relationship in the metaphor processing task, one would not expect metaphor novelty to differentiate this effect. In fact, one might argue that forgetting would be stronger for familiar metaphors, due to their highly salient meaning. Thus, while an interference account may provide the best fit for the pattern of results seen in Experiment 2, it cannot explain the pattern seen in Experiment 3.

This pattern instead suggests that the locus of the forgetting effect lies earlier in the comprehension process and is a result of inhibitory mechanisms. Specifically, we suggest that upon encountering a novel metaphor vehicle in a sentence, attempts at integrating the vehicle and topic are unsuccessful due to inappropriate meaning activation. This failure then drives a selection process which requires inhibition of the episodic trace containing the previously learned literal associate, which results in forgetting. On the other hand, upon encountering a familiar metaphor vehicle, attempts at integrating the vehicle and topic may be more successful if the vehicle readily activates a known metaphoric category. This reduces the need for inhibition and therefore less forgetting is seen.

This explanation is compatible with both categorization (Glucksberg, 2008), and comparison (Bowdle & Gentner, 2005) models of metaphor processing. These models suggest that, generally, metaphors are processed as categorization statements when possible. As

described above, for familiar metaphors, it may be relatively easy to select the relevant properties from the irrelevant properties because the vehicle word strongly activates a superordinate category of meaning. Because there is no competition during retrieval of the appropriate meaning, category-based processing does not result in forgetting. However, attempts at processing novel metaphors via such a categorization process will fail. This will prompt the reader to engage in a selection process which involves activating many features of the topic and vehicle in order to compare them and find an alignment. While novel metaphors might also be understood as categorizations *once* they are processed and understood, achieving this resolution requires a search process in which irrelevant features of the vehicle are likely to be activated, and thus may need to be inhibited, resulting in forgetting.

These results suggesting inhibitory processes are also consistent with individual difference findings implicating the need for control mechanisms to inhibit irrelevant information during metaphor processing (Chiappe & Chiappe, 2007), and modeling work which requires inhibitory connections to features of the metaphor vehicle that are less important (Kintsch, 2000). Additionally, these findings dovetail with neuroimaging research indicating increased activity in left inferior frontal gyrus while reading novel metaphoric or non-meaningful sentences compared with literal sentences (Rutter et al., 2012; Stringaris, Medford, Giampietro, Brammer, & David, 2008). Activation in this area has been associated with controlled semantic retrieval (Wagner, Paré-Blagoev, Clark & Poldrack, 2001) as well as with RIF (Wimber, et al., 2008).

There are some limitations to this work that should be noted. For instance, this work compared forgetting effects for familiar and novel metaphor stimulus sets which could not be matched as completely (i.e. it was not possible to change metaphors from familiar to novel by using the same sentence frame and changing only a single word). Thus, there is a need to

replicate these effects using better matched literal control sentences as comparisons. In addition, it seems important to add comprehension checks for the read-only conditions. More work is also needed to address how other properties of metaphors, such as aptness and topic constraint, might affect forgetting patterns. It would also be worthwhile to extend this work to other linguistic tropes including idioms, sarcasm and irony.

Conclusion

In summary, the results of these experiments extend previous work showing forgetting as a consequence of creative problem solving in which irrelevant information must be overcome (Storm et al., 2011; Storm & Patel, 2014). These findings indicate that forgetting of irrelevant literal information may be a useful part of novel figurative language processing. When encountering such creative uses of language, successful comprehension may partly depend on reducing the activation of irrelevant literal information in memory. Particularly the results of the third experiment suggest this is likely a reflection of inhibitory processes that are utilized to aid processing.

References

Anderson, M. C., Bjork, E. L., & Bjork, R. A. (1994). Remembering can cause forgetting: Retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory & Cognition, 20,* 1063-1087.

Blasko, D.G., & Connine, C.M. (1993). Effects of familiarity and aptness on metaphor processing. *Journal of Experimental Psychology: Learning, Memory & Cognition, 19,* 295-308.

Bowdle, B.F., & Gentner, D. (2005). The career of metaphor. *Psychological Review, 112,* 193-216.

Chiappe, D. L., & Chiappe, P. (2007). The role of working memory in metaphor production and comprehension. *Journal of Memory and Language, 56,* 172-188.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science, 7,* 155-170.

Gentner, D., & Wolff, P. (1997). Alignment in the processing of metaphor. *Journal of Memory and Language, 37,* 331-355.

