Analogy-Induced Forgetting:

Inhibitory Mechanisms During Analogical Transfer

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THESIS

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I dedicate this thesis to my wife, Laura Schuetz, who supported me emotionally and financially for 6 years of graduate school without filing for divorce, and to my dog, Judy, who is a national treasure.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
F	Test Statistic Based on the Fisher-Snedecor Distribution
M	Mean
η_p^2	Partial eta-squared Measure of Effect Size
N	Number in group
RAT	Remote Associates Test
RIF	Retrieval-Induced Forgetting
SD	Standard Deviation
t	Test Statistic Based on Gasser's Student Distribution
X^2	Chi-Squared Test

SUMMARY

Connecting prior experiences to current problems is one means of generating solutions and is important for creative cognition. However, people often fail to retrieve useful solutions when cued with a novel problem. When non-useful sources of information (containing unviable solutions) are activated, inhibitory mechanisms may be needed to overcome this competition so that more useful sources (containing viable solutions) can be considered. These experiments explored the role of surface-similarity and accessibility of potential analogues in producing competition among multiple candidate solutions. A forgetting paradigm (Experiment 1) and a reminding paradigm (Experiment 2) were used to test for competition from unviable but surface-similar solutions presented in *separate* stories. Experiment 3 utilized a forgetting paradigm to test for competition arising from multiple solutions embedded within a *single* story context. Predictions from prior work on analogical transfer and problem solving have highlighted how surface similarity misdirects solution attempts and has implicated the need to reduce competition from non-useful surface-only analogues. In contrast, these studies showed that it was when multiple candidate solutions were embedded within a single source story that the most robust forgetting of unviable solutions was found.

INTRODUCTION

When attempting to solve or reason about a novel problem, it can often be helpful to use experience with a prior situation that contains key similarities to the new problem. When the solution experience from a previous *source* problem or situation is directly applied to reach the solution to a novel *target* problem, analogical transfer is said to have occurred (Gick & Holyoak, 1980). While it is fairly common to use old solutions to solve new (but similar) problems within a domain, often the most compelling analogies are between dissimilar situations that cross domains (Green, Kraemer, Fugelsang, Gray, & Dunbar, 2010). Additionally, sometimes there are no useful similar situations available to help solve a novel problem, requiring a search for more distant but analogically-relevant situations. Part of what makes analogical transfer across domains difficult is that it requires focusing on *structural* or *relational* information between objects or story elements, rather than on the objects or elements themselves (Gentner, 1983). Because cross-domain analogues tend to lack obvious similarity, the structural overlap is often not apparent. This may cause people to bring to mind situations that bear some similarity to the target problem, but that ultimately offer unviable solutions (Bassok, 2003). Thus, people must overcome these obvious ideas so that they make creative connections to more remote situations (Smith & Linsey, 2011; Smith & Ward, 2012). However, people are often unable to accomplish this. One common explanation for the low rates of analogical transfer that are typically observed is that solvers are unable to retrieve relevant analogues due to competition among potential candidate solutions. The main questions explored in this set of studies are whether and when forgetting may play a role in overcoming competition among potential candidate solutions during cross-domain analogical problem solving.

1.1 <u>Prior Research on Cross-Domain Analogical Problem Solving</u>

For illustration of a cross-domain analogy, one can consider the classic work using Duncker's (1945) Ray problem (the target problem) and "The General" source story (Gick & Holyoak, 1980; 1983). The main character in "The General" plans to lead his army to capture a fortress. There are many roads converging on the fortress that have been mined by the enemy. This prevents the general from sending his entire army down a single road, because the weight of such a large force would detonate the mines, harming the army and nearby villages. His solution is to divide his army into smaller groups, and send them down the multiple roads simultaneously toward the fortress without detonating the mines so that the forces converge to capture the fortress. In the Ray problem (see Appendix A), a doctor must treat a patient with an inoperable stomach tumor. There is a ray that can be used to destroy the tumor if the ray's intensity is high enough, but this would result in destroying healthy tissue as well. The analogous solution suggested by "The General" story is to direct multiple low-intensity rays at the tumor simultaneously from different directions, sparing the healthy tissue while destroying the tumor. These two stories and their solutions are structurally consistent with each other due to the shared *convergence* principle that relates the story elements with one another. However, these stories differ considerably in their surface content (e.g., rays vs. armies, tumor vs. fortress), that is they are low in semantic overlap.

While the correspondence between the stories seems obvious from a *post hoc* perspective, it is actually quite uncommon to observe spontaneous transfer between such problems in experimental settings (see George & Wiley, 2018, for a recent review). For instance, in one of Gick and Holyoak's (1983) experiments, participants initially studied "The General" in one phase, followed by a second phase in which they attempted to solve the Ray problem. However, the observed solution rates for the Ray problem were only around 30% (for comparison, baseline solution rates in the absence of a source story were around 10%). Many other studies have also documented low transfer rates using similar paradigms involving processing a source story followed by a target problem (Anolli, Atonietti, Crisafulli & Cantoia, 2001; Catrambone & Holyoak, 1989; Corkill & Fager, 1995; Gick, 1985; Holyoak & Koh, 1987; Keane, 1987; Spencer & Weisberg, 1986). The typical rate of spontaneous transfer to the Ray problem in these sorts of studies averages around 24% (George & Wiley, 2018).

What is it that prevents transfer from taking place at higher rates? There are three broad phases of transfer to consider in answering this question. First, in order for transfer to take place, an analogical source must be sufficiently encoded into memory. Second, upon a subsequent encounter with a target problem, the source must be accessed and retrieved. Third, there must be a mapping or application – the relations in the source are put in correspondence with those of the target in a way the leads to successful problem solving. It appears that one of the major obstacles to transfer lies in the second phase: the failure to retrieve the prior source problem in relation to solving the target problem. That is, even though the source has been encoded into memory, people are unlikely to spontaneously retrieve the critical information that can then subsequently be applied to the target problem. This is demonstrated by a condition first used by Gick and Holyoak (1983), which provided participants with an explicit hint to use the source story in attempting to solve the Ray problem. This resulted in solution rates increasing to around 50%. Additionally, in their earlier series of experiments (1980), this rate of hinted solution approached 100% when participants were permitted to fully reread the source story during problem solving (i.e., when the burdens of both retrieval and encoding were completely removed). This suggests that people may not experience as much difficulty in mapping analogical relations between two situations once they are aware that there is a connection between them, but rather that they experience difficulty spontaneously retrieving past analogical situations.

1.2 Retrieval Competition as an Obstacle for Transfer

One way of viewing this obstacle is through the framework of retrieval competition. When faced with a novel problem, we have a large number of prior life experiences that we could consider in our search for a solution. Similarly, in laboratory studies, there are often multiple sources of information that may be encountered prior to attempting a problem. When prompted to think of solutions for a new problem, the semantic content of the problem will trigger retrieval processes that activate multiple sources of information in memory. There are several ways in which retrieval competition may arise from the activation of multiple sources of information during analogical problem solving. The most frequently-addressed in the literature is surface-level competition – that is, solutions that share more surface-level similarity to the target problem are assumed to interfere with access to solutions that share less surface-level similarity. However, other factors related to encoding may also influence the degree to which unviable solutions may interfere with problem solving. For instance, when an unviable solution has primacy in memory (i.e., is encoded earlier) then it may be more likely to produce proactive interference (Storm & Bjork, 2016). Additionally, when an unviable solution is located within the same context as a viable one, then it may be more likely to create interference due to the shared context.

1.2.1 Competition Due to Surface-level Overlap. The dominant explanation for the lack of retrieval of analogical sources stems from the distinction between surface-level and structural-level similarity among analogues, and their differential impact on retrieval. Structural information is integral to the meaning of the analogy and refers to the higher-order relationships between the different elements and objects of the source. In order for an analogy to convey meaning, a system of relations that is present in the source must also be present in the target (Gentner, 1983). Surface information is non-essential information related to the specific objects and details presented within each analogue. In this context, surface similarity refers to similarity in semantic content (e.g., a situation about treating a patient with a tumor has surface-similarity to a situation about a person seeking medical treatment for back pain). Whereas changing structural information in one story of a source-target pair will influence the meaning or soundness of an analogy, changing surface information has no effect on the underlying causal relationships of the analogy. However, surface-level similarity, rather than structural similarity, plays a large role in the likelihood of an analogue being accessed in memory.

An example of the influence of surface information on retrieval comes from a set of studies by Gentner, Ratterman, and Forbus (1993) in which participants initially studied a set of brief source stories. In one story, "Karla the Hawk", a hunter attempts to shoot a hawk with an arrow that has no feathers, which results in the arrow missing the hawk. The hawk then offers the hunter some of her tail feathers to use. The hunter is grateful for this, and pledges to never shoot the hawk. A week after reading this story, participants were presented with a set of new stories that matched the source stories on either structural information (analogical match), or surface information. For example, a structurally-similar target might describe a warlike country's failed missile-attack on a neighbor, followed by the neighbor offering computers to help guide the aggressor's missiles, which results in the aggressor promising to cease its attacks. A surface-similar target might describe a story involving an eagle and a hunter, but without the key thematic structural overlap (i.e., retraction of aggression after receiving a favor). Participants were asked to report which of the previous studied stories they were reminded given the new story, and to recall as much as they could from the source story. They found that surface matches produced the greatest amount of recall compared to analogical matches. However, when subsequently asked how good of a match a given pair of stories was (indicated by soundness ratings), structural matches were rated as being the most sound. This indicates a dissociation between the kind of source-target similarity that affects retrieval and the kind that affects the evaluation of the aptness of an analogy.

Other work has more directly addressed the notion of competition in retrieval and selection of analogical sources. In a series of experiments by Wharton et al. (1994), participants studied a series of brief passages containing key target sentences embedded within them. Later they were presented with a series of cue sentences and were asked to write down the text of any previous passages of which they were reminded, writing down as much information as they could. Cue sentences (e.g., *The rabbi calmed the chairmen*) were sometimes related to the previous passages by being either 1) relationally consistent with them (e.g., *Having just been fired from a high level job, he decided to go to his church for counseling. The pastor calmed the businessman),* or 2) inconsistent due to switched roles (e.g., *The church was having trouble approaching local corporations for contributions to the shelter. The executive soothed the priest*). In both cases, there is a strong semantic similarity despite the structural inconsistency of the second example. An additional important manipulation of Wharton et al. is that some people read *both* of these passages (the competition condition), whereas others got only one of them (singleton condition). Unlike other studies on analogical retrieval that generally use only single sources (e.g., Gentner et al., 1993), this competition condition meant that there were two items in memory that were likely to be triggered by the cue: one bearing semantic overlap only, and one bearing semantic and relational overlap. Overall retrieval tended to be lower in the competition condition. Using a similar paradigm, this general pattern was found even when participants were forced to try their best to remember both targets (Wharton, Holyoak, & Lange, 1996). The overall reduced retrieval for sources in the competition condition is consistent with the idea that analogical retrieval can be impaired by the presence of competing information in memory.

While the Wharton et al. (1994) used simple sentence materials, research has also explored the accessibility of potential analogues as a function of surface overlap in the Gick and Holyoak paradigm. For example, Catrambone (2002) examined reminding rates of previously studied source stories which varied in their match with new stories in terms of both the amount of surface matches (object-level), and the amount of lower-order relational matches (first-order relations between objects), while keeping higher-order relations constant (i.e., the overall causal structure of the analogue). Increasing both the number of object and first-order relational matches increased the likelihood of retrieval. Thus, new stories that shared few similar objects and few similar first-order relations with the source story (despite containing an overall analogical match in higher-order relations) produced the lowest rate of retrieval, while increasing the number of similar objects and first-order relations increased the rate of retrieval.

The dissociation between retrieval and mapping is a recurring theme in other research. Keane (1987) presented participants with either a remote analogue (The General) or a literal analogue (The Surgeon). Both analogues used the convergence solution, but the literal analogue also shared a large number of surface features with the subsequent target Ray problem. Participants were explicitly instructed to think of analogous problems before attempting to solve the Ray problem. Participants who had initially received the remote analogue rarely retrieved it in response to the Ray problem, while participants who had received the literal analogue frequently retrieved it. However, when explicitly instructed to use the previously-read story to solve the target problem, participants' solution success was fairly high and similar between the remote and literal conditions, indicating that they were able to make use of the structural information when it was prompted.

Blanchette and Dunbar (2000) demonstrated a similar dissociation between generation and retrieval. They found that when participants were tasked with generating their own compelling source analogies for a given target situation, they produced analogies that were generally high in structural overlap while superficially dissimilar. However, when the task was to *retrieve* a similar source among a set of previously encountered stories given the target, people tended to retrieve the sources that were superficially similar, rather than structurally similar.

It should be noted that people are not completely insensitive to structural similarity during retrieval and are only sensitive to surface similarity. For instance, Holyoak and Koh (1987) found that both better structural overlap and better surface overlap between a source and target led to higher rates of spontaneous transfer. Catrambone's (2002) finding that the presence of more first-order relations between a source and target led to a greater likelihood of participants being reminded of the source also suggests that some structural information plays a role in analogical access. In general, however, surface similarity plays a large role in how people retrieve potential analogues.

