Understanding Different Kinds of Mental Fixation

BY

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THESIS
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I dedicate my thesis to my family. Mom and Dad, you have been the best parents and I never would have gotten to this point without your encouragement, patience, support, and belief in me. Thank you for unconditionally being there. Amanda, you march to the beat of your own drum and have fun doing it- thanks for inspiring me to do the same.
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<tr>
<td>ACT</td>
<td>American College Testing</td>
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<td>ANOVA</td>
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<td>AUT</td>
<td>Alternative Uses Task</td>
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<td>BDS</td>
<td>Backwards Digit Span</td>
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<td>CFI</td>
<td>Comparative Fit Index</td>
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<td>FCS</td>
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<td>LNS</td>
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<td>MCAR</td>
<td>Missing Completely at Random</td>
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<td>MCMC</td>
<td>Markov Chain Monte Carlo</td>
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<td>NS</td>
<td>Number Stroop</td>
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<td>RAT</td>
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<td>RIF</td>
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<td>RMSR</td>
<td>Root Mean Square Residual</td>
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<td>RS</td>
<td>Running Span</td>
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<td>RT</td>
<td>Response Time</td>
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<td>SS</td>
<td>Spatial Stroop</td>
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<td>UIC</td>
<td>University of Illinois at Chicago</td>
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<td>WC</td>
<td>Word Categorization</td>
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<td>WMC</td>
<td>Working Memory Capacity</td>
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Problems can be difficult to solve because people become fixated by exposure to misleading information, or fixated by misleading prior knowledge. The two instances of fixation feel like they’re qualitatively different, but whether there are different types of fixation that may be overcome by different means has received little attention. Three experiments tested whether fixation that is experimentally-induced versus induced by prior knowledge can be shown to be qualitatively different via an individual-differences approach. To examine these questions, both kinds of fixation were explored in a word-fragment completion task (based on Smith & Tindell, 1997) which contained words that were orthographically similar but impossible to solve with music-related terms. To manipulate experimentally-induced fixation, half of the participants saw music-related misleading primes prior to problem solving. To manipulate fixation due to prior knowledge, experiments compared a novice musician sample to an “expert” sample of musicians. Restraint, updating, and retrieval-induced forgetting were assessed to explore how different “flavors” of executive functioning predict problem solving. Results suggest distinct roles for the three measures based on priming condition, expertise, and warnings that solutions would not be related to music. Updating positively predicted correct solutions for all participants when a warning was provided, while restraint tended to positively predict performance only for expert musicians. Retrieval induced forgetting negatively predicted correct solutions when fixation was experimentally induced and when a warning was provided.
I. INTRODUCTION

Relying on prior knowledge allows us to navigate new situations. However, domain knowledge or experiences, recently-primed knowledge, or cues and information in the environment are all factors that can make problems harder to solve (Smith, 1995). One reason why people fail to find solutions to problems is because they may become fixated by these factors and “slide insensibly into a groove and not be able to escape at the moment” (Woodworth & Schlosberg, 1954). Fixation increases by counterproductively adhering to information or approaches, or when inappropriate information blocks access to other viable information in memory (Smith, Ward, & Schumacher, 1993). Impaired solution generation, slower solution response times, or the production of negatively-primed, incorrect responses (intrusions) are possible indicators of fixation during problem solving.

Experimentally-Induced Fixation

Although only a handful of studies have explored the idea that there are qualitatively different kinds of fixation, experimentally-induced fixation and fixation induced by domain knowledge have been examined separately. Several studies by Smith and others have demonstrated that fixation during problem solving can be induced by exposure to misleading information (e.g., Smith & Blankenship, 1989; Smith & Blankenship, 1991; Smith, et al., 1993). For example, Smith and Tindell (1997) showed that exposing participants to words that primed misleading solutions to word fragments caused fixation. Before solving a word fragment (e.g., “T_R__IN”), participants were either presented with the target word (“TERRAIN”), an orthographically similar word (“TURBINE”), or an unrelated word (“UNICORN”). Exposure to the orthographically similar word impaired performance, an effect referred to as negative priming. Stimuli that cause negative priming are referred to as negative primes. Participants
even provided the negative primes as answers during a fragment completion task despite noticing the obvious orthographic mismatch (Landau & Leynes, 2006). Overcoming fixation has proven to be particularly difficult during word fragment completion because the fragments themselves can induce the involuntary retrieval of the negative primes. Fixation even remained after instructing participants to avoid thinking about the negative primes (Smith & Tindell, 1997), and after warning participants about specific negative primes immediately before presenting the corresponding fragments (see also Logan & Balota, 2003).

Fixation can also be induced in the Remote Associates Test (RAT; Mednick, 1962). Mednick originally created the RAT to assess creativity, which he defined as the ability to access remote associates in lieu of more highly-associated, common responses. The RAT is difficult because the solution is not highly associated with the three cue words—it is a remote associate. In the RAT, participants view three cue words and must generate a fourth word that is in some way related to the other three. The fourth word can be semantically related, form a common phrase, or be a synonym of the each of the three cue words. For example, a participant may be provided with lick, sprinkle and mines. The correct answer, salt, forms the phrases salt lick and salt mines, and is closely related to sprinkle (salt is sprinkled on food, for instance.) Smith and Blankenship (1991) demonstrated that fixation can be experimentally induced by misleading associates, which are words that strongly relate to the RAT cue words but guide participants away from the solution. Participants can be exposed, or learn the misleading associates before each problem, before attempting all problems, or during each problem. For instance, some participants were provided with RAT cue word-misleading associate pairs and then tested multiple times on the misleading associates prior to problem solving. Participants solved fewer RAT problems if they learned misleading associates than if they did not learn misleading
associates (Experiment 4, Smith & Blankenship, 1991). The use of a fixation phase prior to problem solving is an incredibly powerful and efficient method to induce fixation that has since been employed in other experiments examining fixation in RAT problem solving (e.g., Storm & Angello, 2010; Storm, Angello, & Bjork, 2011; Koppel & Storm, 2014). Sometimes participants are unaware that the associates are going to hinder problem solving (like in Experiment 4 of Smith & Blankenship, 1991), and sometimes they are warned of their detrimental effects (such as Storm & Angello, 2010); neither instruction attenuates the cycle of fixation, nor does performance improve. Smith and Blankenship theorized that misleading associates became temporarily activated in all of these cases, increasing their salience and decreasing the activation of other viable solutions, thus impairing performance.

The literature includes a number of other examples of studies that have induced fixation in problem solving including Luchins and Luchins’ (1959, 1970) classic water jug paradigm where the initial equation instills a mental set, design fixation studies (e.g., Jansson & Smith, 1991; Smith, et al., 1993; Purcell & Gero, 1996) where initial examples anchor creativity, and rebus puzzles where hints lead the solver astray (e.g., Smith & Blankenship, 1989). Although different problem-solving paradigms have different goals, and varying task demands, they tend to induce fixation in a manner similar to Smith and Tindell’s word fragment completion task, and RAT problems. That is, participants are exposed to inappropriate information prior to, or during problem solving that subsequently hinders problem-solving success.

**Fixation Induced by Prior Knowledge**

As difficult as it is to overcome experimentally-induced fixation, fixation induced by prior knowledge may be even harder to combat. The classic problem-solving example of fixation induced by prior knowledge is Maier’s (1931) demonstration of functional fixedness, or the
inability to generate uncommon uses for everyday objects. Maier’s (1931) experiment examined functional fixedness in the context of having participants tie two strings together. The two strings were hanging vertically from the ceiling, but participants could not grasp them simultaneously. Various objects such as chairs, jars, and pliers were placed around the room, however, successfully tying the two strings involved using the pliers as a weight instead of a tool. This solution was difficult to generate because participants relied on their prior knowledge and experiences with pliers and categorized them as a tool instead of a weight for the string. Our prior knowledge includes concepts about classification and other assumed properties for objects or situations, and we draw from it to avoid learning about every novel object or situation that comes across our path (Ward, 1994). Relying on prior conceptual knowledge is generally an adaptive mechanism, but in some cases of problem solving it guides participants down the wrong solution path. Fixation may be further exacerbated if participants become blocked by a self-generated, incorrect solution.