Gernsbacher, M. A., Keysar, B., Robertson, R. R., & Werner, N. K. (2001). The role of suppression and enhancement in understanding metaphors. *Journal of Memory and Language, 45,* 433-450.

Glucksberg, S., Gildea, P., & Bookin, H. B. (1982). On understanding nonliteral speech: Can people ignore metaphors? *Journal of Verbal Learning & Verbal Behavior, 21,* 85-98.

Glucksberg, S., McGlone, M. S., & Manfredi, D. (1997). Property attribution in metaphor comprehension. *Journal of Memory and Language, 36,* 50-67.

Glucksberg, S., Newsome, M. R., & Goldvarg, Y. (2001). Inhibition of the literal: Filtering metaphor-irrelevant information during metaphor comprehension. *Metaphor and Symbol, 16*, 277-293.

Glucksberg, S. (2008). How metaphors create categories--quickly. *The Cambridge Handbook of Metaphor and Thought.* (pp. 67-83) Cambridge University Press, New York, NY.

Kintsch, W. (2000). Metaphor comprehension: A computational theory. *Psychonomic Bulletin and Review 7*, 257-266.

MacLeod, C. M., Dodd, M. D., Sheard, E. D., Wilson, D. E., & Bibi,U. (2003). In opposition to inhibition. In B. H. Ross (Ed.), *The Psychology of Learning and Motivation* (Vol. 43, pp. 163–214). San Diego, CA: Academic Press.

Ortony, A. (1979). Beyond literal similarity. *Psychological Review 86*, 161-180.

Rutter, B., Kröger, S., Stark, R., Schweckendiek, J., Windmann, S., Hermann, C., & Abraham, A. (2012). Can clouds dance? Neural correlates of passive conceptual expansion using a metaphor processing task: Implications for creative cognition. *Brain and Cognition, 78*, 114-122.

Searle, J. (1979). Metaphor. In A. Ortony (Ed.), *Metaphor and Thought* (2nded., pp. 83-111). Cambridge, England: Cambridge University Press.

Silvia, P.J., & Beaty, R. E. (2012). Making creative metaphors: the importance of fluid intelligence for creative thought. *Intelligence 40*, 343–351.

Storm, B. C., Angello, G., & Bjork, E. L. (2011). Thinking can cause forgetting: Memory dynamics in creative problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37*, 1287-1293.

Storm, B. C., & Levy, B. J. (2012). A progress report on the inhibitory account of retrieval-induced forgetting. *Memory & Cognition, 40,* 827-843.

Storm, B. C., & Patel, T. N. (2014). Forgetting as a consequence and enabler of creative thinking. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40,* 1594-1609.

Stringaris, A. K., Medford, N. C., Giampietro, V., Brammer, M. J., & David, A. S. (2007). Deriving meaning: Distinct neural mechanisms for metaphoric, literal, and non-meaningful sentences. *Brain and Language, 100*, 150-162.

Wagner, A.D., Paré-Blagoev, E.J., Clark, J., & Poldrack, R.A. (2001). Recovering meaning: Left prefrontal cortex guides controlled semantic retrieval. *Neuron, 2,* 329-338.

Wimber, M., Bäuml, K., Bergström, Z., Markopoulos, G., Heinze, H., & Richardson-Klavehn, A. (2008). Neural markers of inhibition in human memory retrieval. *The Journal of Neuroscience, 28,* 13419-13427.

Wolff, P., & Gentner, D. (2011). Structure-mapping in metaphor comprehension. *Cognitive Science, 35,* 1456-1488.

Table 1

Final recall for the metaphor and no-metaphor interpretation conditions in Experiment 1

Metaphor condition	*M*	*SD*
Metaphor	76%	19%
No-Metaphor	85%	16%

Table 2

Final recall for the metaphor and no-metaphor interpretation conditions for familiar and novel metaphors in Experiment 2

	Familiar		Novel	
Metaphor condition	*M*	*SD*	*M*	*SD*
Metaphor	86%	13%	78%	15%
No-Metaphor	92%	10%	86%	12%

Table 3

Final recall for the metaphor and no-metaphor reading conditions for familiar and novel metaphors in Experiment 3

	Familiar		Novel	
Metaphor condition	*M*	*SD*	*M*	*SD*
Read Metaphor	84%	16%	74%	19%
No Metaphor	83%	14%	84%	13%

Footnotes

[1] The novel metaphor sentences did appear to have a higher character count than the familiar metaphor sentences. Entering the difference in the RT/character ratio between familiar and novel sentences as a covariate in an ANCOVA produced the same pattern of results as the ANOVA for both Experiments 2 and 3.