Taken together, the message of these findings is that when presented with a target problem retrieval does not automatically lead one to remote analogies, and there is a large amount of competition from irrelevant sources (Wharton et al., 1994). Even though people can be fairly effective at drawing relational comparisons from a source to a target when explicitly prompted to do so, the initial access to viable, remote analogical sources may get blocked by information that has more obvious commonalities with the target. This prior literature seems to suggest that the tendency to focus on surface features can impede access to remote sources of information that are nonetheless structurally relevant to the generation of a solution. For instance, when prompted with the Ray problem, this may initially cue retrieval of knowledge closely related to medical procedures (Gick & Holyoak, 1983). If an unviable solution is introduced in a context related to medical procedures, then this analogue may be highly activated, and may require inhibition in order for the solver to access the viable but more remote analogue. Such an inhibitory view of analogical access is consistent with modeling frameworks such as ARCS (Thagard, Holyoak, Nelson, & Gochfeld, 1990), MAC/FAC (Forbus, Gentner & Law, 1995), and LISA (Hummel & Holyoak, 1997).

1.2.2 Competition Due to Other Encoding Factors

Additionally, order of encoding may impact retrieval competition among potential solutions. Strong primacy effects over brief delays have been observed such that texts studied earlier in a study period tend to gain greater access than texts studied later (Bjork, 2011; Bjork & Storm 2016; Sehulster, McLaughlin, & Crouse, 1974; Thorndyke, 1977). If encoding order impacts the accessibility of later solutions, then this may involve greater need to resolve competition when unviable solutions are encoded first.

Another factor that may affect the accessibility of viable solutions is when they are embedded in the same context as unviable solutions. Prior work suggests that the need to *selectively* retrieve information from a single context may also require more inhibition than when information appears in distinct contexts. Studies using Retrieval-induced Forgetting (RIF) paradigms with text material typically find that selective retrieval *within* a text causes forgetting of other information specifically from that text (relative to another text). The logic of this is that when one is required to selectively retrieve information from a particular passage, other information from that passage may also come to mind and compete for retrieval. A consequence of this selective retrieval is forgetting of the other subsections of the text relative to a comparison text. One possibility is that inhibitory processes are recruited to reduce activation of this competing information, which results in forgetting. In general, it appears that this forgetting is most likely to be seen for subsets of information that are presented within the same passage context.

1.3 Using Forgetting Paradigms to Test for Inhibition

To the extent that a novel target problem cues retrieval of competing unviable, extraneous or superficial information, inhibitory processing may be utilized to guide retrieval to more solution-appropriate sources. Cho, Holyoak, and Cannon (2007) have also suggested that a source of difficulty in judging whether one pair of items is analogically related to a previously-encountered pair arises from the need to suppress unviable information that had been maintained in working memory. If this is the case, one consequence of such processing could be a reduction in access to the unviable information (i.e., forgetting). This prediction stems from extensive evidence from the Retrieval-induced Forgetting (RIF) framework (Anderson, Bjork & Bjork, 1994). In RIF, retrieval of a target item in memory causes temporary inaccessibility of other related but irrelevant information, and this is thought to reflect an adaptive inhibitory mechanism (Anderson, 2003; Bjork, 1989).

1.3.1 Early Retrieval-induced Forgetting Studies Using Word Lists

In a prototypical RIF word-list experiment, participants initially study a series of category-exemplar pairs, for instance *FRUIT-banana*, *FRUIT-lemon*, *TOOL-saw*, and *TOOL-hammer*. In a second retrieval practice phase, participants then attempt to retrieve half of the items from half of the categories (e.g., *FRUIT-b*____). In a final test of recall, participants then attempt to recall all of the items. Not surprisingly, items that had appeared in retrieval practice (referred to as *Rp+* items) are recalled the most accurately (i.e., *FRUIT-banana*). However, the critical observation is that recall of unpracticed items from the practiced categories (referred to as *Rp-* items) is impaired (i.e., *FRUIT-lemon*). This observed impairment is relative to the items from the unpracticed categories (i.e., *TOOL*), which serve as baseline items (referred to as *Nrp* items). This below-baseline impairment of items belonging to the same category cue is commonly explained as a result of inhibitory processes that are engaged during retrieval practice. When required to retrieve a specific item from the *FRUIT* category during retrieval practice (i.e., *banana*), this also triggers activation of other competing information in memory (i.e., *lemon*). Inhibitory mechanisms function to reduce this competition by diminishing the accessibility of the competing items, rendering them less likely to be recalled at the final test. While it has been argued that non-inhibitory processes, such as strength-based interference, may contribute to the RIF phenomenon (MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003), there is a large body of empirical work suggesting that such accounts are insufficient to fully explain the forgetting effect. This body of evidence indicates a strong role for inhibition in RIF (for review, see Storm & Levy, 2012).

1.3.2 Retrieval-induced Forgetting Studies with Text Materials

The occurrence of forgetting due to retrieval competition is not confined to paradigms using word-list methods. It has also been observed using more complex passages of text. Experiments have demonstrated that engaging in retrieval practice for some information from a studied text can subsequently cause reduced recall for other information from the same text (Carroll, Campbell-Ratcliffe, Murnane, & Perfect, 2007; Chan, 2009; Little, Bjork, Bjork, & Angello, 2012; Saunders & MacLeod, 2006; Stone, Barnier, Sutton, & Hirst, 2010), or for other texts sharing similar content (Little, Storm, & Bjork, 2011). Although these studies did not consistently find forgetting (and in some cases observed facilitation rather than forgetting), forgetting did occur under conditions where competition between tested and untested items was high (which is theoretically when inhibition is most likely to be needed to resolve competition). For example, in the Little et al. (2011) study, passages were assumed to be highly competitive because they shared a similar structure of factual statements. Thus, retrieval competition appears in retrieval of more complex materials as well as for word lists, suggesting that such effects may also occur in the context of analogical transfer between complex passages of text.

1.3.3 Retrieval-induced Forgetting-like Effects in Problem Solving

Forgetting effects have also already been demonstrated in problem-solving contexts, particularly on creative problem-solving tasks. In these studies, rather than being asked to selectively *retrieve* information, people attempt to solve a problem wherein previously-studied information is assumed to compete during problem solving attempts. For example, Storm, Angello, and Bjork (2011) examined the relationship between forgetting and performance on the remote associates test (RAT; Mednick, 1962) – which requires making creative connections across weakly related words (e.g., *arm – tar – peach;* ANSWER: *pit*). All participants learned a list of paired associates before attempting to solve the RAT. Half of these paired associations involved words that appeared in the RAT problems (but were not useful for finding the correct solution, e.g., *arm-sleeve, tar-black, peach-tree*). They found that subsequent recall of the previously learned associations was impaired when the association words appeared in the RAT problems relative to when associations did not appear in RAT problems. This result was interpreted as showing a *forgetting effect* indicative of inhibition for irrelevant but competing associations.

Similar forgetting effects have been found for creative problem-solving tasks in which participants attempt to generate unusual uses of everyday objects (Ditta & Storm, 2016; Storm & Patel, 2014). As a consequence of thinking of creative uses, participants forgot common uses that they had studied. George and Wiley (2016; 2019) also found that a consequence of processing novel metaphors (e.g., *envy is rust*) was forgetting of irrelevant associates (e.g., *rust - red*) that had been learned previously. In creative cognition tasks like these, it is assumed that initial associations can interfere with access to more remote but viable solutions, necessitating the use of inhibitory mechanisms in retrieval, which causes forgetting of such irrelevant associates. This helps to enable access to more creative solutions. This application of forgetting-based paradigms to problem solving is known as Problem-solving-induced Forgetting (PSIF; Storm et al., 2015). These paradigms have demonstrated that measures of *forgetting* can provide of a useful way of assessing whether competing information is inhibited during cognitive tasks that involve a conflict in selection of appropriate information. In the present studies, this PSIF methodology is extended to the study of analogical problem solving and transfer, using an *Analogy-induced Forgetting* paradigm. If transferring a viable solution to a target problem involves inhibition of competing unviable solutions, then one might expect reduced recall of previously-studied unviable solutions following transfer attempts. The present experiments test for this possibility by presenting people with texts introducing multiple candidate solutions prior to attempting the Ray problem. Such an effect would be consistent with prior work on RIF and PSIF (e.g., Storm et al., 2015), as well as work on the interfering role of competing sources of information in analogical transfer.

1.4 Overview of Present Experiments

The main questions explored in this set of studies are whether and when forgetting may play a role in analogical transfer. When attempting to generate a solution to a target problem such as the Ray problem, there is likely to be competition in memory among potential solutions. There are three different ways that competition may arise from unviable solutions that were tested by these experiments: a) these solutions may contain surface-level overlap with the Ray problem, b) encoding order may give these solutions primacy in memory, and c) these solutions may be embedded *within* the same context as a viable solution. These experiments test for these possible causes of competition. In all experiments, participants were provided three potential solutions prior to attempting the Ray problem: a) the convergence solution (CONVERGE) which provides the most appropriate means of resolving the problem (e. g., using converging ultrasound waves to repair a broken lightbulb), b) an unviable solution where an exact amount of force must be applied (EXACT), and c) an unviable solution involving destroying a portion of a wine shipment in order to save at least some of it (DESTROY).

Adapting the methodology of forgetting frameworks (Anderson et al., 1994; Ditta & Storm, 2016; George & Wiley, 2016; 2019; Storm et al., 2011; Storm & Patel, 2014), Experiment 1 tested for forgetting of competing solutions presented each in their own story before engaging in analogical problem solving. Using a reminding paradigm (Blanchette & Dunbar, 2000; Catrambone, 2002; Gentner et al., 1993), Experiment 2 tested for retrieval competition between solutions that were each presented in their own story. In contrast to Experiments 1 and 2 where each potential solution was presented in a separate story context, Experiment 3 utilized a forgetting paradigm to test for competition arising from multiple solutions embedded within a *single* story context. Across experiments, forgetting and reminding effects observed as a result of encountering the Ray problem were compared to effects for an unrelated control problem.

2. EXPERIMENT 1

Experiment 1 tested for forgetting as a consequence of competition among potential solutions when attempting to solve the Ray problem. Two sources of competition were tested in this study – competition arising from a solution that shares surface similarity with the Ray problem, and competition arising from the position of this surface-similar solution in the encoding order (i.e., primacy effects or proactive interference).

The design for this experiment was inspired partly by Bearman et al. (2003) who reported a study where readers were provided with a set of three source stories before the Ray problem. The three source stories included an analogical (but superficially dissimilar) story, a superficially similar (but non-analogical) story, and an unrelated story (neither surface similar nor analogical). While the primary question of Bearman et al. was how prompting evaluations of source problems can potentially harm target problem solving success, they also probed memory for the three stories following their procedure. Interestingly, they reported the lowest recall for the superficially similar story. One possible explanation for this result, consistent with the above suggestion, is that this impairment was a consequence of the superficial story being activated during solution attempts for the target problem, which in turn cued inhibition of the competing superficial story. However, this interpretation should be taken with caution because low recall rates were observed for the analogous story as well as the superficially similar story in this study, and no measures were reported of which stories were activated by the target story. It is also possible that the recall pattern could have resulted from different textual properties of the stories making some more memorable than others.

Experiment 1 aimed to test whether attempts at analogical problem solving cause forgetting of competing, unviable solutions. To vary surface-similarity, solutions appeared in the context of three different stories. The DESTROY story was designed to share little overlap with the target problem – it was about wine merchants repurposing wine barrels into a raft. The story does not offer a viable solution, but it also is unlikely to be brought to mind. The CONVERGE story offers the viable solution, but it was also designed to share little surface-level overlap with the Ray problem. In contrast, the EXACT story was designed to share greater surface-level overlap with the Ray problem (e.g., involves application of force, involves medical procedures) than either the DESTROY or the CONVERGE story. It should be noted that although the EXACT story does not share much in terms of verbatim text with the Ray problem, it does involve similar semantic content. Thus, throughout all experiments, the term surface-similarity refers to overlap in semantic content. Because the EXACT story does not offer a viable solution, but because it shares surface-level semantic overlap, inhibitory mechanisms may be needed to reduce the accessibility of information within that source, thereby facilitating access to the less similar but more analogically-relevant CONVERGE story. If this were the case, one would expect subsequent reduced recall of the surface-similar story (EXACT) relative to the unrelated (DESTROY) story (i.e., analogy-induced forgetting) as a result of attempting to solve the target problem. Therefore, planned comparisons between EXACT and DESTROY were conducted to test this hypothesis.

Additionally, competition due to primacy effects or proactive interference was explored by varying the order in which the stories appeared. When the EXACT source is studied prior to the CONVERGE source in the encoding order, this may create stronger competition from EXACT compared to when CONVERGE is encoded first. Consequently, this may involve greater inhibitory processing, which could result in more forgetting of EXACT information. However, when CONVERGE precedes EXACT, this may increase the accessibility of

CONVERGE relative to EXACT when prompted with the Ray problem. This means that little competition arises from the EXACT source, which could reduce inhibitory processing and subsequent forgetting. Therefore, more forgetting would be expected in the EXACT-first condition which could result in an interaction between encoding order and story.

Although the main variable of interest in this study is forgetting, examination of transfer rates from the sources to the Ray problem provides a further test of whether competition among solutions is dependent on encoding order. When the EXACT solution is encoded prior to the CONVERGE solution, it may have more potential to interfere with Ray problem solving which would lead to a lower transfer rate in the EXACT-first condition. Finally, no differences are expected in forgetting between stories when participants are asked to solve the unrelated control problem (Two-ribbon problem).