The RAT is designed so that prior knowledge can induce fixation. When a participant sees the RAT problem they can focus on one of the three RAT cue words, which proceeds to activate various associates in memory. The participant must then retrieve one of these associates and determine if it is related to the second and third RAT cue words. At any point during the this process the chosen associate may not be related to one of the three cue words, in which case a different associate from memory is chosen (Smith, 1995). Fixation is highly probable during this procedure because prepotent responses are more accessible than remote associates. Even after the participant realizes that a prepotent response is not the solution it remains highly activated, and can interfere with the generation of other associates. Accordingly, RAT problems designed to activate misleading associates within a particular domain impaired problem solving for
participants with more prior knowledge in that domain. Wiley (1998) asked baseball experts and baseball novices to solve RAT problems, and sometimes the RAT problems included two baseball-related cue words. The solution to these problems, however, was not baseball-related. Baseball experts solved fewer of these baseball-misleading RAT problems than baseball novices, experienced more intrusions from baseball-related responses, and had slower solution times. Thus, the baseball-misleading RAT problems activated baseball experts’ prior knowledge for their first solution attempt, and led them down the wrong, baseball-related solution path. Interestingly, an incubation period differentially reduced fixation for novices and experts. Novices who received misleading responses prior to the first problem-solving attempt generated more solutions after an incubation period, but experts who received misleading responses did not benefit from incubation. Wiley suggested that novices benefitted from incubation because it provided them the opportunity to forget the associates causing fixation during the second problem-solving attempt, while experts returned to same, misleading mental set after incubation.

Moreover, design fixation studies have shown that experts (such as engineers) cannot escape conformity effects caused by previously-seen exemplars (for similar findings in other generative cognition tasks, see Ward, 1994, who used an alien generation task, or Marsh, Ward, & Landau, 1999, who asked participants to generate non-words without employing specific types of suffixes). Jansson and Smith (1991) conducted a series of four experiments to examine the effects of fixation on the design process. In the first three experiments, mechanical engineering students generated new designs for a bike rack, a measuring cup for the blind, and a spill-proof coffee cup. Half of the participants viewed one example design prior to design generation, and the other half did not view the example. Participants who viewed an example before problem solving reliably conformed to features from the example, as measured by the number of example
features in their own designs. Conformity effects persisted for domain experts (professional engineers), and even when they were instructed to avoid using the example features. Purcell and Gero (1996) replicated Jansson and Smith with two notable divergences. First, novice designers only showed conformity effects for the most familiar example even though they were provided with three examples prior to the design phase. Second, industrial design students avoided conformity effects, but mechanical engineering students did not. Purcell and Gero argued that these effects were caused by varying levels of prior knowledge. First, the familiar example triggered the use of everyday knowledge in novice designers, which improved memory for that example and allowed them to later explore it. Similarly, design features embodied principles from mechanical engineers’ domain; industrial designers were not as familiar with this specialized knowledge. Mechanical engineers may have recognized a familiar principle in the example, and then continued to explore that feature in their novel design.

These findings show how prior knowledge can cause mental fixation and impede the ability to generate other viable solutions in memory. Further, the different effects of incubation on problem solving in Wiley’s (1998) third experiment suggest that the source of fixation may affect how it can be best overcome. Further exploration of this suggestion is one main motivation for the present work.

A Cognitive Process Model of Problem Solving

Thus far, the way a problem solver approaches and solves a problem has been generally discussed, but the specific steps that a problem solver follows should be articulated. Smith (1995) discussed how problem solving involves a constructive search of memory in which people dig through and recombine ideas and information, rather than retrieve units as they were originally encoded. Once information is retrieved, mental models and schemas—or plans—
guide the way information is structured and processed alongside other information. A plan can be imagined as a roadmap that guides thinking via an iterative search process. For example, a simple plan for solving word fragments (Smith & Tindell, 1997) starts by the problem solver being presented with a to-be-solved word fragment like CO_RA_E. Potential responses in memory are activated, the problem solver retrieves a viable option, and then tests whether the word fits the fragment. If the word fits, like COURAGE, then the problem solver has completed the task with relatively little difficulty. If the word does not fit, like CORNER, the problem solver must retrieve another associate from memory and test whether the new word fits. The process continues until time runs out, or until the problem solver comes up with the solution.

The plan becomes more complex in the presence of fixation. The generation of viable solutions from memory depends on the accessibility of desired associates and whether stronger associates are blocking them (Storm, Angello, Buchli, Koppel, Little, & Nestojko, 2015). Repeatedly retrieving associates across retrieval episodes, priming using other means, or having a framework where those associates are highly activated due to prior knowledge, all increase the salience of the associates in memory. Therefore, increasing the salience of non-viable associates or information can induce fixation (Smith, 1995; 2003). Although strengthening an item improves the likelihood of its retrieval, retrieving this item also means selecting against other items in memory (Smith, 2003).

One way that Smith and Tindell (1997) experimentally induced fixation in the word-fragment completion task was by exposing participants to a target like CHORALE before having them solve the fragment CO_RA_E. When the word fragment appears on the screen, the problem solver may activate CHORALE because it is similar to the word fragment and it was recently primed. If the problem solver was warned that previously-seen words are incorrect
solutions, one of two possibilities may occur: 1) the problem solver can try to avoid thinking about CHORALE and other negatively-primed associated before they begin their memory search, or, 2) the problem solver can immediately think of a different viable solution if CHORALE pops into mind. If the problem solver was not warned, then they will test the possible solution, realize it is not the answer, and then choose another viable solution from memory. Unless the problem solver comes to a realization that the previously-seen words are not the solutions, they will not avoid thinking about them.

Fixation induced by prior knowledge may affect problem solving at the same points in the process, but to a different extent. It may be more difficult to avoid thinking about an entire domain that is deeply engrained in everyday cognition than it is to avoid thinking about specific, recently-primed information (such as what music novices experience during experimentally-induced fixation). Recently-primed information may also be more easily discarded after coming into the focus of attention, compared to incorrect solutions primed by prior knowledge. Moreover, if domain experts are exposed to domain-related incorrect solutions, the incorrect solutions will be stored in a highly-organized, domain-related schema, and become even more salient during problem solving.

**Overcoming Fixation**

The mechanisms necessary to overcome fixation may differ based on how fixation is induced. Cognitive mechanisms like inhibition and updating may modulate the ability to successfully retrieve the desired associations (Bristol & Viskontas, 2006), and vary the accessibility of stronger, non-viable associates in memory.

Using an individual differences approach, Storm and colleagues have argued that problem solvers can overcome fixation by directly inhibiting the associates causing fixation.
(Storm & Angello, 2010; Storm, et al., 2011; Storm & Koppel, 2012; Koppel & Storm, 2014; for a review, see Storm, 2011). That is, participants may inhibit the misleading associates that cause fixation to reduce interference instead of passively waiting for fixation to dissipate on its own. First, Storm and Angello (2010) examined the relationship between retrieval-induced forgetting (one specific measure of inhibition that is induced by resolving competition in memory), and RAT performance under fixated and non-fixated conditions. Retrieval-induced forgetting was measured first with a variant of the retrieval-practice paradigm (Anderson & Bjork, 1994; Bäuml, 2002), and then participants attempted to solve 20 RAT problems. Half of the participants, however, studied RAT cue word- misleading associate response pairs prior to problem solving. Storm and Angello found that participants who showed the most retrieval-induced forgetting also solved the most RAT problems in the fixated condition, but this pattern did not appear in the non-fixated condition. They theorized that individuals who showed more retrieval-induced forgetting were more successful at inhibiting inappropriate information in different contexts. Proficiency in this ability transferred to inhibiting misleading associates during problem solving and subsequently improved performance. By contrast, there was no relationship between retrieval-induced forgetting and RAT problem solving when inhibition was less necessary, such as in the non-fixated condition. Koppel and Storm (2014) also found that providing participants with a break in between two RAT problem-solving attempts eliminated the relationship between retrieval-induced forgetting and RAT success during the second attempt. An incubation period reduced the need for inhibition in problem solving by reducing the extent to which problem solvers suffered from fixation.