2.1 Method

2.1.1 Participants and Design

Participants were 240 undergraduates (M_{age} = 19.15, *SD* = 1.27, 60% female) recruited from the University of Illinois at Chicago psychology subject pool. All participants provided agreement to participate and received course credit for participation. The design was a 2 x 2 x 3 mixed design crossing the between-subjects factors problem condition (Ray vs. Two-ribbon) and encoding order (EXACT-first vs CONVERGE-first), and the within-subjects factor solution type (CONVERGE, EXACT, DESTROY). This sample size was based on a power analysis from a pilot study using 21 participants indicating an effect size of .47 (Cohen's *d*) for the DESTROY-EXACT forgetting effect (p = .02). A sample of at least 37 per condition is needed to detect this effect with at least 80% probability.

2.1.2 Materials

2.1.2.1 **Source Stories** Each source story is provided in Appendix B. The Lightbulb story includes the CONVERGE solution, the Osteopath story includes the EXACT solution, and the Wine Merchants story gives the DESTROY solution. Each story was slightly modified from the original versions to make them of similar length (277, 286, and 279 words, respectively).

The rationale for the choice of the Lightbulb as the CONVERGE story (instead of The General used by Gick & Holyoak, 1983) is because Cushen and Wiley (2018) found that the rate of spontaneous transfer to the Ray problem was about 50% using a similar population as the proposed experiments. This suggests a level of difficulty that is neither too close to floor nor ceiling, whereas solution rates for the General were around 30%. Moreover, the Lightbulb seems to represent an analogical source that is not so similar to the Ray problem that the connection will be obvious, but not so distant that *no* activation of any structural (analogical) information can occur.

2.1.2.2 **Recall Task** Each story contained 12 words to be recalled (See Appendix C for the cued recall task, and Table I for the list of recall words). These words were chosen to be as similar as possible in number of letters across stories (CONVERGE $M = 7.33$, $SD = 2.88$; EXACT $M = 8.33$, $SD = 2.71$; DESTROY $M = 7.25$, $SD = 2.13$). The stories were not significantly different in number of letters (ps for all contrasts > .28). The words were also similar in written frequency (CONVERGE $M = 34.88$, $SD = 30.93$; EXACT $M = 54.78$, $SD = 74.70$; DESTROY $M = 41.43$, $SD = 29.99$) and did not significantly differ from each other (ps for all contrasts >.46). For all stories, there were three nouns, five adjectives, and four verbs. (A subset of only the 9 most relevant recall words from each story were also identified and were used in supplemental analyses.)

2.1.2.3 Baseline Recall Rates. To ensure that the three stories did not significantly differ in memorability in the absence of any problem solving, a baseline recall study was first conducted ($N = 36$). This study used the same materials and procedures as the present study, except the problem-solving phase was removed, and participants moved to the recall phase immediately after the filler task. Final recall rates across the three stories did not significantly differ (all ts < 1, CONVERGE = 62%, EXACT = 61%, DESTROY = 59%). Although the use of a control problem condition (Two-ribbon) already provides a comparison to test whether patterns of forgetting following the Ray problem differ from that of an unrelated problem, this preliminary assessment helped to provide initial assurance that memorability is roughly equivalent across the stories.

Table I

Recall Words in Experiment 1

CONVERGE	EXACT	DESTROY
physics	Philadelphia	generous
researcher	alleviate	solid
fused	traveled	expire
sealed	interfering	horse-drawn
ultrasound	lumbar	raging
break	high-velocity	exhausted
jar	assistants	overturned
circle	increase	raft
low-intensity	engineering	barrel
converged	exact	floated
intact	hospital	shore
experiment	thankful	setting

2.1.2.4 Target Problems The Ray problem and Two-ribbon (control) problem were used as target problems (see Appendix A and D).

2.1.2.5 Final Questionnaire A final questionnaire (Appendix E) asked participants' age, gender, and whether they had encountered any of the stories or problems before the experiment.

2.1.3 Procedure

Participants were first presented with the three source stories via Qualtrics. The order of stories was counterbalanced across participants (six possible orders). For each story, participants studied it for 3 min, and then wrote a summary of it for 3 min before moving on to the next story. While writing each summary, the stories were available for participants to refer to. This study-plus-summarize procedure was intended to ensure that participants were actively processing the content of the stories and was used across all experiments.

Participants were provided the following instructions at the start of the study phase:

> "In this task, you will study three stories.
> For each story, you'll get 3 minutes to read the story and then 3 minutes to write a summary of the story (referring back to the story if you wish).
> Study the stories carefully and pay attention to their details, so that you can remember them on a later memory test."

Following the study and summarization phase, participants completed a brief 2 min version of the backward digit span (BDS) as a non-verbal filler task. The BDS involves sequential presentation of strings of digits (ranging from 2-6 digits) which participants are required to recall in reverse order.

Following the filler task, participants completed the problem-solving phase, in which they were presented with the Ray problem (or the Two-ribbon problem) via Qualtrics. Participants were given 5 min to type out as many possible solutions as they could.

Following the problem-solving phase, participants completed the computerized cued-recall task for the source stories. Participants were required to type in the missing word from each sentence within 10 s. The order of stories was randomized to minimize participant predictions about upcoming recall based on original story order, but the cue sentences were presented one at a time, and in the order in which they appeared in the story during the study and summarization phase. The title of the story appeared at the top of the screen so that participants knew which story was to be recalled. Participants were presented with the following instructions prior to the task:

> "You will now be asked to recall all the stories you read earlier.
> You will recall one story at a time. A cue will appear letting you know which story you should recall.
> For each story, you will see some of the sentences along with a response box for you to type in a missing word from the sentence.
> Each sentence will be presented one at a time.
> You will have 10 seconds to type in your response."

There is rationale for choosing this fill-in-the-blank cued-recall task. It was expected that forgetting at this level of representation (i.e., word level) would occur in these experiments for a few reasons. First, participants were initially instructed to pay attention to the details of each story so that they would be recalled on a later memory test. This was intended to decrease the chances that only conceptual-level encoding would occur for each of the stories. Second, the to-be-recalled items mainly reflected content words of the three stories. It was assumed that the target problem would not only cue activation of the general story contexts, but that this activation would spread to these individual content words to some extent. Consequently, any processes that affected the accessibility of this content (i.e., inhibition) should produce differential recall rates at final test. Finally, previous studies using text passages have observed forgetting using similar fill-in-the-blank methods (Chan, 2009; Little et al., 2011).

This was followed by the final questionnaire. The complete order of tasks in sequence was to study and summarize each story, then complete the filler task, then attempt to solve the target problem, followed by the recall task, followed by the final questionnaire.

2.2 Results

2.2.1 Recall

The primary dependent measure for recall was gist-based recall.[1] For gist recall a response was scored as correct if it matched the exact word or used a synonymous term. Two coders scored the responses and agreement was excellent (ICC[2] = .92). Recall scores were entered into a 2 x 2 x 3 mixed ANOVA crossing problem condition (Ray vs Two-ribbon), encoding order (EXACT-first vs. CONVERGE-first) and solution type (CONVERGE, EXACT, DESTROY). Recall rates are displayed in Figure 1.

There were no main effects of problem condition or encoding order (*F*s < 1). There was a marginal main effect of solution type, $F(2, 466) = 2.60$, $p = .08$. The problem condition x encoding order interaction was not significant, nor was the problem condition x solution type interaction, or the three-way interaction (*F*s < 1). The encoding order x solution type interaction was significant, $F(2, 466) = 9.09$, $p < .001$, $\eta_p^2 = .04$). These results are best understood in the context of testing the planned comparisons for each target problem separately.

For the Ray problem, the planned comparison between EXACT and DESTROY was not significant. However, there was an interaction between solution type and encoding order $F(2, 230) = 6.55$, $p < .01$, $\eta_p^2 = .05$. Recall for EXACT was not significantly lower than DESTROY overall, $t(119) = 1.42$, $p = .16$, $d = .13$. However the EXACT-first order led to reduced recall of EXACT compared to DESTROY, $t(59) = 2.06$, $p < .05$, $d = .28$, but the CONVERGE-first order did not, $t < 1$.

For the Two-ribbon problem, the planned comparison revealed that EXACT was marginally lower than DESTROY, $t(119) = 1.42$, $p = .07$. However, although there was an

[1] Supplemental verbatim recall measures were also analyzed. Because these measures were redundant with the primary measure, they are reported in Appendix F. Parallel analyses using only the 9 most relevant recall items for each story are also reported in Appendix F.

interaction between encoding order and problem, $F(2, 230) = 3{,}49$, $p < .05$, $\eta_p^2 = .03$, there were no significant differences between EXACT and DESTROY recall in either the EXACT-first, $t(59) = 1.26$, $p = .21$, or CONVERGE-first order, $t(59) = 1.29$, $p = .20$. This suggests the interaction was partially driven by unexpected differences in CONVERGE recall.

The significant interaction with order both overall and specifically in the Ray problem condition provides some evidence that order and surface similarity combine to produce forgetting in the Ray problem condition. However, the trend for some overall forgetting of EXACT in the Two-ribbon condition suggests this may have been a poor choice as a control problem.

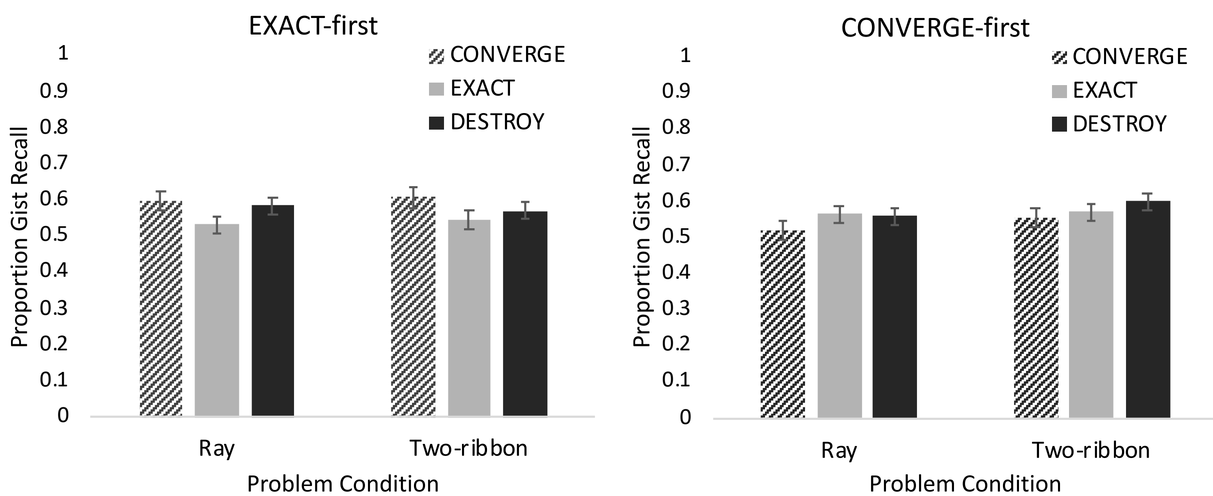

Figure 1. Mean recall proportions for each solution in the Ray and Two-ribbon (control) problems in Experiment 1. The left panel is when the EXACT solution preceded the CONVERGE solution in the encoding order. The right panel is when the CONVERGE solution preceded the EXACT solution in the encoding order. Error bars represent standard errors.

2.2.2 <u>Ray Solution Rates</u>

Examination of transfer rates to the Ray problem helps provide an additional test of whether competition from EXACT may have been stronger in the EXACT-first order. Transfer of the CONVERGE solution to the Ray problem was coded in a binary fashion (correct-incorrect). A solution was coded as correct if it included: a) application of rays from multiple directions, b) simultaneous application of the rays, and c) use of weak rays. The features were based on the scoring procedure of Bearman, Ormerod, Ball, and Deptula (2011). The transfer rate to the Ray problem was 43%. Solution rates were marginally higher in the CONVERGE-first order (52%) than the EXACT-first order, (35%) $\chi^2(2) = 3.39$, $p = .06$.

2.3 Discussion

Experiment 1 tested for forgetting of unviable solutions in a recall task subsequent to analogical transfer attempts. Potential solutions were embedded in separate story contexts and the stories were varied in the order in which the solutions appeared. Some evidence was observed for forgetting of a surface-similar source (EXACT) relative to a dissimilar source (DESTROY) as a result of attempting to solve the Ray problem (but not the control problem) when the EXACT solution was read before the CONVERGE solution. It appears that some forgetting of EXACT was also observed in the Two-ribbon condition, indicating that this control problem may have been problematic.

3. EXPERIMENT 2

The results of Experiment 1 provided some minimal support for the role of forgetting in analogical transfer. The only place where forgetting (DESTROY – EXACT) was significantly observed was when the CONVERGE solution was read before the EXACT solution and participants were attempting to solve the Ray problem. One assumption of Experiment 1 was that competition arises from EXACT due to its surface-level overlap with the Ray problem and that the EXACT source would be more strongly activated than the CONVERGE source upon the initial encounter with the Ray problem. Thus, Experiment 2 was intended to test the assumption of surface-level competition using a reminding paradigm, and whether reminding also varies with encoding order. It also allowed for a test of whether the Two-ribbon problem would cause reminding of either of the sources, which may have been responsible for the unexpected results in the control condition for Experiment 1.