Storm, et al. (2011) provided direct evidence for the assumption that misleading associates are inhibited during problem solving by showing that a simple problem solving
attempt can cause problem-solving-induced forgetting. In their experiment, participants studied cue-associate pairs; half of pairs were misleading and the other half were unrelated to subsequent RAT problems. After attempting to solve the RAT problems, participants were tested on their ability to recall the previously-studied associates. Fewer misleading associates were recalled than unrelated associates on this test (an effect they referred to as problem-solving-induced forgetting), presumably because misleading associates interfered during earlier problem-solving attempts and had been inhibited. In a subsequent experiment, Storm et al. found that participants who showed the most problem-solving-induced forgetting were also better problem solvers on a separate set of fixated RAT problems. This finding suggests that the process underlying problem-solving-induced forgetting plays an adaptive role in facilitating performance during problem solving where fixation is experimentally induced.

In a study exploring the relationship between individual differences in executive functioning and overcoming fixation due to prior knowledge, Ricks, Turley-Ames, and Wiley (2007) examined the relationship between working memory capacity (WMC) and RAT performance for individuals with varying amounts of baseball knowledge using Wiley’s (1998) baseball-misleading problems. After giving participants the complex span tasks to measure individual differences in working memory, participants solved 20 RAT problems. Half the RAT problems were neutral and half were baseball-misleading (2 of the 3 cue words related to baseball, but the solution was not baseball-related). WMC positively predicted performance for both kinds of problems for baseball novices, and if anything, there was a stronger relationship for the baseball-misleading problems. However, WMC positively predicted performance for baseball experts for the neutral problems only. They theorized that WMC helps problem solving in general because higher WMC individuals are better at retrieving information from long term
memory (consistent with Rosen & Engle, 1997). Higher WMC may have benefited novices, but not experts, in the baseball-misleading condition because experts with higher WMC focused too much of their attention on the misleading solution attempt (consistent with Conway, Cowan, & Bunting, 2001). That is, WMC may help novices overcome fixation caused by initial solution attempts, but it does not help experts overcome fixation induced by their prior knowledge.

As noted above, Wiley’s (1998) findings also support the idea that fixation induced by prior knowledge may be qualitatively different than experimentally-induced fixation, although she demonstrated this via experimental manipulation as opposed to an individual differences approach. In Wiley’s third experiment, participants (baseball novices and experts) solved baseball-misleading and baseball-neutral problems, but half of the participants received an incubation period in between two RAT problem-solving attempts. Baseball novices benefited from the incubation period and solved more problems following the break, but baseball experts did not. Wiley suggested that fixation dissipates during the break for baseball novices, but baseball experts come back to the same mental set in the second problem-solving attempt because their fixation is induced by domain knowledge. Findings from Wiley and colleagues suggest that the fixation experienced by experts- induced by their prior domain knowledge- cannot be overcome in the same way as experimentally-induced fixation.

**Do Different Executive Functions Predict Overcoming Different Kinds of Fixation?**

The main question to be tested in the present experiments is whether fixation that is experimentally-induced versus induced by domain knowledge can be shown to be qualitatively different via an individual-differences approach. Underwood (1975) argued that individual-difference approaches can be used as a crucible in nomothetic theory construction because they promote a deeper understanding of the underlying process variables. Because individual
differences that are presumed to underlie nomothetic theories can be reliably assessed outside of said theory, relationships between performance outcomes and individual difference measures can be a green light to explore the validity of the theory. If, for example, a strong relationship is found between the individual difference measure presumed to underlie performance and performance outcomes, the theory deserves further exploration and may be substantiated through further experimentation. A relationship does not validate the theory on its own, but rather acts as a crucible in theory construction. If, however, there is no relationship between the individual difference measure thought to underlie the theory and performance outcomes, then the theory is flawed and should be re-examined. Thus, an individual-differences approach is a thoughtful way to explore the theory that people experience qualitatively different kinds of fixation, and allows us to ultimately create a better model of fixation.

Does the relationship between different kinds of executive functioning and overcoming fixation change depending on how fixation is induced? Are different mechanisms required to reduce the activation of long-term information in memory, as opposed to recently-activated information in memory? The two instances of fixation feel like they’re qualitatively different, but whether there are different types of fixation that may be overcome by different means has received little attention. To further explore this question, both kinds of fixation were explored in a word-fragment completion task (based on Smith & Tindell, 1997) which contained words that were orthographically similar to music-related terms, but impossible to solve using music-related words. To manipulate experimentally-induced fixation, half of the participants saw music-related misleading primes (music-misleading primes) prior to problem solving, and half of the participants did not. To manipulate fixation due to prior knowledge, the first experiment investigated problem solving using a non-expert/novice sample with less than 5 years of music
experience, while the second experiment used an “expert” sample of participants who had more than six years of music experience.

To explore how different “flavors” of executive functioning predict the ability to overcome different kinds of fixation, the three kinds of executive functioning measures were collected in these studies: restraint, updating, and retrieval-induced forgetting. Two of these constructs (restraint and updating) come from the taxonomy developed by Miyake and colleagues (Miyake & Friedman, 2012; see also Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000, or Friedman & Miyake, 2004). Miyake et al. (2000) describe restraint as a controlled, deliberate, intentional suppression process in memory. Miyake et al. found that the anti-saccade task (Hallett, 1978), stop-signal task (Logan, 1994), and Stroop task (Stroop, 1935) loaded onto a single factor, which they interpreted as representing the ability to suppress dominant, prepotent responses. Stroop measures, in particular, are prototypically used to explore restraint because success depends on overriding automatic, strong responses in order to produce the atypical response (i.e., naming the color the word is printed in, instead of reading the color of the word). Stroop-like effects also occur in word categorization tasks when participants view incongruent picture-word compounds, and must ignore the picture to categorize the word (Arieh & Algom, 2002). Categorizing pictures is easier than categorizing words (as represented by faster categorization response times), so word categorization performance is impaired by the presence of irrelevant pictures. The kind of restraint needed to consciously suppress interfering concepts in these tasks seems like a plausible candidate for an individual differences construct that may help to reduce the activation of unhelpful, but prepotent prior knowledge during problem solving. This suggests restraint may be particularly helpful for overcoming fixation in the expert sample. One could argue that if experts are warned that their prior knowledge will
hurt them during problem solving, then restraint might suppress prior knowledge before problem solving. Restraint may also act to suppress prior knowledge after incorrect solutions pop up.

Both processes may occur, however, word categorization requires the participant to restrain the picture after it appears on the screen, which aligns more closely with the idea that restraint attenuates prior knowledge after it pops up during problem solving.

Miyake et al. (2000) describe updating as the process underlying monitoring episodic representations, and revising those representations when irrelevant information needs to be replaced (Morris & Jones, 1990). This construct is closely aligned to the notion of WMC, or the ability to control one’s attention. The automated running span (Broadway & Engle, 2010), backwards digit span (Unsworth & Engle, 2007), and letter-number sequencing task (LNS; Wechsler, 1997) often represent updating, or WMC, in the literature. WMC can be thought of as the ability to focus in the face of distraction (Engle, Kane, & Tuholski, 1999). WMC may relate to problem solving because WMC helps reduce the search set size to include fewer irrelevant items in memory (Unsworth, Spillers, & Brewer, 2010), decrease competition during retrieval (Mall & Morey, 2013), reinstate the initial learning context at retrieval (Unsworth & Spillers, 2010), and move items in and out of the focus of attention (Rosen & Engle, 1997; Wiley & Jarosz, 2012). However, as suggested by the findings of Ricks, et al., WMC may not particularly help to reduce the activation of unhelpful, but prepotent prior knowledge during problem solving, so it may be particularly helpful for resolving experimentally-induced fixation, or in overcoming fixation in the novice sample. Updating may help novices narrow the problem space prior to problem solving if novices are warned that previously-seen words will not help them, and updating may improve the ability to pull viable solutions from memory during problem solving.
solving, or help to move incorrect solutions out of attentional control during problem solving, regardless of a warning.

A third construct that will be explored is retrieval-induced forgetting, which Storm and colleagues have already shown can relate to overcoming experimentally-induced fixation. Retrieval-induced forgetting results from selecting against competing, non-target information, to better access target information in memory (Bjork, 1989; Levy & Anderson, 2002). In the retrieval-practice paradigm, participants study a list of category-exemplar pairs (fruit-lemon, tools-hammer, fruit-orange, tools-pliers) and then practice retrieving half of the exemplars from half of the categories (e.g., fruit-le__). Retrieval-induced forgetting is observed on a final recall test when unpracticed exemplars from practiced categories (i.e., orange) are recalled less than unpracticed exemplars from unpracticed categories (i.e., hammer, pliers). There is now substantial evidence supporting the inhibitory account of retrieval-induced forgetting, which theorizes that inhibition acts during retrieval practice to reduce competition from non-target items that interfere with the retrieval of target items (for a review see Storm & Levy, 2012). Retrieval-induced forgetting is thought to play a role in problem solving when participants must generate a response in the presence of competing information, so the role for retrieval-induced forgetting should be strongest when the solver needs to reduce the accessibility of inappropriate solutions. Because participants who are fixated are experiencing competition from inappropriate solutions, one could predict that retrieval-induced forgetting should help to overcome fixation when it is experimentally-induced, but retrieval-induced forgetting should be less predictive when fixation is not induced. Further, because retrieval-induced forgetting has only been shown to predict overcoming fixation when it is experimentally induced, it may not be related to overcoming fixation from prior knowledge. This suggests that retrieval-induced forgetting may
only predict performance of novices in the experimentally-induced fixation condition. Retrieval-induced forgetting should help novices suppress incorrect solutions after they are activated and compete for retrieval. However, a warning to avoid using previously-seen words may decrease the role for retrieval-induced forgetting if participants believe the warning and forget about the previously-seen words prior to problem solving.

Thus, it seems that restraint, updating, and retrieval-induced forgetting could help to demonstrate that different mechanisms may be necessary to overcome the two different sources of fixation in problem solving. To overcome experimentally-induced fixation one may need to successfully update episodic representations and inhibit misleading responses, but to overcome fixation induced by prior domain knowledge one may need to restrain prepotent, dominant responses.
II. GENERAL METHODS

Similar methods were used across studies and are described before reporting specific
details and the results for different experiments.

Measures

Executive function measures. The three types of executive functions that were assessed
were updating, retrieval-induced forgetting, and restraint (see Appendix A for stimuli examples).
Updating was measured with automated running span, backwards digit span, and letter-number
sequencing, retrieval-induced forgetting was measured with the retrieval-practice paradigm, and
restraint was measured with the word categorization task, number Stroop, and spatial Stroop. All
are described below.

Automated running span. The automated running span, based on Broadway and Engle’s
(2010) task, presented a string of letters on the screen one at a time. Participants saw between
four to nine letters for 300 ms each, and then had 15 s to type the last three to six letters in the
series. After one worked example and 6 practice trials, participants completed two blocks; each
block included three trials of each length. The task took about five minutes to complete, during
which participants must continue to update the last letters in memory, while forgetting the earlier
letters. The automated running span was scored by calculating the number of items recalled in
the correct serial position.

Backwards digit span. The backwards digit span, based on Unsworth and Engle’s (2007)
task, presented a string of numbers on the screen one at a time. Participants saw between two
and eight numbers for 500 ms each, and after the numbers disappeared they had 15 s to type
them in reverse order. After one worked example, there were two trials of each set size, with set
size increasing as the task progressed. To complete the task participants must update the
remaining numbers during reverse recall, while forgetting the earlier numbers. The backwards
digit span was also scored by calculating the number of items recalled in the correct serial position.

**WAIS letter-number sequencing (LNS).** LNS, based on Wechsler’s (1997) task (see also, Emery, Myerson, & Hale, 2007), presented a string of alternating letters and numbers on the screen one at a time. Participants saw between two and eight items for 1s each, and then typed the numbers in ascending order, followed by the letters alphabetically. The test began by showing the participant one letter and one number, and continued until presenting a maximum of four letters and four numbers. After one example, there were three trials of each length. Participants completed the entire task, but scoring stopped after they failed three trials of one length. To do the task, participants must organize the remaining numbers and letters during recall, while forgetting the already-recalled items. The letter-number sequencing task was scored by summing the number of series correctly recalled, with a maximum score of 21 (Wechsler, 1997).

**Retrieval-practice paradigm.** The retrieval-practice paradigm (Anderson, Bjork, & Bjork, 1994; Bäuml, 2002) is comprised of the study phase, the retrieval-practice phase, and final test. In the study phase, participants learned 48 category-exemplar pairs consisting six exemplars in each of eight categories (e.g., profession-janitor, drink-cognac, profession-dentist, drink-tequila). Every exemplar in a given category began with a different letter, ensuring that participants received unique first-letter cues at final test. Category-exemplar pairs were based on Anderson et al. (see their Appendix C for example stimuli). Participants viewed the category-exemplar pairs in a block-randomized order for 4s each, and each block of 8 category-exemplar pairs included one exemplar from each category.
Participants then experienced three rounds of extra-list retrieval practice. Participants had 7 s to generate (type) a new exemplar when given a category-plus-two-letter-stem cue (e.g., profession-ac____) for each of the four to-be-practiced categories. There were six cues related to each category-- a total of 72 retrieval-practice trials (six new cues for four categories, and three repetitions of the 24 distinct cues). The categories that received extra-list retrieval practice were counterbalanced, and each exemplar was just as likely to be an item from an unpracticed category (Nrp item) as it was a practiced category (Rp item).

Participants immediately took a category-plus-one-letter-stem cued-recall test following retrieval practice. All 48 exemplars from the study phase were tested, and participants had 5 s to type each exemplar. Because participants typed their responses, sometimes they spelled the answers incorrectly. Two judges reviewed all of the responses, and judged whether the response sounded like the answer when read aloud. If the judges disagreed about whether the response sounded like the answer, a third judge made the final decision. Inhibitory-based accounts of retrieval-induced forgetting (Anderson, 2003; Storm & Levy, 2012; Verde, 2012) theorize that participants experience competition from the Rp-items during retrieval practice, and try to select against them. The reduced activation of Rp-items remains at final test, causing them to be less recallable than Nrp items. Retrieval-induced forgetting was calculated at final test by taking the difference in recall performance between Rp-items and Nrp items. Positive numbers indicated more retrieval-induced forgetting.

**Word categorization task.** Word categorization, based on Amit, Algom, and Trope’s (2009) task (see also Arieh & Algom, 2002), presented a picture of fruit (apple, banana, cherry, lemon) or furniture (table, piano, vase, stool) on the screen with the name of a fruit or furniture overlaid on top, one at a time. Fifty percent of the trials had a word and picture from the same
category (congruent), and 50% of the trials had a word and picture from different categories (incongruent). Participants received 2 blocks with 64 items in each block, comprised of every possible combination of the fruit-furniture pairs. The order of items within each block was randomized across participants. Participants pressed one of two buttons on the keyboard as fast as possible indicating whether the word was a type of fruit (‘a’) or furniture (‘l’). Before beginning the task, participants were instructed to categorize the words and ignore the pictures, and then received four examples (two congruent, two incongruent) with feedback. Success depends on the ability to stop the dominant response of categorizing the picture, and instead categorize the word. Word categorization was scored by calculating the difference in reaction times on correct trials by subtracting incongruent from congruent trials so that larger scores indicated more restraint. Only reaction times between 150ms and 1500ms were included (following Amit et al.’s protocol).

**Number Stroop.** Number Stroop, based on Bull and Scerif’s (2001) task (see also, Salthouse & Meinz, 1995), presented a string of 1 to 4 stimuli on the screen. Each string was either comprised of the letter X, or the digits 1, 2, 3, or 4. Participants typed the quantity of the items on the screen. Following the instructions and 12 practice trials with corrective feedback, there were 4 blocks of 24 trials each. One-third of the trials were neutral and presented between 1 and 4 X’s on the screen (e.g., XXX), one-third of the trials were congruent and presented the quantity of digits that the number represents (e.g., 333), and one-third of the trials were incongruent and presented a quantity of digits that the number did not represent (e.g., 44). The order of items within each block was randomized across participants. In incongruent trials participants must ignore prepotent, prior knowledge in memory (number meaning) to type the
quantity of the stimuli on the screen. Number Stroop was scored by subtracting incongruent from neutral trials so that larger scores indicated more restraint.