In Experiment 2, participants were asked to report how much the target problem reminded them of each previous story, in the absence of any problem-solving attempts. Reminding was assessed in two ways: First, participants were forced to select which story they were reminded of in response to the target problem. Second, they were further asked to rate how much the target problem reminded them of each story. When prompted with the Ray problem, it was expected that participants would select the EXACT solution more often than the CONVERGE solution while very few participants should select the DESTROY solution. Likewise, reminding ratings for the EXACT solution should be higher than the CONVERGE solution, while ratings for the DESTROY solution should be very low.

This finding would be consistent with prior work using reminding-based paradigms showing that the cases that are readily brought to mind tend to be surface-level cases (Blanchette

& Dunbar, 2000; Catrambone, 2002; Gentner et al., 1993). In these studies, participants typically study a large list of brief source passages, followed by a later presentation of a list of cues that may bear surface or analogical resemblance to the previous passages. When asked to recall the stories they are reminded of, participants report more surface-level matches. Demonstrating a similar pattern in this experiment is important because it helps establish that a form of retrieval competition takes place when encountering the Ray problem. Prior results would predict both that participants presented with the Ray problem should be more reminded of EXACT than DESTROY (the same planned comparison as used in Experiment 1), but also that they should be more reminded of EXACT than CONVERGE. On the other hand, if the results do not indicate that reminding is higher for EXACT than CONVERGE, this could suggest that surface similarity does not induce the presumed competition between solutions. Additionally, as in Experiment 1, encoding order was manipulated to test whether competition from EXACT is strongest when it is encoded prior to CONVERGE. If this is the case, then reminding for EXACT should be higher than CONVERGE in the EXACT-first order but reminding should not differ between EXACT and CONVERGE in the CONVERGE-first order because competition from the EXACT story would be reduced.

For the Two-ribbon problem, reminding ratings should be low and similar across the stories.

3.1 Method

3.1.1 Participants and Design

Participants were 96 undergraduates (M_{age} = 18.92, *SD* = 0.96, 58% female) recruited from the University of Illinois at Chicago psychology subject pool. All participants provided agreement to participate and received course credit for participation. The design was a 2 x 2 x 3 mixed design crossing the between-subjects factors problem condition (Ray vs. Two-ribbon) and encoding order (CONVERGE-first vs EXACT-first) and the within-subjects factor solution type (CONVERGE, EXACT, DESTROY). This sample size is comparable to prior studies that have examined analogical reminding rates (Blanchette & Dunbar, 2000; Catrambone, 2002; Clement et al., 1994; Gentner et al., 1993; Lane & Schooler, 2004; Wharton et al., 1994). Pilot data indicated that this sample was more than sufficient to detect an effect of story (EXACT vs. DESTROY) on reminding ratings (d = 1.50) with 95% probability.

3.1.2 Materials

The materials were the same as in Experiment 1, except the final sentence that prompted participants to actually solve the target problem was removed. This was meant to eliminate any potential covert attempts at problem solving so that patterns of reminding would better reflect initial memory activation. There was no recall task.

3.1.3 Procedure

The procedure for the study and summarization phase in Experiment 2 was the same as in Experiment 1, except following the filler task, participants were asked to simply read the target problem (Ray or Two-ribbon) via Qualtrics. Participants then completed the reminding task. Participants were first given a forced-choice task in which they selected which of the three source stories they were reminded (via story titles). In order to avoid any deeper processing of the problem in a way that may lead to utilization of abstract solution concepts, participants were required to complete their judgments fairly quickly (10 sec). Following this choice, they were additionally asked to rate within 20 sec how much the target problem reminded them of each story on a 1 to 10 scale (1 = *does not remind me of this story*; 10 = *reminds me strongly of this story*).

The reminding task was followed by a questionnaire asking whether they had encountered any of the source stories or the target problem prior to the experiment.

The complete order of tasks in sequence was to study and summarize each story, then complete the filler task, then read the target problem, then complete the reminding task followed by the final questionnaire.

3.2 Results

3.2.1 Reminding Ratings

Reminding ratings were entered into a mixed 2 x 2 x 3 ANOVA crossing problem condition (Ray vs Two-ribbon), encoding order (CONVERGE-first vs. EXACT-first), and solution type (CONVERGE, EXACT, DESTROY). The means are displayed in Figure 2. The main effect of encoding order was not significant ($F < 1$). There was no interaction of solution type and encoding order ($F < 1$), and no three-way interaction ($F < 1$). There was a main effect of problem condition, $F(1, 92) = 13.42$, $p < .001$, $\eta_p^2 = .13$ with higher overall reminding ratings for the Ray problem ($M = 5.51$, $SD = 2.15$) than the Two-ribbon problem ($M = 4.33$, $SD = 2.15$). There was a main effect of solution type, $F(2, 184) = 41.32$, $p < .001$, $\eta_p^2 = .31$, with higher ratings for EXACT ($M = 5.34$, $SD = 3.16$) than DESTROY ($M = 2.99$, $SD = 3.16$), $t(95) = 5.42$, $p < .001$, consistent with the planned comparison. However, in contrast to the predicted results, higher ratings were given to CONVERGE ($M = 6.42$, $SD = 3.15$) than EXACT ($M = 5.34$, $SD = 3.16$), $t(95) = 2.43$, $p < .05$.

This significant main effect is better understood in the context of the significant problem condition x solution type interaction, $F(2, 184) = 29.05$, $p < .001$, $\eta_p^2 = .24$, and by examining the results for each problem separately. For the Two-ribbon problem, CONVERGE was rated higher than both EXACT, $t(48) = 4.23$, $p < .001$, and DESTROY, $t(48) = 4.23$, $p < .05$. Ratings for

EXACT and DESTROY did not significantly differ, $t(48) = 1.13$, $p = .27$. These results are in contrast the prediction that none of the sources should seem highly related to the control problem.

For the Ray problem, the reminding ratings for EXACT were higher than for DESTROY (consistent with the planned comparison, $t(48) = 10.70$, $p < .001$), but the ratings for CONVERGE and EXACT did not differ $t < 1$. These results were in contrast to the prediction that EXACT would have higher reminding ratings.

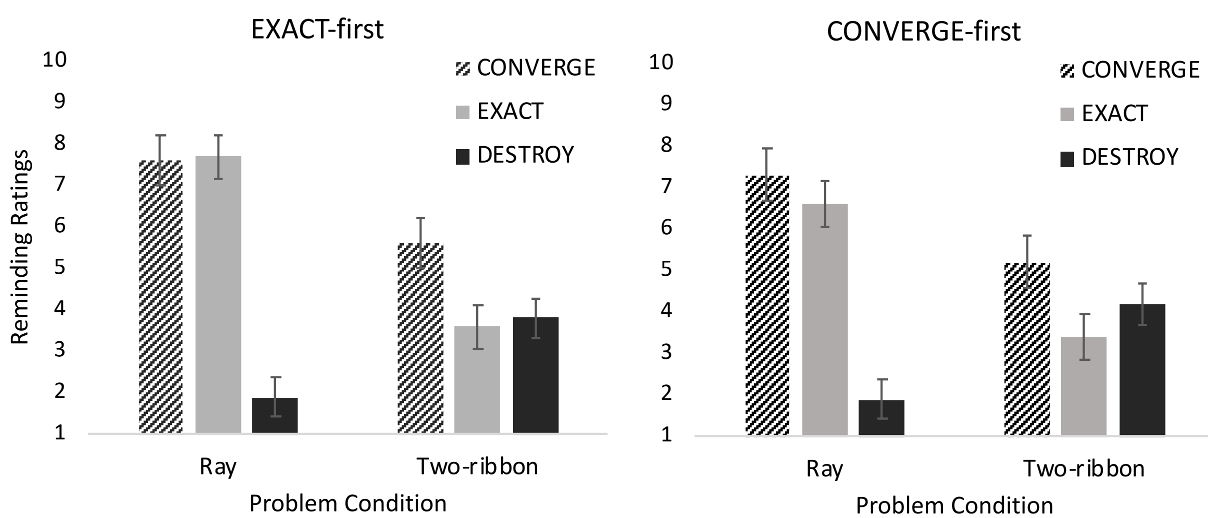

Figure 2. Mean reminding ratings for each solution for Ray and Two-ribbon (control) problems in Experiment 2. The left panel is when the EXACT solution preceded the CONVERGE solution in the encoding order. The right panel when the CONVERGE solution preceded the EXACT solution in the encoding order. Error bars represent standard errors.

3.2.2 Forced Choice Response

As shown in Table II, fairly similar percentages of people selected the CONVERGE and EXACT solutions for the Ray problem regardless of order, with few choosing the DESTROY solution, $\chi^2(2, N = 44) = 1.13$, $p = .57$ (Four people failed to provide a response.)

For the Two-ribbon problem, the majority of participants chose the CONVERGE solution. However, 21 people also failed to choose a response. This is likely because this problem did not remind them strongly of any story which made them fail to select a story within the deadline. A “no response” category was entered into this Chi-square. There was no significant effect of condition on story selection in the Chi-square, $\chi^2(3, N = 48) = 5.52, p = .14$.

Table II.

Percentages of Participants in the Ray Problem and Two-Ribbon (Control) Problem Condition Selecting the Different Solutions in the Forced-choice Reminding Task of Experiment 2.

	CONVERGE	EXACT	DESTROY	No Response
Ray Problem condition				
CONVERGE-first	54%	38%	4%	4%
EXACT-first	46%	42%	0%	12%
Two-ribbon Problem condition				
CONVERGE-first	33%	4%	17%	46%
EXACT-first	46%	12%	0%	42%

Note. The top row of each panel contains participants who received CONVERGE before EXACT in the encoding order. The bottom row of each panel contains participants who received EXACT before CONVERGE in the encoding order.

3.3 Discussion

The reminding paradigm of Experiment 2 demonstrated minimal evidence of competition from EXACT when encountering the Ray problem. Although the Ray problem did not remind people of DESTROY, the pattern did not support the prediction that people would be more strongly reminded of EXACT than CONVERGE. The Ray problem reminded people strongly of both CONVERGE and EXACT and reminding did not seem to depend on order of encoding. Thus, the results do not provide strong evidence for competition in the sense of EXACT producing stronger reminding than CONVERGE. These reminding results (and the lack of competition they imply) is consistent with the weak forgetting effects that were seen in Experiment 1. If participants were not more strongly reminded of EXACT than CONVERGE, then no forgetting would be needed. In addition, the results further suggest that the Two-ribbon problem was not a good choice for the control condition and should be replaced.

Another feature of the paradigm used in Experiment 1 that might have reduced the likelihood of finding forgetting effects could be that the different possible solutions were each contained in their own separate story contexts. When the different solutions appear in their own contexts, competition among solutions may be reduced. Because the competing solution information (EXACT) was isolated to its own context, this may have reduced the amount of competition experienced from EXACT upon attempting the Ray problem, which in turn failed to trigger inhibitory mechanisms that could cause forgetting in Experiment 1 and led to relatively similar reminding ratings for EXACT and CONVERGE in Experiment 2.

This line of reasoning is consistent with other work in retrieval-induced forgetting (RIF). In particular, prior studies on RIF using text-based materials have not typically found forgetting across separate texts. Rather, these studies find that selective retrieval practice for subsections of one text results in forgetting of other sections of only that same text, while memory for other texts is spared. Only one prior experiment (Little et al., 2011) found forgetting *across* texts, and this is likely because all texts shared the same structure of statements. In a similar vein, it is possible that forgetting of unviable solutions in the context of analogical problem solving may be more likely to be needed when multiple solutions are embedded *within the same story* context. In this condition, retrieval competition would be induced by sharing a single story context. Experiment 3 tested whether inducing this form of retrieval competition would produce a more consistent forgetting effect.

4. EXPERIMENT 3

The results of the first two experiments demonstrated minimal evidence for competition from and forgetting of unviable solutions during analogical problem solving. Because each unviable solution was contained in its own story context, one possibility is that this created little competition in memory. The goal of Experiment 3 was to test whether a forgetting effect might be observed when viable and unviable solutions are contained in the same story context. This involved creating a version of the Lightbulb story in which there were *two* broken lightbulbs, one of which was repaired with the original convergence (CONVERGE) solution, while the other was repaired using the exact-force solution (EXACT) which previously appeared in the Osteopath story. Upon attempting the Ray problem, any memory activation of solutions from the Lightbulb story should create a greater need for selective retrieval. If inhibitory processing helps with this selective retrieval process and diminishes activation of the unviable solution information (EXACT), then reduced recall should be observed relative to the other unviable solution presented in its own story (DESTROY). Therefore, as in prior experiments, planned comparisons between EXACT and DESTROY were conducted to test this hypothesis. Also as in Experiments 1 and 2, order of EXACT and CONVERGE solutions was manipulated. Based on the results of Experiment 1, one could expect more forgetting in the EXACT-first conditions. However, if embedding the unviable EXACT solution in the same story increases overall competition from EXACT, then this may lead to forgetting in both orders. Additionally, based on the results of Experiment 1 one could expect fewer solutions in the EXACT-first condition. However, if embedding the unviable EXACT solution in the same story increases overall competition in this experiment, this would result in more similar transfer rates between the encoding orders than in Experiment 1.