**Spatial Stroop.** Spatial Stroop, based on Fox, Shor and Steinman’s (1971) task, presented the stimuli *LEFT, RIGHT,* or *OOOO* on either the left, or right side of the computer screen. Participants pressed the side of the keyboard that corresponded to the side on which the stimuli appeared. After receiving the instructions and 12 practice trials with corrective feedback, there were 3 blocks of 30 trials each. One-third of the trials were neutral and presented *OOOO* on either side of the screen, one-third of the trials were congruent and presented *LEFT* or *RIGHT* on the side corresponding with the word meaning, and the last third of the trials were incongruent and presented *LEFT* or *RIGHT* on the side contradictory to the word meaning. The order of items within each block was randomized across participants. In incongruent trials participants must ignore prepotent, prior knowledge in memory (word meaning) to respond to the screen side of that word. Spatial Stroop was scored by subtracting incongruent from neutral trials so that larger scores indicated more restraint.

**Fixation induction and word-fragment completion task.** The word-fragment completion task (based on Smith & Tindell, 1997) occurred in a separate session from the executive function battery (see Appendix B and Appendix C for word-fragment completion task stimuli). In this task participants attempted to solve 18 word fragments that were orthographically similar to 18 music-related terms. The targets and primes were comprised of 7 letters each, shared the same first letter, and shared 3-6 other letters in the same sequence. For example, BARGAIN was the target for the word fragment B_RG_I_, but BAGPIPE was an orthographically-similar, music-related word that did not complete the word fragment. Participants also attempted to solve 18 neutral word fragments that were not orthographically
similar to music-related words. The 18 neutral word fragments were matched in baseline completion rates to the 18 music-misleading words.

Prior to the word-fragment completion task, participants were exposed to either the 18 music-related solution words as misleading primes to induce fixation (misleading prime condition), or not (no prime condition). In the misleading prime condition, participants saw the 18 music-related solution words and rated their pleasantness on a scale from 0 to 5. However, in the no prime condition participants were never exposed to the music-related solution words. In lieu of the primes, participants saw 18 swatches of colors and rated their pleasantness on a scale from 0 to 5. Participants then received instructions and a worked example for the word-fragment completion task before solving 36 word fragments (the block of 18 neutral fragments, and then the block of 18 music-misleading fragments).

The word-fragment completion task was scored by calculating the 1) proportion of music-misleading fragments that were successfully solved, 2) proportion of neutral fragments that were successfully solved, 3) average solution times for successfully-completed music-misleading fragments, 4) average solution times for successfully-completed neutral fragments, and 5) proportion of intrusions (misleading music primes that were provided as responses) for music-misleading fragments. Better problem solving performance would be indicated by a larger proportion of correct solutions, faster solution times, and fewer intrusions.

**Final survey.** At the end of the study participants completed a series of assessments and questionnaires relating to their music knowledge. Participants first rated the familiarity (using a 1-7 likert scale) for each music-related solution word, considering how often they encountered each word in the typical week. Then participants took a multiple-choice test in which they chose the definition for each music-related word from four response options. After choosing one of
four options for each question, they rated the confidence in their answer on a 1-7 likert scale. Finally, participants completed a musicianship questionnaire (see Appendix D) to assess individual differences in music expertise (domain knowledge). Expertise was assessed based on participants’ instrumental and/or vocal experience in structured or private settings, and their familiarity with transcribing, creating, or improvising music. The questionnaire also included basic demographic information about gender, age, ACT scores, and language background.

Procedure. Participants were informed that they would do different kinds of tasks during the sessions. Experiments were run using E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA). On Day 1, participants completed the spatial Stroop, number Stroop, and word categorization task. Participants then completed the running span, immediately followed by the backwards digit span, and then LNS. Finally, participants completed the retrieval-practice paradigm. In the study phase participants were told to study the category-exemplar pairs and relate the member to its category. For extra-list retrieval practice, participants were given a worked example and instructed that the answers “MAY OR MAY NOT come from the list [they] just learned”. Then participants completed the final test. Before the participant left, the experimenter scheduled a time for them to return the following week around the same time of day.

On Day 2, participants started by competing the word-fragment completion task. If the participant was in the no prime condition, they had 5 s to rate the pleasantness of each color swatch, but if they were in the misleading prime condition, they had 5 s to rate the pleasantness of each music-misleading word. The music-misleading words negatively primed subsequent word fragments. Because experts for Experiment 2 had to be recruited by advertising for people with music experience, to make sure this did not set up an expectation that they should use their
music knowledge during the study, all participants in Experiment 1 and 2 received a warning
(based on Wiley, 1998) that, “Some of the problems may bring music-related terms to mind.
However, you should try to ignore them because they will NOT lead you to the correct solution.”
A third experiment recruited another novice sample, and these participants did not receive this
warning. Participants then had 5 s to view each of the 36 word fragments on the screen (18
neutral trials, and then 18 music-misleading trials), and 4 s to type in a response. The response
time that was analyzed began at the onset of the answer screen and terminated when they pressed
Enter. Participants viewed the fragments in the same, set order. Participants then received a
packet and took as much time as they needed to fill out the music familiarity section, the
multiple-choice music term recognition quiz, the musicianship questionnaire (found in Appendix
D), and the demographic questionnaire. Participants were debriefed before exiting the lab.

**Deriving Individual Difference Measures**

**Imputing missing data.** Before attempting to derive factors for the individual
differences constructs, missing data were imputed for 31 missing scores across the three studies
(N= 293). Due to equipment malfunction, backwards digit span scores for two participants were
not collected in Experiment 1, and running span scores were not collected for two participants in
Experiment 2 and Experiment 3. LNS scores for 27 participants were removed because the
participants did not understand the instructions (10 participants each in Experiments 1 and 2, and
7 participants in Experiment 3). In all, the 31 missing scores were from 31 participants. Ignoring
these cases completely would lead to a loss of power and biased estimates (Rubin, Witkiewitz,
St. Andre, & Reilly, 2007). Instead, the 31 missing scores (2.11% of the individual difference
scores, or 3.7% of the scores loading onto the updating factor) were multiply imputed in SPSS in
a model that included backward digit span scores, running span scores, and LNS scores. Multiple
imputation is an appropriate way to estimate missing values in studies where less than 10% of the data in the entire matrix of scores are missing (Kline, 1998). A MCMC algorithm called fully conditional specification (FCS) imputed missing values one at a time, using the predictors’ imputed values in one step to predict missing values in the subsequent steps via linear regression. FCS may be used in situations where the data shows an arbitrary pattern of missing values (i.e., Missing Completely At Random; MCAR; Allison, 2002), as was the case with this experiment.

SPSS provided five imputations of the data, and each imputation was based on 1000 iterations to estimate missing values (for guidelines see Little & Rubin, 2002). SPSS provided pooled estimates of the five imputations for some inferential statistics (e.g., bivariate correlations, linear regression, and independent samples t-tests), but not descriptive statistics (e.g., normality tests, bar graphs, or scatterplots). To deal with this problem an average was calculated for each missing value by collapsing across the five imputed data sets, to create one data set for which all descriptive and inferential statistics could be run. Inferential test results were similar for the data set using pooled estimates and the data set using average imputed values. The following results are therefore based on one data set with 31 data points that have been averaged across five imputed values. Relations among the measures are shown in Table 1.
Table 1
Overall correlation table for individual difference measures.

<table>
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<th>Measure</th>
<th>RIF</th>
<th>RS</th>
<th>BDS</th>
<th>LNS</th>
<th>WC</th>
<th>NS</th>
<th>SS</th>
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<td>-</td>
</tr>
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<td>.40***</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
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<td>.37***</td>
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<td>-</td>
<td>-</td>
<td>-</td>
</tr>
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<td>-.05</td>
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<td>-</td>
<td>-</td>
</tr>
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<td>-.05</td>
<td>-.05</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>SS</td>
<td>-.01</td>
<td>.05</td>
<td>-.03</td>
<td>-.03</td>
<td>.03</td>
<td>.07</td>
<td>1</td>
</tr>
</tbody>
</table>

Note. RIF= retrieval-induced forgetting, RS=running span, BDS=backwards digit span, LNS=letter-number sequencing, WC=word categorization, NS= number Stroop, SS=spatial Stroop.