4.1 Method

4.1.1 Participants and Design

Participants were 329 people recruited via Amazon Mechanical Turk. All participants provided agreement to participate and were compensated for their time. The design was a 2 x 2 x 3 mixed design crossing the between-subjects factor problem condition (Ray vs. Liars), encoding order (CONVERGE-first, EXACT-first) and the within-subjects factor solution type (CONVERGE, EXACT, DESTROY). Twenty participants were excluded from analyses for not recalling any words, having prior familiarity with the Ray problem or source stories, or copying and pasting the story text into the summary field, which left the final sample as 309 (M_{age} = 41.26, *SD* = 12.59, 75% female). Although this sample has different demographic characteristics than the UIC sample, the results section demonstrates similar recall and transfer rates to the UIC sample, suggesting comparability between the two samples. Based on the effect size for the forgetting effect seen in the EXACT- DESTROY planned comparison in Experiment 1 (d = .28), this sample size allows for detection of this effect with 93% power.

4.1.2 Materials

4.1.2.1 Source Stories A two-solution version of the Lightbulb story (The *Lightbulbs*) was created (see Appendix G) incorporating both the convergence (CONVERGE) solution from the original Lightbulb story, and the exact-force solution (EXACT) from the original Osteopath story. This new version of the story involved two broken lightbulbs, one of which was repaired with the CONVERGE solution, while the other was repaired with the EXACT solution. A common opening paragraph was used, in addition to a connecting sentence between the two solution descriptions for story continuity. Order of solutions within the story was counterbalanced across participants (i.e., CONVERGE-first vs. EXACT-first). The CONVERGE solution contained 195 words, and the EXACT solution contained 222 words. The Wine Merchants story with the destroy (DESTROY) solution was the same as the previous experiments.

4.1.2.2 <u>Cued-Recall Task</u> Eight relevant recall words each were selected from each solution. The word lists had a similar number of characters across the CONVERGE ($M = 7.6$, $SD = 2.77$), EXACT ($M = 8.1$, $SD = 3.04$), and DESTROY ($M = 7.1$, $SD = 2.53$) solutions (ts <1 for all contrasts). The recall words are displayed in Table III.

Table III

Recall Words in Experiment 3

CONVERGE	EXACT	DESTROY
sealed	unscrewed	expire
ultrasound	tools	horse-drawn
break	stop	raging
lower	thrust	exhausted
circle	force	overturned
directions	engineering	raft
converged	machine	barrel
intact	accelerate	shore

4.1.2.3 <u>Baseline Recall Rates</u> As in Experiment 1, an assessment of baseline recall in the absence of problem-solving attempts was conducted ($N = 36$). Although it appeared that CONVERGE recall was lower than that of EXACT ($p = .06$) and DESTROY ($p = .01$), importantly, recall rates for EXACT and DESTROY recall did not significantly differ (ts < 1). Thus, for the critical measure of forgetting (the planned comparison between EXACT and DESTROY), this preliminary assessment suggests that recall rates were similar in the absence of problem-solving attempts.

4.1.2.4 Target Problem In Experiment 3, a different control problem (Liars) was selected. Because the Two-ribbon story mentions joining two strings, and the Lightbulb mentions two disconnected filaments, there may have been an inadvertent similarity between these two problems. In Experiment 3, the Liars problem (control, Appendix D) were used instead.

4.1.2.5 Final Questionnaire The final questionnaire was the same as Experiment 1.

4.1.3 Procedure

The procedure began with the story study and summarization phase as in Experiment 1 with some modifications. Participants had 3 minutes to study, then 3 minutes to summarize the Wine Merchants (containing the DESTROY solution). However, participants had 6 minutes to study, then 6 minutes to summarize the Lightbulbs (containing both the CONVERGE and EXACT solutions). The additional time for this story was meant to accommodate its doubled length. The order of CONVERGE vs. EXACT was counterbalanced across participants (CONVERGE-first vs. EXACT-first), as was the order of the Lightbulbs and The Wine Merchants.

Next participants completed the filler task as in the previous experiments before moving on to the problem-solving phase, which was the same as in Experiment 1. Then participants completed the final cued-recall task which also similar to Experiment 1. Lastly, participants completed the final questionnaire.

4.2 Results

4.2.1 Recall

Recall scores[2] were entered into a 2 x 2 x 3 mixed ANOVA crossing problem condition (Ray vs Liars), encoding order (CONVERGE-first vs. EXACT-first) and solution type

[2] Verbatim recall measures were also analyzed. Because these measures were redundant with the primary measure, they are reported in Appendix F.

(CONVERGE, EXACT, DESTROY). Agreement between the two coders for gist-recall was excellent (ICC[2] = .92). Recall rates are displayed in Figure 3.

There were no main effects of problem condition or encoding order (*F*s < 1). There was a main effect of solution type, $F(2, 610) = 6.81$, $p < .01$, $\eta_p^2 = .02$. In general, recall for DESTROY ($M = 68\%$, $SD = 19\%$) was higher than the CONVERGE ($M = 64\%$, $SD = 21\%$) and EXACT recall rates ($M = 64\%$, $SD = 26\%$). The problem condition x encoding order interaction was not significant, $F(1, 305) = 1.86$, $p = .17$, nor was the three-way interaction, $F < 1$. The problem condition x solution type interaction was marginal, $F(2, 610) = 2.95$, $p = .06$, and the encoding order x solution type interaction was significant, $F(2, 610) = 2.35$, $p = .04$. These results are best understood in the context of testing the planned comparisons for each target problem separately.

As shown in Figure 3, the planned comparison revealed that for the Ray problem, recall for EXACT was significantly lower than DESTROY, $t(149) = 3.25$, $p < .01$, $d = .27$. This effect was similar in both encoding orders, $F(2, 296) = 2.16$, $p = .12$. For the Ray problem, EXACT recall was lower than DESTROY recall in the EXACT-first order, $t(71) = 2.73$, $p < .01$, $d = .33$, and marginally lower in the CONVERGE-first order, $t(71) = 1.93$, $p = .06$, $d = .22$. This forgetting effect is consistent with the predicted result.

For the Liars problem, recall for EXACT was not significantly different than recall for DESTROY ($t < 1$). There was no difference in recall in either order (*t*s < 1) and no interaction ($F < 1$). The lack of differences between solutions on this problem demonstrates it was a better choice as a control problem than the Two-ribbon problem.

These results demonstrate that forgetting of an unviable solution embedded within the same context as a viable solution occurred as a result of attempting the Ray problem. This effect was not dependent on encoding order.

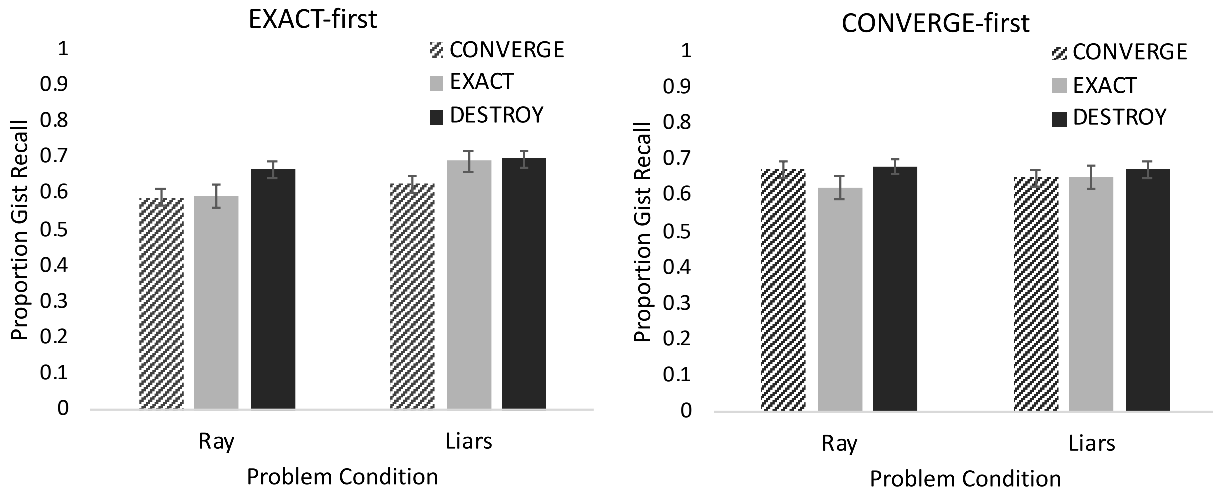

Figure 3. Mean recall proportions for each solution in the Ray and Liars (control) problems in Experiment 3. The left panel is when the EXACT solution preceded the CONVERGE solution in the encoding order. The right panel when the CONVERGE solution preceded the EXACT solution in the encoding order. Error bars represent standard errors.

4.2.2 Ray Solution Rates

Encoding order made little difference in the transfer rates for the Ray problem (CONVERGE-first = 40%, EXACT-first = 36%, $\chi^2 < 1$).

4.3 Discussion

In Experiment 3, when an unviable solution (EXACT) was embedded within the same context as the viable solution (CONVERGE), forgetting of EXACT (relative to DESTROY) was observed as a result of attempting the Ray problem, but not the control (Liars) problem. Additionally, transfer rates to the Ray problem were more similar across the encoding orders in Experiment 3 than in Experiment 1.

5. GENERAL DISCUSSION

Problem solvers sometimes have the opportunity to use previous situations to solve novel target problems via analogical transfer. However, retrieving these non-obvious solutions may involve interference from other unviable solutions that compete in memory. These experiments explored a potential role for inhibition of unviable solutions in analogical transfer by using a forgetting paradigm to test for reduced recall of unviable solutions following transfer attempts (analogy-induced forgetting).

Based in prior theorizing, the primary source of competition among candidate solutions was assumed to arise from surface-level similarity to the target problem. To test this, in Experiment 1, participants attempted Duncker's Ray problem following studying three separate stories containing an analogically-related solution, a surface-related (but unviable) solution, and an unrelated unviable solution. It was predicted that reduced recall of the surface-related unviable solution should occur relative to the unrelated unviable solution. However, such forgetting was minimally observed. It only occurred when the surface-level unviable solution was encoded prior to the analogically-related solution, demonstrating only weak evidence for analogy-induced forgetting due to surface-level competition. Moreover, in the reminding paradigm of Experiment 2 which prompted people to report which of the three solutions they were reminded after encountering the Ray problem, people did not demonstrate stronger reminding for the surface-related solution than the analogical solution. Thus, the first two experiments demonstrated minimal support for the theoretical notion that competition arises from surface-level sources during analogical problem solving.

Experiment 3 tested another form of competition by embedding an unviable solution from Experiments 1 and 2 within the same story context as the analogically-related solution. This resulted in more consistent analogy-induced forgetting – that is, forgetting of an unviable solution that was encoded in the same context as the viable (analogical) solution occurred.

The most striking aspect of these results is the lack of support for competition from surface-level similarity. Prior theoretical and empirical work on analogical transfer has strongly suggested that a major obstacle to analogical transfer is a tendency to easily bring to mind information that contains surface-level overlap with target problems at the expense of more viable solutions (Anolli et al., 2001; Blanchette & Dunbar, 2000; Catrambone, 2002; Gentner et al., 1993; Holyoak & Koh, 1987; Keane, 1987; Ross, 1989; Wharton et al., 1994). This makes the prediction that when both an analogically-related and a surface-only-related problem are encoded in memory, this should lead to strong competition and produce forgetting of the surface solution as a result of attempting the Ray problem. Yet, inconsistent forgetting was observed under these conditions. In the Ray problem condition, when the surface solution appeared before the analogical solution during encoding, forgetting was observed but no forgetting was observed when it appeared after the analogical solution. An interpretation of this pattern is that when the surface solution was encoded first, a primacy effect was created such that more proactive interference was experienced during Ray attempts, which may have triggered a stronger need for forgetting compared to the other order. Further evidence of this interpretation comes from the fact that transfer rates to the Ray problem tended to be lower when the surface solution was encoded before rather than after the analogically-related solution. Taken together, this suggests that competition from surface-similar sources may occur less than expected. Although prior research (and the reminding paradigm of Experiment 2) indicates that people do tend to activate surface-level connections, there may not be a need to alter the activation of these sources.

Instead, the strongest evidence for analogy-induced forgetting occurred when an unviable solution was embedded within the same story context as the viable analogical solution (Experiment 3). These results suggest that retrieval competition may arise during problem-solving attempts when a shared context prompts simultaneous co-activation of both solutions in memory, and this co-activation may occur regardless of whether the viable or unviable solution appeared first in the story. Consistent with this interpretation, the rate of transfer also appeared to be lower in Experiment 3 than in Experiment 1, suggesting more competition from the alternative candidate solutions when they were embedded in a shared context.

This finding from Experiment 3 is in line with prior work on RIF research for text material (Carroll et al., 2007; Chan, 2009; Little et al., 2011; Little et al. 2012; Saunders & MacLeod, 2006; Stone et al., 2010) and with the RIF framework more generally. In these paradigms, participants practice retrieving subsets of information from a text. Relative to information from a separate text that receives no retrieval practice, forgetting is seen for the unpracticed subsets, and this can be interpreted as a consequence of the need to resolve competition between subsets of information that come from the same text. Notably, this competition is created within a single text rather than across texts. Less competition would be created when potential candidate solutions are located across separate stories as was the case in Experiment 1.

What these results indicate is that analogical transfer may result in forgetting of unviable solutions primarily when a single prior situation contains multiple solutions or relations - only some of which may be relevant to a target problem. This is consistent with work suggesting that a source of interference in analogical reasoning is the presence of multiple relations that must be selected among (Cho, Holyoak, & Cannon, 2007). In contrast, surface-level similarity in itself may not make candidate solutions as strong of competitors as implied by the prior literature.

However, it is also possible that the competitive influence due surface overlap between the problem and an unviable solution may also depend on the perceived overlap between the problem and the viable solution. In other words, these results may be specific to the particular stimuli that were used for both the unviable and viable solution sources. In the present experiments, the Lightbulb was selected as the context for the viable solution because it seemed to represent a midpoint in the continuum of surface vs. structural overlap with the Ray problem. It is possible that if the viable solution were presented in a context with even less perceived overlap (e.g.., The General), then the completion from the surface-similar unviable solutions could be stronger which could increase the likelihood of observing forgetting. Using a range of source materials in future studies would be very informative for understanding how far the current results might generalize.

These findings also align with work on forgetting of irrelevant information as a consequence of creative problem-solving attempts (Ditta & Storm, 2016; George & Wiley, 2016; 2019; Storm et al., 2011). In these experiments, participants attempt to solve problems, understand novel metaphors, or generate new ideas after first studying a list of misleading or unhelpful associates. The activation of this information creates competition during problem solving wherein one must select more remote ideas. This results in forgetting of these misleading associates on later recall tests. Although these problem-solving tasks involve generation of non-studied information, and in the present experiments it involves retrieval and application of a studied source, the results of Experiment 3 and the prior work parallel one another in that resolving competition during problem solving seems to involve forgetting of less helpful information. Additionally, the forgetting effect for the unviable solutions conceptually replicates the findings of Bearman et al. (2003) who used a similar set of source stories - but with the important addition of a non-Ray problem comparison group. These forgetting patterns and the present forgetting patterns may reflect the use of inhibitory processes that help to reduce activation of competing information during problem solving attempts. In a review of RIF, Storm and Levy (2012) have described support for the notion that this forgetting reflects inhibition through studies showing that forgetting is tied to the degree of competition during retrieval, and that forgetting only occurs following selective retrieval *attempts* and not through simple selective re-exposure. Forgetting even occurs when attempts at retrieval practice or problem solving are made to be impossible (George & Wiley, 2019; Storm et al., 2011). These results suggest that forgetting is the result of processes recruited *during* retrieval or problem-solving attempts under which competition from other information is high. Although forgetting can result from many different processes, these studies suggest that these processes may include an inhibitory component that reduces activation of this competing information.

Although the patterns observed in the present experiments are consistent with an inhibitory account, without a direct test of inhibition it is not possible to strongly conclude that forgetting occurred as a consequence of inhibitory mechanisms. There are alternate explanations besides inhibition for the forgetting effect that cannot be entirely ruled out by the results. For example, one possibility is that *post*-problem solving interference blocked retrieval of the EXACT information during final recall. By strengthening the retrieval strength of viable solutions, this may block retrieval of other similar solutions later on, which could produce forgetting. This is in contrast to the inhibitory account which suggests that the forgetting effect is caused by inhibition of the EXACT information *during* problem solving attempts. One way to address this would be to demonstrate that mere exposure to the solution to the Ray problem does not produce forgetting of EXACT. Previous work on RIF has demonstrated that replacing the selective retrieval practice phase with restudy significantly reduces the amount of RIF, suggesting that forgetting specifically results from processes that take place during retrieval attempts (Storm & Levy, 2012). If the forgetting effect fails to occur from mere exposure to the Ray solution, this may help provide more support for the notion that inhibitory processes are involved in problem-solving attempts. Another way to provide more support for an inhibitory account of forgetting would be to use a measure that is less tied to retrieval strength, such as lexical decision latencies to the target words rather than a cued-recall test. For example, Verde and Perfect (2011) found increased recognition latencies for items that were selected against during retrieval practice.

In summary, these experiments provided a novel experimental approach to test for forgetting of non-useful sources of information in cross-domain analogical transfer. The results suggest that forgetting of unviable solutions that share surface-level overlap with the target problem may be less important than suggested by prior work. Instead, greater evidence of forgetting was obtained when unviable solutions were embedded within the same context as viable solutions. These findings suggest that competition from surface-similar information itself may not be a major obstacle to transfer, but rather the main obstacle may be the selection of *relevant* solution concepts.

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APPENDICES

Appendix A
Target problem

The underlined sentence (prompt to solve) did not appear in Experiment 2.

Ray Problem

Suppose you are a doctor faced with a patient who has a malignant tumor in his stomach. It is impossible to operate on the patient, but unless the tumor is destroyed the patient will die.

There is a kind of ray that can be used to destroy the tumor. If the rays reach the tumor all at once at sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the rays pass through on the way to the tumor will also be destroyed. At lower intensities the rays are harmless to healthy tissue, but they will not affect the tumor either.

<u>What type of procedure might be used to destroy the tumor with the rays, and at the same time avoid destroying the healthy tissue?</u>

Appendix B

Three source stories with 12 recall words underlined in bold; 9 problem-relevant words italicized.

The Lightbulb (CONVERGE)

In a **physics** lab at a major university, researchers were conducting experiments involving a very expensive lightbulb which would emit precisely controlled quantities of light. Ruth was the **researcher** responsible for operating the sensitive lightbulb. One morning she came into the lab and found to her dismay that the lightbulb no longer worked. She realized that she had forgotten to turn it off the previous night. As a result, the lightbulb overheated and the two wires in the filament inside the bulb ***fused*** together. The surrounding glass bulb was completely ***sealed***, so there was no way to open it. Ruth knew that the lightbulb could be repaired if a brief, powerful ***ultrasound*** wave could be used to jar apart the fused parts. Furthermore, the lab had the necessary equipment to do the job.

However, a high-intensity ultrasound wave would also ***break*** the fragile glass surrounding the filament. At lower intensities the ultrasound wave would not break the glass, but neither would it ***jar*** apart the fused parts. So it seemed that the lightbulb could not be repaired, and a costly replacement would be required.

Ruth was about to give up when she had an idea. She placed several ultrasound machines in a ***circle*** around the lightbulb. Then, she administered ***low-intensity*** ultrasound waves from several directions all at once. The waves all ***converged*** on the filament, where their combined effect was enough to jar apart the fused parts. Since each spot on the surrounding glass received only a low-intensity wave from one ultrasound machine, the bulb was left ***intact***. Ruth was greatly relieved that the lightbulb was repaired, and she then went on to successfully complete the **experiment**.

The Osteopath (EXACT)

For many years, a **Philadelphia** doctor of osteopathy worked on his research. Eventually, he thought that he had found a way to ***alleviate*** chronic back pain. Hearing about the doctor's potential cure, a woman with severe back pain **traveled** halfway across the country to consult with the doctor. Relieving the pain was very important to her because it was ***interfering*** with her career. When they met, the doctor explained his idea to the patient. He theorized that she could be cured of her back pain if a thrust could be applied to a fairly wide section of the ***lumbar*** region of the patient's back.

Unfortunately, the doctor thought it impossible to attempt his cure because he was unable to deliver a ***high-velocity*** thrust of sufficient force. This was because such a thrust would require more strength than the doctor or his ***assistants*** possessed. Any thrust that didn't have the appropriate amount of force would either have had no effect or would ***increase*** the pain. So it seemed that the doctor could not cure the patient, and that she would have to continue living in pain.

The patient was about to leave the city and return home when the doctor had an idea. That morning he met with a local ***engineering*** firm to convince them to help. They agreed to construct a machine that would deliver the ***exact*** amount of force necessary for the treatment to work. He called the patient back into the ***hospital***. Because the machine could deliver a high-velocity thrust, the doctor was able to administer the treatment to the patient. The patient was greatly **thankful** that the treatment had worked, and she then went on to live her life free of back pain.

The Wine Merchants (DESTROY)

One day a rich man who lived in a palace in the countryside walked downstairs to his wine cellar only to find that it was completely empty. Being upset by this discovery, he decided to send out messengers to announce a **generous** offer. The first person to bring the rich man a barrel of wine would be given a brick of **solid** gold. However, the offer would ***expire*** at sundown, meaning there was little time to earn the reward.

Two wine merchants heard the news. Each had several large barrels of wine loaded on ***horse-drawn*** carts. They both set out for the rich man's palace at once. An hour before sundown they came to a place where the bridge had been washed out by a ***raging*** river. The first merchant drove his horses and cart into the flood in a desperate attempt to reach the other side. But the horses were already ***exhausted*** and could not fight the current. The cart ***overturned***, and the horses, wine, and driver were washed away.

The second merchant tried a different tactic. He poured the wine out of all but one of his barrels and lashed them together to form a ***raft***. Then, he loaded the one full ***barrel***, a horse, and himself on top. He set the raft adrift and ***floated*** downstream. In a few minutes the raft came to rest on the ***shore*** in front of the town where the rich man lived. The merchant disembarked, loaded the wine barrel on the horse, and led it to the rich man's house. He arrived just as the sun was **setting**, and collected the gold brick as a reward for his efforts.

Appendix C

Cued recall sentences for The Lightbulb (CONVERGE)

1. In a ________ lab at a major university, researchers were conducting experiments involving a very expensive lightbulb which would emit precisely controlled quantities of light.
2. Ruth was the ________ responsible for operating the sensitive lightbulb.
3. She realized that she had forgotten to turn it off the previous night. As a result, the lightbulb overheated and the two wires in the filament inside the bulb ________ together.
4. The surrounding glass bulb was completely _______, so there was no way to open it.
5. Ruth knew that the lightbulb could be repaired if a brief, powerful ________ wave could be used to jar apart the fused parts.
6. However, a high-intensity ultrasound wave would also break the ________ glass surrounding the filament.
7. At lower intensities the ultrasound wave would not break the glass, but neither would it ______ apart the fused parts.
8. Ruth was about to give up when she had an idea. She placed several ultrasound machines in a ________ around the lightbulb.
9. Then, she administered_________ ultrasound waves from several directions all at once.
10. The waves all ________ on the filament, where their combined effect was enough to jar apart the fused parts.
11. Since each spot on the surrounding glass received only a low-intensity wave from one ultrasound machine, the bulb was left _______.
12. Ruth was very satisfied that the lightbulb was repaired, and she then went on to successfully complete the ________.

Cued recall sentences for The Osteopath (EXACT)

1. For many years, a ________ doctor of osteopathy worked on his research.
2. Eventually, he thought that he had found a way to _________ chronic back pain
3. Hearing about the doctor's potential cure, a woman with severe back pain _______halfway across the country to consult with the doctor.
4. Relieving the pain was very important to her because it was _________ with her career.
5. He theorized that she could be cured of her back pain if a thrust could be applied to a fairly wide section of the________ region of the patient's back.
6. Unfortunately, the doctor thought it impossible to attempt his cure because he was unable to deliver a _________ thrust of sufficient force
7. This was because such a thrust would require more strength than the doctor or his ________ possessed.
8. Any thrust that didn't have the appropriate amount of force would either have had no effect or would _______ the pain.
9. The patient was about to leave the city and return home when the doctor had an idea. That morning he met with a local engineering ______ to convince them to help.
10. They agreed to construct a machine that would deliver the ________amount of force necessary for the treatment to work.
11. He called the patient back into the________.
12. The patient was greatly ________ that the treatment had worked, and she then went on to live her life free of back pain.

Cued recall sentences for The Wine Merchants (DESTROY)

1. Being upset by this discovery, he decided to send out messengers to announce a ________offer.
2. The first person to bring the rich man a barrel of wine would be given a brick of _______ gold.
3. However, the offer would _______ at sundown, meaning there was little time to earn the reward.
4. Two wine merchants heard the news. Each had several large barrels of wine loaded on ________ carts
5. An hour before sundown they came to a place where the bridge had been washed out by a ________ river.
6. The first merchant drove his horses and cart into the flood in a desperate attempt to reach the other side. But the horses were already ________ and could not fight the current.
7. The cart ________, and the horses, wine, and driver were washed away.
8. The second merchant tried a different tactic. He poured the wine out of all but one of his barrels, and lashed them together to form a ________.
9. Then, he loaded the one full _______, a horse, and himself on top.
10. He set the raft adrift and floated ________.
11. In a few minutes the raft came to rest on the ________ in front of the town where the rich man lived.
12. The merchant _________, loaded the wine barrel on the horse, and led it to the rich man's house

Appendix D

Problems used in the control conditions of Experiments 1-3.

Two Ribbons (Experiments 1 and 2)

Before the inaugural gala, organizers were hurriedly trying to decorate the hall. Everything was nearly ready, and it was about ten minutes before the President-Elect was scheduled to arrive. Mr. Smith was decorating the walls and ceiling with balloons and party streamers made out of ribbon. He had nearly completed a fancy decoration pattern when he noticed two final pieces of ribbon were left dangling from the tiled ceiling above.

He had planned to knot these two final pieces of ribbon together in order to attach balloons to them. However, when he grabbed the end of the green ribbon, he was unable to grasp the end of the blue ribbon at the same time. The ribbons could simply not be knotted together in this way. Since everyone had left the room, Mr. Smith thought that he would have to abandon this bit of decoration altogether. What might Mr. Smith do in order to tie the two ribbons together?

Liars (Experiment 3)

On a television quiz program's bonus round, the lucky contestant is given the opportunity to select one of two envelopes (a yellow one and a red one). Inside one envelope is a check for $25,000. In the other envelope is a slip of paper informing the contestant that he/she has lost everything that was accumulated during the regular game.