* p<.05, **p<.01, ***p<.001.

**Retrieval-induced forgetting.** Descriptive statistics for the tasks are presented in Table 2. Skewness was symmetrical based on the Kline (1998) cut-offs of being between -2.0 and +2.0, and kurtosis fell well within the range of -4.0 to +4.0, which is considered acceptable proof of a normal, univariate distribution (Kline, 1998). The reliability estimates were calculated by computing a strict parallel test of reliability (Kuder & Richardson, 1937). Retrieval-induced forgetting was unreliable based on Kline’s (1998) cut-off of surpassing 0.7. A recent meta-analysis of retrieval-induced forgetting found an average score of 8.7% (95% CI = [7.5%, 9.8%]) (Murayama, Mitatsu, Buchli, & Storm, 2014), which was similar to the average retrieval-induced forgetting score of 7.42% (95% CI = [5.97%, 8.87%]).
Table 2
Overall descriptive statistics.

<table>
<thead>
<tr>
<th>Task</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Reliability Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIF</td>
<td>293</td>
<td>.07</td>
<td>.13</td>
<td>-.25</td>
<td>.46</td>
<td>0.08</td>
<td>-0.08</td>
<td>.12</td>
</tr>
<tr>
<td>RS</td>
<td>293</td>
<td>47.65</td>
<td>15.35</td>
<td>7</td>
<td>87</td>
<td>0.14</td>
<td>-0.58</td>
<td>.99</td>
</tr>
<tr>
<td>BDS</td>
<td>293</td>
<td>41.16</td>
<td>9.60</td>
<td>14</td>
<td>68</td>
<td>0.18</td>
<td>0.00</td>
<td>.99</td>
</tr>
<tr>
<td>LNS</td>
<td>293</td>
<td>9.85</td>
<td>3.07</td>
<td>1</td>
<td>20</td>
<td>-0.05</td>
<td>0.38</td>
<td>.78</td>
</tr>
<tr>
<td>WC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NS</td>
<td>293</td>
<td>55.66</td>
<td>53.16</td>
<td>284.93</td>
<td>128.1</td>
<td>-0.17</td>
<td>1.28</td>
<td>.14</td>
</tr>
<tr>
<td>SS</td>
<td>293</td>
<td>2.54</td>
<td>24.77</td>
<td>-98.11</td>
<td>220.4</td>
<td>2.42</td>
<td>22.62</td>
<td>.26</td>
</tr>
</tbody>
</table>

Note. RIF= retrieval-induced forgetting, RS=running span, BDS=backwards digit span,
LNS=letter-number sequencing, WC=word categorization, NS= number Stroop, SS=spatial Stroop.

Restraint. A factor derived from performance on the word categorization, number Stroop, and spatial Stroop tasks was originally proposed to represent the restraint construct. However, as shown in Table 1, there was a lack of convergence among the measures. Skewness (descriptives in Table 2) for word categorization and number Stroop fell between -2.0 and +2.0, but spatial Stroop was more positively skewed. Kurtosis for word categorization and number Stroop fell within the range of -4.0 to +4.0, but spatial Stroop was extreme (if >10, based on Kline, 1998). Reliability for the three tasks failed to surpass the 0.7 threshold (Kline, 1999), but word categorization was the most reliable of the three. Word categorization had an average Stroop effect of -44.43 ms (95% CI = [-39.68, -49.18]), which was similar to the -33 ms Stroop effect (95% CI = [11.29, 54.71]) found by Arieh and Algom (2002). Number Stroop had an
average Stroop effect of -55.66 ms (95% CI = [-49.57, -61.75]), which seemed lower than Hart, Green, Casp, and Belger’s (2010) -97.66 ms Stroop effect (95% CI = [-41.58, -153.74]) despite overlapping confidence intervals. However, Hart et al.’s confidence intervals were quite large due to a very small sample size. Spatial Stroop had an average Stroop effect of 2.54 ms (95% CI = [-.30, 5.38]), which was dissimilar to the -10.49 ms Stroop effect (95% CI = [-5.3, -15.68]) found by Fox, et al. (1971).

A majority of participants used a strategy in the spatial Stroop task that invalidated the measure, and performance on the number Stroop and word categorization measures were unrelated, \( r = -.05, p = .42 \). Word categorization was selected to represent the restraint construct because it best replicated prior findings and seemed to best represent the kind of restraint that would be useful for experts who were fixated by their domain knowledge. Word categorization depends on restraining a prepotent response related to objects and prior conceptual knowledge stored in long-term memory. Additionally, word categorization was more reliable than either the number Stroop or the spatial Stroop.

**Updating.** On the other hand, as shown in Table 1, performance on the three updating measures was more convergent and running span, backwards digit span, and LNS were all significantly, positively correlated with each other. Skewness and kurtosis (found in Table 2) for the three tasks were well within the range that defines a normal, symmetrical distribution. Reliability for the three tasks also exceeded the cut-off of .70. The LNS averaged 9.85 (95% CI = [9.51, 10.19]), which was slightly lower than the 12.53 average (95% CI = [12.14,12.92]) reported by Hill, Elliott, Shelton, Pella, O’Jile, and Gouvier (2010). Backwards digit span averaged 41.16 (95% CI = [40.06, 42.46]), which was slightly lower than Ackerman, Beier, and Boyle’s (2002) score of 48.94 (95% CI = [46.08, 51.80]), but their study had a maximum of 99,
and this study had a maximum of 70. Studies that used partial scoring for running span did not include the same number of trials as this study, so raw scores were converted into proportions for comparison purposes. The proportion of correct items in running span was 44.12% (95% CI = [42.49%, 44.75%]), which was slightly lower than Broadway and Engle’s (2010) proportion of 60.06% (95% CI = [56.00%, 64.12%]). It should be noted that Broadway and Engle included trials with 0, 1, or 2 distractors preceding the critical items, and our study used 1, 2, or 3 distractors. Twenty-five percent of their trials were easier than ours, increasing their scores.

An updating factor that included the running span, backwards digit span, and LNS, was created based on exploratory factor analysis; retrieval-induced forgetting and word categorization stood as their own measures (Figure 1 shows standardized factor loadings for the proposed model). The psych package in R was used to run a parallel analysis to explain as much variance as possible with the fewest number of factors (Hayton, Allen, & Scarpello, 2004). Parallel analysis is less subjective than a more traditional scree plot method. First, parallel analysis compared the eigenvalues of the observed data set to the eigenvalues of simulated variables with random correlations. Two factors were extracted from the five tasks, meaning two factors had observed eigenvalues that were greater than the random eigenvalues. A principal axis analysis with promax rotation then specified the underlying constructs in the data. One factor, updating, underlied running span, backwards digit span, and LNS. Another factor, inhibition, underlied retrieval-induced forgetting. Word categorization (the restraint measure) was kicked out of the analysis because it did not relate significantly to either factor, failing to pass the 0.30 threshold (Nunnally, 1978). Promax rotation allowed for recognition of the relationships between the updating construct and retrieval-induced forgetting, which was -.09 (replicating the negative relationship Mall & Morey, 2014, found between WMC and retrieval-
induced forgetting). The model produced a non-significant chi-square test, $\chi^2(10, N = 293) = 0.39, p = .53$. The RMSR of 0.01 was also below the .08 threshold (Hu & Bentler, 1999). The RMSR and non-significant $\chi^2$ statistic suggest that the two-factor model is a good fit for the observed data. Retrieval-induced forgetting was identified as representing its own factor separate from the updating factor. As word categorization did not relate to any of the factors in the model, word categorization stood as a distinct measure of restraint. These are the three different executive function measures that were used to predict who is able to overcome different kinds of fixation.