There are two hosts, each holding an envelope. The hosts know the contents of each envelope. The contestant is told that one host always lies and the other host always tells the truth. Unfortunately, the contestant is not told which is which. The contestant can ask only one question to one of the hosts to decide which envelope to select and hopefully win the $25,000. What could the contestant do to guarantee that he/she wins the $25,000?

Appendix E

Final questionnaire

What is your gender? (check one)

Male
Female

What is your age?

Prior to today's experiment, had you encountered any of the stories or problems that you read? (check one)
YES
NO

If so, please explain:

Appendix F

Additional analyses of recall and transfer data.

Experiment 1

Additional results are reported for the planned comparisons using verbatim recall scoring, under which a word was scored as correct if it exactly matched the original word from the story (misspellings permitted), and re-analyses for both verbatim and gist scoring using only a subset of the original words. Alternate solution analyses are also reported using a more continuous measure of transfer.

Verbatim recall. For the planned comparison between EXACT and DESTROY, EXACT recall was significantly lower than DESTROY for the Ray problem, $t(119) = 2.10$, $p < .05$, $d = .19$, but not the Two-ribbon problem, $t(119) = 1.51$, $p = .13$. Additionally, encoding order mattered. For the Ray problem, reduced recall of EXACT compared to DESTROY was observed only when the EXACT story was encoded first, $t(59) = 2.29$, $p < .05$, $d = .31$, and not when CONVERGE was encoded first ($t < 1$). For the Two-ribbon problem, EXACT recall was not lower than DESTROY recall in either the EXACT-first order ($t < 1$), or in the CONVERGE-first order, $t(59) = 1.75$, $p = .09$.

CONVERGE-first	CONVERGE	EXACT	DESTROY
Ray	0.40 (.02)	0.43 (.02)	0.44 (.02)
Two-ribbon	0.41 (.02)	0.43 (.02)	0.47 (.02)
EXACT-first	CONVERGE	EXACT	DESTROY
Ray	0.47 (.02)	0.40 (.02)	0.46 (.02)
Two-ribbon	0.48 (.02)	0.43 (.02)	0.44 (.02)

Subset Analyses. Further examination of recall words suggested that 3 of 12 words within each story were not as relevant to the problem, constraints, or solution. Separate parallel analyses using only the 9 most relevant words were also conducted.

Gist recall of relevant words. For the planned comparisons, EXACT recall was not significantly different than DESTROY for either the Ray or Two-ribbon problems (ts < 1). For the Ray problem, no significant difference was present for the EXACT-first order, $t(59) = 1.29$, $p = .20$. For the CONVERGE-first order, EXACT recall was marginally higher than DESTROY recall, $t(59) = 1.80$, $p = .08$. For the Two-ribbon problem, there was no significant difference in EXACT vs DESTROY recall in either order (ts < 1).

CONVERGE-first	CONVERGE	EXACT	DESTROY
Ray	0.51 (.03)	0.58 (.02)	0.55 (.02)
Two-ribbon	0.58 (.03)	0.61 (.02)	0.60 (.02)
EXACT-first	CONVERGE	EXACT	DESTROY
Ray	0.60 (.03)	0.54 (.02)	0.58 (.02)
Two-ribbon	0.59 (.03)	0.56 (.02)	0.57 (.02)

Verbatim recall of relevant words. For the planned comparisons, EXACT recall was not significantly lower than DESTROY for the Ray problem, $t(119) = 1.43$, $p = .16$, nor for the Two-ribbon problem ($t < 1$). However, encoding order mattered. For the Ray problem, reduced recall of EXACT compared to DESTROY was observed when the EXACT solution was encoded first, $t(59) = 2.13$, $p < .05$, $d = .28$, and not when CONVERGE was encoded first ($t < 1$). For the Two-ribbon problem, there was no significant difference in EXACT vs DESTROY in either order (*t*s < 1).

CONVERGE-first	CONVERGE	EXACT	DESTROY
Ray	0.35 (.03)	0.40 (.02)	0.40 (.02)
Two-ribbon	0.38 (.03)	0.42 (.02)	0.44 (.02)
EXACT-first	CONV	EXCT	DEST
Ray	0.43 (.03)	0.37 (.02)	0.42 (.02)
Two-ribbon	0.42 (.03)	0.40 (.02)	0.40 (.02)

Alternate Transfer Scores. For each of the three solution concepts described in Experiment 1, a participant's solution was given a point if it included it (0-3 score). This measure showed no significant difference in transfer scores due to order (CONVERGE-first = 0.98, $SD = 1.05$, EXACT-first = 0.72, $SD = 1.01$, $t(118) = 1.42$, $p = .16$).

Experiment 3

Additional results are reported for the planned comparisons using verbatim recall, under which a word was scored as correct if it exactly matched the original word from the story (misspellings permitted), and for the alternative transfer scores.

Verbatim recall. For the planned comparisons, EXACT recall was not significantly lower than DESTROY ($t < 1$) for the Ray problem. EXACT recall was not lower than DESTROY recall in in either encoding order (*t*s < 1).

For the Liars problem, EXACT recall was marginally higher than DESTROY, $t(158) = 1.97$, $p = .08$. EXACT recall was not significantly higher than DESTROY in the CONVERGE-first ($t < 1$) or EXACT-first order, $t(78) = 1.52$, $p = .13$.

CONVERGE-first	CONVERGE	EXACT	DESTROY
Ray	0.57 (.02)	0.53 (.03)	0.54 (.02)
Liars	0.54 (.02)	0.56 (.03)	0.53 (.02)
EXACT-first	CONVERGE	EXACT	DESTROY
Ray	0.49 (.02)	0.52 (.03)	0.52 (.02)
Liars	0.50 (.02)	0.57 (.03)	0.53 (.02)

Alternate Transfer Scores. Using the alternate (0-3) scoring for transfer showed no differences in transfer scores across order conditions (CONVERGE-first = 0.88, $SD = 1.16$, EXACT-first = 0.75, $SD = 1.10$) ($t < 1$).

Appendix G

Two-solution version of the Lightbulb story used in Experiment 3. In Order 1, the CONVERGE solution precedes the EXACT solution. In Order 2, the EXACT solution precedes the CONVERGE solution. Recall words are highlighted in bold. The gray text indicates the common introduction text that was not specific to either solution, the transition text, and concluding text.

The Lightbulbs (Order 1 – CONVERGE-first)

In a **physics** lab at a major university, researchers were conducting experiments involving two very expensive lightbulbs which would emit precisely controlled quantities of light. Ruth was the **researcher** responsible for operating the sensitive lightbulbs. One morning she came into the lab and found to her dismay that the lightbulbs no longer worked. She realized that she had forgotten to turn them off the previous night. As a result, the lightbulbs overheated and the two wires in the filament inside the bulb **fused** together.

She examined the first lightbulb and observed that the surrounding glass bulb was completely **sealed**, so there was no way to open it. Ruth thought that the lightbulb could be repaired if a brief, powerful **ultrasound** wave could be used to vibrate the fused wires. Furthermore, the lab had the necessary equipment to do the job. However, a high-intensity ultrasound wave would also **break** the fragile glass surrounding the filament. The lightbulb would not work if the glass casing was broken. At **lower** intensities the ultrasound wave would not break the glass, but neither would it affect the fused parts. So it seemed that the lightbulb could not be repaired, and a costly replacement would be required.

Ruth was about to give up when she had an idea. She placed several ultrasound machines in a **circle** around the lightbulb. Then, she administered low-intensity ultrasound waves from several **directions** all at once. The waves all **converged** on the filament, where their combined effect was enough to separate the fused parts. Since each spot on the surrounding glass received only a low-intensity wave from one ultrasound machine, the glass was left **intact** and the lightbulb was repaired.

She was about to fix the second bulb, when the power supply to the ultrasound machine failed. This meant that she would have to find another way to repair the second bulb.

The second bulb had no openings in the glass casing, but the base was able to be **unscrewed.** However, even with the base removed there was only a very narrow opening allowing access to the filament. There were no **tools** small enough to insert inside to pry apart the wires. She theorized that the filament wires would separate if the lightbulb was rapidly thrust forward and then brought to a sudden **stop**. Unfortunately, Ruth was unable to deliver a high-velocity **thrust** of sufficient force. This was because such a thrust would require more strength than she or her assistants possessed. It was also important not to use too much **force** because that would destroy the filament altogether. So it seemed that Ruth could not fix the lightbulb, and the research would be delayed.

Ruth was about to submit a research extension when she had a thought. That afternoon she met with her colleagues in the **engineering** department to convince them to help. They agreed to adapt their stress-test **machine** to deliver the exact amount of force necessary for the repair to work. She brought the lightbulb to her colleagues. They secured it in the grasp of the machine. Because the machine could rapidly **accelerate** and then come to a sudden stop, the force was able to repair the filament inside the bulb. With the second lightbulb repaired, Ruth was able to successfully complete the experiment.

The Lightbulbs (Order 2 – EXACT-first)

In a **physics** lab at a major university, researchers were conducting experiments involving two very expensive lightbulbs which would emit precisely controlled quantities of light. Ruth was the **researcher** responsible for operating the sensitive lightbulbs. One morning she came into the lab and found to her dismay that the lightbulbs no longer worked. She realized that she had forgotten to turn them off the previous night. As a result, the lightbulbs overheated and the two wires in the filament inside the bulb **fused** together.

The first bulb had no openings in the glass casing, but the base was able to be **unscrewed.** However, even with the base removed there was only a very **narrow** opening allowing access to the filament. There were no **tools** small enough to insert inside to pry apart the wires. She theorized that the filament wires would separate if the lightbulb was rapidly thrust forward and then brought to a sudden stop. Unfortunately, Ruth was unable to deliver a **high-velocity** thrust of sufficient force. This was because such a thrust would require more strength than she or her **assistants** possessed. It was also important not to use too much force because that would destroy the filament altogether. So it seemed that Ruth could not fix the lightbulb, and the research would be delayed.

Ruth was about to submit a research extension when she had a thought. That afternoon she met with her colleagues in the **engineering** department to convince them to help. They agreed to adapt their stress-test machine to deliver the **exact** amount of force necessary for the repair to work. She brought the lightbulb to her colleagues. They secured it in the grasp of the machine. Because the machine could rapidly accelerate and then come to a **sudden** stop, the force was able to repair the filament inside the bulb

She was about to fix the second bulb, when the power supply to the stress-test machine failed. This meant that she would have to find another way to repair the second bulb.

She examined the second lightbulb and observed that the surrounding glass bulb was completely **sealed**, so there was no way to open it. Ruth thought that the lightbulb could be repaired if a brief, powerful **ultrasound** wave could be used to vibrate the fused wires. Furthermore, the lab had the necessary equipment to do the job. However, a high-intensity ultrasound wave would also **break** the fragile glass surrounding the filament. The lightbulb would not work if the glass casing was broken. At lower intensities the ultrasound wave would not break the glass, but neither would it **affect** the fused parts. So it seemed that the lightbulb could not be repaired, and a costly replacement would be required.

Ruth was about to give up when she had an idea. She placed several ultrasound machines in a **circle** around the lightbulb. Then, she administered **low-intensity** ultrasound waves from several directions all at once. The waves all **converged** on the filament, where their combined effect was enough to separate the fused parts. Since each spot on the surrounding glass received only a low-intensity wave from one ultrasound machine, the glass was left **intact** and the lightbulb was repaired. With the second lightbulb repaired, Ruth was able to successfully complete the experiment.

HUMAN SUBJECTS COMMITTEE PROTOCOL APPROVAL

This research was approved by the University of Illinois Human Subjects Institutional Review Board under protocol 2010-1018.

CURRICULUM VITAE

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EDUCATION

University of Illinois at Chicago, Chicago, IL
PhD, Psychology, 2019
Major: Cognitive Psychology
Minor: Cognitive Neuroscience
Master of Arts, Psychology, 2015

American University, Washington, DC
Master of Arts, Psychology, 2008
Bachelor of Arts, Psychology, 2006

DISSERTATION

Analogy-induced Forgetting: Inhibitory Mechanisms During Analogical Transfer

AWARDS

2019 Society for the Neuroscience of Creativity Travel Award Recipient
2017 American Psychological Association Dissertation Research Award Recipient
2017 UIC Excellence in Undergraduate Mentoring – Honorable Mention
2016 UIC Graduate College Outstanding Thesis Award Recipient

PUBLICATIONS

Storm, B. C., Ditta A. S. & George, T. (in press). Memory and creativity. To appear in M. Runco & S. Pritzker (Eds.), *Encyclopedia of creativity, 3rd edition*. Elsevier.

George, T., & Wiley, J. (in press). Fixation, flexibility, and forgetting during alternate uses tasks. *Psychology of Aesthetics, Creativity, and the Arts*.

George, T., & Wiley, J. (2019). When is literal meaning inhibited? Evidence from nonsense in the metaphor-induced lexical forgetting paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 45,* 869-880.

George T., & Wiley, J. (2018). Breaking past the surface: Analogical transfer as creative insight. In F. Vallée-Tourangeau (Ed.), *Insight: On the origin of new ideas* (pp. 143-168). New York, NY: Routledge.

Wiley, J., George, T., & Rayner, K. (2018). Baseball fans don't like lumpy batters: Influence of domain knowledge on the access of subordinate meanings. *The Quarterly Journal of Experimental Psychology*, *71*, 93-102.