![Diagram of two-factor model](image)

*Figure 1.* Two-factor model for updating and inhibition for all participants (N=293). Word categorization did not load significantly onto either factor. Standardized regression coefficients are presented.
III. EXPERIMENT 1

The first experiment explored the effects of individual differences in three measures of executive functioning on overcoming experimentally-induced fixation in a novice sample. Based on the results of Ricks et al. (2007), there should be a positive relationship between the number of correct solutions and the updating factor in both the misleading prime condition and the no prime condition.

Based on the results of Storm and Angello (2010) there should be a positive relationship between retrieval-induced forgetting and problem solving performance in the misleading prime condition. However, when non-experts are not exposed to misleading primes, the role for retrieval-induced forgetting may be reduced as there is less competition in episodic memory to resolve. If true, there would be no relationship in the no prime condition between retrieval-induced forgetting and problem solving. This predicts an interaction between retrieval-induced forgetting and fixation condition.

Restraint should not predict problem solving for non-experts in either the misleading prime or the no prime condition, because restraint should be related to reducing the activation of dominant, pre-potent responses in long-term memory.

Method

Participants. The final sample included 107 undergraduates from the Introductory Psychology subject pool at University of Illinois at Chicago (UIC), who received partial course credit for participation. There were originally 115 non-experts total, classified as having less than 5 years of music experience. Although Ericsson, Krampe, and Tesch-Romer (1993) suggested a 10-year threshold for expertise, this criterion made it difficult to find music experts in the UIC subject pool. Lowering the threshold to 5 years allowed us to classify an 18-year old freshman who started singing or playing an instrument at age 13 as having extensive experience
with music. Participants who had music familiarity or music quiz scores in the top 2% of the distribution (5 participants) were also removed because their scores appeared extremely high for non-experts. One participant with a running span score of 13 (outlier) was removed, and two participants who were missing a retrieval-induced forgetting score and a restraint score were removed. The final sample sizes for number of solution analyses was \( n = 52 \) in the misleading prime condition, and \( n = 55 \) in the no prime condition. For solution time analyses, final sample sizes were \( n = 54 \) for neutral fragments in the no prime condition, \( n = 55 \) for music-misleading fragments in the no prime condition, \( n = 52 \) for neutral fragments in the misleading prime condition, and \( n = 44 \) for music-misleading fragments in the misleading prime condition. Some participants did not get any correct solutions on one type of fragment (misleading or neutral), in which case, solution time data could not be analyzed.
IV. RESULTS

Equivalence of Conditions

To test for equivalence of conditions on individual difference measures, t-tests compared the variables in the misleading prime condition and no prime condition. Descriptive statistics and t-statistics are shown in Table 3. Individual difference measures did not differ between the misleading prime and no prime conditions, although differences were seen in age, and percentage of native English speakers, and trends were seen in updating, and restraint. Although non-experts were slightly younger in the no prime condition than in the misleading prime condition, age did not correlate with any of the individual difference measures, the number of music-misleading fragments solved, or the number of neutral fragments solved in either condition (see Table 4 for correlations). There were also more native English speakers in the no prime condition than in the misleading prime condition. Moreover, non-native English speakers experienced a similar amount of fixation in the misleading prime condition ($M=7.14$, $SD=0.09$) and in the no prime condition ($M=6.48$, $SD=0.07$), $t(18)=0.16$, $p=.87$, while there was a pattern that native English speakers experienced more fixation in the misleading prime condition ($M=12.72$, $SD=0.12$) than in the no prime condition ($M=8.73$, $SD=0.15$), $t(85)=-1.35$, $p=.18$. It seems unlikely that this difference could be driving effects, though, because there was still fixation in the misleading prime condition. If anything, the greater number of non-native English speakers in the misleading prime condition should have eliminated the fixation effect, but it did not. Finally, there were patterns that updating scores were higher in the misleading prime condition, and restraint scores were higher in the no prime condition. However, these scores showed similar correlations with the number of neutral and music-misleading fragments solved in the no prime condition (see Table 5), and the misleading prime condition (see Table 6).
Table 3

Descriptive statistics and t-statistics for demographics and individual difference measures by prime condition.

<table>
<thead>
<tr>
<th>Prime Condition</th>
<th>No Prime</th>
<th>Misleading Prime</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>n</td>
</tr>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>18.56 (0.94)</td>
<td>55</td>
</tr>
<tr>
<td>ACT composite</td>
<td>23.33 (4.22)</td>
<td>51</td>
</tr>
<tr>
<td>Native English speakers</td>
<td>.89 (.32)</td>
<td>55</td>
</tr>
<tr>
<td>Years Instrument</td>
<td>0.56 (1.24)</td>
<td>55</td>
</tr>
<tr>
<td>Years Sang</td>
<td>0.15 (0.56)</td>
<td>55</td>
</tr>
<tr>
<td>Music Familiarity</td>
<td>3.37 (1.02)</td>
<td>55</td>
</tr>
<tr>
<td>Music Quiz</td>
<td>10.11 (1.67)</td>
<td>55</td>
</tr>
<tr>
<td><strong>Individual Difference Measures</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIF</td>
<td>.09 (.13)</td>
<td>55</td>
</tr>
<tr>
<td>Updating Factor</td>
<td>-0.20 (0.87)</td>
<td>55</td>
</tr>
<tr>
<td>Restraint</td>
<td>-39.19 (36.36)</td>
<td>55</td>
</tr>
</tbody>
</table>

*Note. RIF=retrieval-induced forgetting. Music familiarity uses a 1-7 Likert scale where 7=highly familiar, and the music quiz is scored out of 18.

*p<.05.

Table 4

Correlation table between age, individual difference measures, and correct solutions by prime condition.

<table>
<thead>
<tr>
<th>Measure</th>
<th>RIF</th>
<th>Updating</th>
<th>Restraint</th>
<th>Neutral Fragments</th>
<th>Music Fragments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>.10</td>
<td>.07</td>
<td>-.08</td>
<td>-.14</td>
<td>-.01</td>
</tr>
<tr>
<td>No Prime</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Misleading Prime</td>
<td>.01</td>
<td>-.07</td>
<td>.06</td>
<td>.06</td>
<td>-.15</td>
</tr>
</tbody>
</table>

*Note. RIF= retrieval-induced forgetting.*
Table 5

Correlation table for no prime condition.

<table>
<thead>
<tr>
<th>Measure</th>
<th>RIF</th>
<th>Updating</th>
<th>Restraint</th>
<th>Neutral Fragments</th>
<th>Music Fragments</th>
<th>Neutral Fragment RT</th>
<th>Music Fragment RT</th>
<th>Music Intrusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIF</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Updating</td>
<td>.26</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Restraint</td>
<td>-.11</td>
<td>.04</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neutral Fragments</td>
<td>.09</td>
<td>.34*</td>
<td>-.09</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Music Fragments</td>
<td>.03</td>
<td>.31*</td>
<td>.08</td>
<td>.54***</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neutral Fragment RT</td>
<td>-.05</td>
<td>-.07</td>
<td>.32*</td>
<td>-.15</td>
<td>-.03</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Music Fragment RT</td>
<td>-.16</td>
<td>-.19</td>
<td>.10</td>
<td>-.27*</td>
<td>-.36**</td>
<td>.52***</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Music Intrusions</td>
<td>.06</td>
<td>.06</td>
<td>-.13</td>
<td>-.11</td>
<td>-.10</td>
<td>-.18</td>
<td>-.09</td>
<td>1</td>
</tr>
</tbody>
</table>

Note. RIF = retrieval-induced forgetting.

* p<.05, **p<.01, ***p<.001.
Table 6

Correlation table for misleading prime condition.