George, T., Wiley, J., Koppel, R. H. & Storm, B. C. (2017). Constraining or constructive? The effects of examples on idea novelty. *The Journal of Creative Behavior*. doi: http://dx.doi.org/10.1002/jocb.178

George, T., & Wiley, J. (2016). Forgetting the literal: The role of inhibition in metaphor comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42*, 1324-1330.

O'Rourke, P., Haarmann, H. J., George, T., Smaliy, A., Grunewald, K., & Dien, J. (2015). Hemispheric alpha asymmetry and self-rated originality of ideas. *Laterality: Asymmetries of Body, Brain and Cognition, 20*, 685-698.

Haarmann, H. J., George, T., Smaliy, A., & Dien, J. (2012). Remote associates test and alpha brain waves. *The Journal of Problem Solving, 4,* Article 5.

MANUSCRIPTS IN PREPARATION

George, T., & Wiley, J. (2019). Need something different? Here's what's been done: Effects of examples and task instructions on creative originality. [Revise and resubmit from *Memory & Cognition*].

George, T. (2019). Analogy-induced forgetting: Retrieval competition, inhibition, and analogical transfer. [Data collection complete, manuscript in progress].

George, T., & Wiley, J. (2019). Working memory benefits creative thinking about long-term consequences. [Data collection complete, coding and manuscript in progress].

George, T., & Wiley, J. (2019). Testing practice of verbal analogies benefits cross-domain transfer to new instances. [Manuscript in preparation].

CONFERENCE PRESENTATIONS (*indicates undergraduate presenter)

George, T., & Wiley, J. (2019, March). *Photographic images can impair creativity on the alternate uses task while inflating confidence.* Poster to be presented at the 5th Annual Meeting of the Society for the Neuroscience of Creativity. San Francisco, CA.

George, T., & Wiley, J. (2019, April). *Eliminating the competition during analogical problem solving.* Paper to be presented at the 91st Annual Meeting of the Midwestern Psychological Association. Chicago, IL.

*Chou, A., George, T., & Wiley, J. (2019, April). *Creative idea generation during optimal/non-*

optimal time of day. Poster to be presented at the 91st Annual Meeting of the Midwestern Psychological Association. Chicago, IL.

George, T., & Wiley, J. (2018, November). *Knowing what to avoid: Verbal example exposure improves originality, visual example exposure hinders it.* Poster presented at the 59th Annual Meeting of the Psychonomic Society. New Orleans, LA.

George, T., & Wiley, J. (2018, April). *From common to clever: Unoriginal idea exposure improves creative originality.* Paper presented at the 90th Annual Meeting of the Midwestern Psychological Association. Chicago, IL.

George, T., & Wiley, J. (2018, March). *Creative thinking about long-term consequences benefits from working memory capacity.* Poster presented at the 4th Annual Meeting of the Society for the Neuroscience of Creativity. Cambridge, MA.

George, T., & Wiley, J. (2017, November). *Breaking through the surface: Competition, inhibition, and forgetting in analogical transfer.* Poster presented at the 58th Annual Meeting of the Psychonomic Society. Vancouver, BC.

George, T., & Wiley, J. (2017, April). *Benefits of retrieval practice for analogical transfer.* Paper presented at the 89th Annual Meeting of the Midwestern Psychological Association. Chicago, IL.

George, T., & Wiley, J. (2016, November). *Going the distance: The effects of testing on analogical transfer*. Poster presented at the 57th Annual Meeting of the Psychonomic Society. Boston, MA.

Griffin, T. D., Sarmento, D., Wiley, J., & George, T. (2016, November). *Metacognitive pitfalls of using animations to illustrate scientific processes*. Poster presented at the 57th Annual Meeting of the Psychonomic Society. Boston, MA.

George, T., Koppel, R. H., Storm, B. C., & Wiley, J. (2016, May). *Constraining or constructive? The effects of examples on creative design.* Poster presented at the 56th Annual Meeting of the Association for Psychological Science. Chicago, IL.

George, T., & Wiley, J. (2016, May). *It doesn't ring a bell: metaphor-induced lexical forgetting.* Poster presented at the Annual Meeting of the Midwestern Psychological Association. Chicago, IL.

George, T., & Wiley, J. (2015, November). *Fixation, flexibility, and forgetting during alternate-uses tasks.* Poster presented at the Annual Meeting of the Psychonomic Society. Chicago, IL.

George, T., & Wiley, J. (2015, April). *The more the merrier: Diversity of items leads to more creative alternate uses.* Poster presented at the Annual Meeting of the Midwestern Psychological Association. Chicago, IL.

George, T., & Wiley, J. (2014, November). *Forgetting the literal: The role of inhibition in metaphor comprehension.* Poster presented at the Annual Meeting of the Psychonomic Society. Long Beach, CA.

George, T., Koppel, R. H., & Wiley, J. (2014, August). *Forgetting the literal: Reduced memory for metaphor-irrelevant information following metaphor comprehension.* Poster presented at the Annual Meeting of the Society for Text & Discourse. Chicago, IL.

George, T., & Haarmann, H. J. (2014, May). *Left hemisphere sensitivity to detection of weak associates.* Poster presented at the Annual Meeting of the Midwestern Psychological Association. Chicago, IL.

O'Rourke, P. George, T., Smaliy, A., Grunewald, K., Dien, J., & Haarmann, H. (2012, March). *Verbal creativity and Alpha: A brain wave entrainment study*. Poster presented at the Annual Meeting of the Cognitive Neuroscience Society. Chicago, IL.

Berens, M., Blok, S., Smaliy, S., George, T., Cook, J., & Haarmann, H. (2011, November). *Validation of a workplace-relevant divergent thinking task*. Poster presented at the Annual Meeting of the Psychonomic Society. Seattle, WA.

Haarmann, H., George, T., & Smaliy, A. *Surprising left hemisphere advantage for detection of novel metaphors*. (2011, May). Poster presented at the Annual Meeting of the Association for Psychological Science. Washington, DC.

Haarmann, H., George, T., Dien, J., Chrabaszcz, J., Smaliy, A., Freynik, S., & Novick, J. (2010, April). *Creative cognition benefits from incubation with neurofeedback.* Poster presented at the Annual Meeting of the Cognitive Neuroscience Society, Montreal, QC, Canada.

Haarmann, H., George, T., Smaliy, A., Grunewald, K., & Novick, J. (2009, March). *Alpha neurofeedback training and its implications for studies of cognitive creativity.* Poster presented at the Annual Meeting of the Cognitive Neuroscience Society. San Francisco, CA.

TECHNICAL REPORTS

Haarmann, H. J., George, T. G., Berens, M. S., Grunewald, K. E., & Freynik, S. (2012). *The efficacy of a divergent thinking course for analysts: Technical details. (TTO 3503 Technical Report Deliverable September 30).* College Park: University of Maryland Center for Advanced Study of Language.

Haarmann, H. J., Berens, M. S., O'Rourke, P., Blok, S., Smaliy, A., George, T. G., Grunewald, K. E., Cook, J. Dien, J., & Freynik, S. (2011*). Improving assessment of analyst-relevant divergent thinking: Test validation, automated scoring, and brain signature. (TTO 3503: Technical Report Deliverable CDRL A017).* College Park: University of Maryland Center for Advanced Study of Language.

Haarmann, H. J., George, T. G., Dien, J., Chrabaszcz, J. Smaliy, A., Freynik, S., & Novick, J. M. (2010). *Right-brain alpha neurofeedback improves verbal creative problem solving*. (*TTO 3502: Technical Report Deliverable E.4.1).* College Park: University of Maryland Center for Advanced Study of Language.

Novick, J. M, George, T. G., Chrabaszcz, J., Smaliy, A., Clausner, T., & Haarmann, H. J., (2009). *Evaluating brief cognitive intervention techniques for improving divergent thinking: Considerations on how to solve problems in creative ways. (TTO 3502 Technical Report Deliverable E.5.1.*) College Park: University of Maryland Center for Advanced Study of Language.

Haarmann, H. J., George, T. G., Smaliy, A., Grunewald, K., & Novick, J. (2008). *A method for quickly increasing alpha brain waves through neurofeedback: implications for divergent thinking and creative problem solving. (TTO 3502: Technical Report Deliverable E.3.2, October 30)*. College Park: University of Maryland Center for Advanced Study of Language.

GRANT-FUNDED RESEARCH EXPERIENCE

University of Illinois at Chicago, Department of Psychology, Chicago, IL

Effects of Illustrations and Analogies on Metacomprehension of Science Text (Summer 2016-present). NSF-funded project
PI: Jennifer Wiley
Examines the extent to which the presence of illustrations and analogies within science texts impacts students' judgments of how well they understood the concepts in the text.

University of Maryland, Center for Advanced Study of Language (CASL), College Park, MD

Divergent Thinking in Language Analysis (June 2008 - August 2013)
Senior Research Assistant
Supervisor: Henk J. Haarmann, Ph.D.
Researched neural and behavioral underpinnings of divergent thinking ability in order to develop methods for improving this ability. Designed and implemented behavioral and EEG studies. Recruited and tested participants. Organized and analyzed data. Assisted with writing technical reports.

OTHER RESEARCH PROJECTS AND EXPERIENCE

University of Illinois at Chicago, Department of Psychology, Chicago, IL

Inhibition and Metaphor Comprehension (Fall 2013 - present)
Conducted six studies examining whether metaphor comprehension involves inhibition of metaphor-irrelevant literal information using a variant of the retrieval-induced forgetting paradigm, including studies that served as my Masters' Thesis (defended August 2015).

Divergent Thinking (Fall 2013 – present)
Examining the task conditions which benefit creativity via divergent thinking tasks, and in what ways inhibitory control and working memory capacity are beneficial to creative idea generation.

Analogical Transfer (Spring 2016 – present)
Examining what factors influence the likelihood of making distant analogical connections. The main project tests whether retrieving an analogy requires inhibiting surface-level cases in memory. This project serves as the basis of my dissertation work.

American University, Department of Psychology, Washington, DC

Priming of Metaphorical Meaning (August 2007 - May 2008)
Human Memory & Cognition Laboratory
Advisor: Zehra Peynircioglu, Ph.D.
Conducted research on figurative language processing in a lexical decision paradigm testing whether access to metaphor vehicle words is strengthened following metaphor-relevant sentences.

TEACHING EXPERIENCE

University of Illinois at Chicago, Department of Psychology, Chicago, IL

Instructor, PSCH 242, Introduction to Research in Psychology, Spring 2017, Spring 2018
Average Instructor Effectiveness Rating: 4.50/5

Teaching Assistant, PSCH 353, Laboratory in Cognition and Memory, Spring 2016-Spring 2019
Teaching Assistant, PSCH 343, Statistical Methods in Behavioral Science, Summer 2015
Teaching Assistant, PSCH 242, Introduction to Research in Psychology, Spring - Fall 2015
Teaching Assistant, PSCH 352, Cognition and Memory, Spring 2015
(Guest lecturer, PSCH 352: Language, Fall 2015)
Teaching Assistant, PSCH 262, Behavioral Neuroscience, Spring 2014
(Guest lecturer: PSCH 262, Sensory systems, Language & lateralization, Spring 2014)
Teaching Assistant, PSCH 100, Introduction to Psychology, Fall 2013; Fall 2014

American University, Department of Psychology, Washington, DC

Teaching Assistant, PSYC 200, Behavior Principles, Fall 2005

MENTORING EXPERIENCE

Feryal Morad	Spring 2019	Emotional memory	Honor's Capstone
Amy Cho	Spring 2018-present	Creative Thinking	LASURI awardee
Jessica McAleer	Fall 2018-present	Creative Thinking	
Nida Fayyaz	Spring 2018	Creative Thinking	
Fawn Wang	Summer 2017-2018	Analogical Thinking	
Shiwangi Pandya	Summer-Fall 2017	Analogical Thinking	

Morgan Hager	Spring 2017	Analogical Thinking	
Priya Patel	Spring 2017	Analogical Thinking	URE Awardee
Mayte Noriega	Fall 2016-Spring 2017	Analogical Thinking	
Uliana Solovieva	Fall 2016	Analogical Thinking	
Jennifer Chun	Spring 2016	Creative Thinking	LASURI Awardee
Kianna Musaraca	Spring 2016	Inventive Thinking	
Himani Kumar	Fall 2015-Spring 2016	Creative Consequences	
Wai Yung	Spring 2015	Inventive Thinking	
Paula Kilpatrick	Fall 2014	Inventive Thinking	
Monica Makar	Summer 2014	Inventive Thinking	Honors College Grant

AD HOC REVIEWING EXPERIENCE

The Journal of Problem Solving, Journal of Experimental Psychology: Learning, Memory, & Cognition, Current Issues in Thinking and Reasoning, Discourse Processes, Thinking & Reasoning, PLoS ONE

PROFESSIONAL SOCIETIES

Psychonomic Society, Graduate Student Member
Association for Psychological Science, Graduate Student Member
Midwestern Psychological Association Graduate Student Member
APA Division 10 Graduate Student Affiliate
Society for the Neuroscience of Creativity, Graduate Student Member

ADDITIONAL SKILLS & EXPERIENCE

SPSS, R, E-Prime, Qualtrics, Amazon Mechanical Turk, EGI's NetStation EEG software, EEGLAB

PROFESSIONAL REFERENCES

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