<table>
<thead>
<tr>
<th>Measure</th>
<th>RIF</th>
<th>Updating</th>
<th>Restraint</th>
<th>Neutral Fragments</th>
<th>Music Fragments</th>
<th>Neutral Fragment RT</th>
<th>Music Fragment RT</th>
<th>Music Intrusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIF</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Updating</td>
<td>-.24</td>
<td>1</td>
<td>-.20</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Restraint</td>
<td>-.11</td>
<td>-.20</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neutral Fragments</td>
<td>-.06</td>
<td>.35*</td>
<td>.06</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Music Fragments</td>
<td>-.24</td>
<td>.41**</td>
<td>-.03</td>
<td>.69***</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neutral Fragment RT</td>
<td>.02</td>
<td>.02</td>
<td>-.06</td>
<td>-.21</td>
<td>-.25</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Music Fragment RT</td>
<td>-.01</td>
<td>.26</td>
<td>-.11</td>
<td>-.14</td>
<td>-.19</td>
<td>.37*</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Music Intrusions</td>
<td>.25</td>
<td>-.24</td>
<td>.20</td>
<td>-.22</td>
<td>-.37**</td>
<td>.18</td>
<td>.06</td>
<td>1</td>
</tr>
</tbody>
</table>

Note. RIF= retrieval-induced forgetting.

* p<.05, **p<.01, ***p<.001.

Manipulation Check for Fixation

The differences between conditions in solution rates and solution times for neutral fragments and music-misleading fragments, and differences in intrusions for the music-misleading fragments are shown in Table 7. A 2 (Fragment type) X 2 (Prime condition) repeated-measures ANOVA was run on correct responses, and then on response time. Although the ANOVA for correct responses was non-significant, there were differences within fragment
type that replicated previous work on fixation in word-fragment completion tasks. Specifically, non-experts solved fewer music-misleading fragments in the misleading prime condition than in the no prime condition, $t(105) = 2.25, p = .03, d = .44$, but there was no difference in the number of neutral fragments solved in the misleading prime and no prime conditions, $t(105) = 0.90, p = .37, d = .18$. Non-experts also experienced more intrusions in the misleading prime condition than in the no prime condition. There was no two-way interaction for response time; there were no differences in response times due to prime condition for either neutral or music-misleading fragments.

### Table 7

Descriptive statistics and $t$-statistics for performance measures by prime condition.

<table>
<thead>
<tr>
<th>Prime Condition</th>
<th>No Prime</th>
<th>Misleading Prime</th>
<th>Test Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$ (SD)</td>
<td>$n$</td>
<td>$M$ (SD)</td>
</tr>
<tr>
<td>Neutral Fragments</td>
<td>.32 (.16)</td>
<td>55</td>
<td>.29 (.15)</td>
</tr>
<tr>
<td>Music Fragments</td>
<td>.24 (.12)</td>
<td>55</td>
<td>.18 (.13)</td>
</tr>
<tr>
<td>Neutral Fragment RT</td>
<td>2155.62 (343.30)</td>
<td>54</td>
<td>2210.55 (367.66)</td>
</tr>
<tr>
<td>Music Fragment RT</td>
<td>2103.44 (478.43)</td>
<td>55</td>
<td>2127.88 (382.87)</td>
</tr>
<tr>
<td>Music Intrusions</td>
<td>.01 (.02)</td>
<td>55</td>
<td>.05 (.07)</td>
</tr>
</tbody>
</table>

*Note. RT stands for response time, indicating solution times in ms.

* $p < .05$, ** $p < .01$, *** $p < .001$. 
Main Analysis: Individual Differences as Predictors of Performance

Correct solutions. Simple correlations between word fragments solved (neutral fragments and music-misleading fragments), updating, retrieval-induced forgetting, and restraint are shown in Table 5 for the no prime condition and Table 6 for the misleading prime condition. Figure 2 shows the adjusted means for the proportion of music-misleading fragments solved (after controlling for neutral performance) as a function of updating, retrieval-induced forgetting, and restraint in each prime condition, with lines showing the best fitting linear regression.
Figure 2. Adjusted means for proportion of music-misleading fragments solved (after controlling for neutral performance) as a function of updating (top left panel), retrieval-induced forgetting (top right panel), and restraint (bottom panel). Positive retrieval-induced forgetting indicates more forgetting. Larger restraint scores represent more restraint.

Updating scores positively predicted the proportion of neutral fragments solved in both the no prime condition and the misleading prime condition. Updating scores also positively predicted the proportion of music-misleading fragments solved in the misleading prime condition, and although not significant, the same trend was seen in the no prime condition. Thus, higher updating scores were generally related to better problem solving.

Retrieval-induced forgetting was not related to the proportion of neutral fragments solved in the no prime condition, nor in the misleading prime condition, and there was no relationship between retrieval-induced forgetting and the proportion of music-misleading fragments solved in
the no prime condition. However, a trend was seen in the misleading prime condition for a negative relationship between retrieval-induced forgetting and problem-solving success, such that non-experts who showed less retrieval-induced forgetting solved more music-misleading fragments.

There was no relationship between restraint and problem solving success in any condition.

To further examine these relationships, hierarchical regressions examined the main and interactive effects of individual differences and prime condition on the proportion of music-misleading fragments solved. One hierarchical regression was conducted for each individual difference score — one regression examined the variance predicted by updating, one regression examined retrieval-induced forgetting (centered), and a third regression examined restraint (centered). In all of the regressions, performance on neutral fragments was entered in the first step to co-vary out problem solving ability. The second step included the individual difference (either updating, retrieval-induced forgetting, or restraint) to evaluate the main effect of the individual difference score on performance, and the prime condition (no prime or misleading prime) to evaluate the main effect of the condition on performance. The final step entered condition x individual difference scores that represented the two-way interaction.

For the updating regression, the full model was significant $F(4, 102) = 18.91, p<.001, R^2 = .43$. The proportion of neutral fragments solved predicted a significant amount of the variance in the proportion of music-misleading fragments solved, $B = 0.50, t(105) = 7.92, p<.001$, as did prime condition, $B = -0.05, t(103) = -2.49, p = .01$. The updating factor also predicted a significant amount of the variance in music-misleading fragments solved, $B = 0.02,$
\( t(103) = -2.02, \ p = .05 \). The two-way interaction of prime condition x updating was not significant, \( B = 0.02, t(102) = 0.72, \ p = .48, \Delta R^2 = .003. \)

For the retrieval-induced forgetting analysis, the full model was significant \( F(4, 102) = 18.44, p < .001, R^2 = .40. \) The proportion of neutral fragments solved predicted a significant amount of the variance in the proportion of music-misleading fragments solved, \( B = 0.50, t(105) = 7.92, \ p < .001, \) as did prime condition, \( B = -0.04, t(103) = -2.09, \ p = .04. \) Retrieval-induced forgetting tended to negatively predict variance in music-misleading fragments solved, \( B = -0.11, t(103) = -1.37, \ p = .17. \) Prime condition x retrieval-induced forgetting was not significant, \( B = -0.20, t(102) = -1.24, \ p = .22, \Delta R^2 = .01. \)

For the restraint analysis, the full model was significant \( F(4, 102) = 17.81, p < .001, R^2 = .41. \) The proportion of neutral fragments solved predicted a significant amount of the variance in the proportion of music-misleading fragments solved, \( B = 0.50, t(105) = 7.92, \ p < .001, \) as did prime condition, \( B = -0.04, t(103) = -2.03, \ p = .05. \) Restraint did not predict a significant amount of the variance in music-misleading fragments solved, \( B = 0.00, t(103) = 0.52, \ p = .61. \) The prime condition x restraint interaction was also not significant, \( B = 0.00, t(102) = -1.29, \ p = .20, \Delta R^2 = .01. \)

**Solution times.** Simple correlations between solution times for correct items (neutral fragments and music-misleading fragments), the updating factor, retrieval-induced forgetting, and restraint are shown in Table 5 for the no prime condition and Table 6 for the misleading prime condition. Figure 3 shows adjusted mean solution times for correctly-solved music-misleading fragments (controlling for neutral RT) as a function of updating scores, retrieval-induced forgetting, and restraint in each prime condition, with lines showing the best fitting linear regression.
Figure 3. Adjusted mean solution time/response time (RT) for correctly-solved music-misleading fragments solved (after controlling for neutral RT) as a function of updating (top left panel), retrieval-induced forgetting (top right panel), and restraint (bottom panel). Positive retrieval-induced forgetting indicates more forgetting. Larger restraint scores represent more restraint.
Hierarchical regressions were again conducted to examine the main and interactive effects of individual differences and prime condition on the average solution time for correct music-misleading fragments. The regressions followed the same steps as the regressions examining correct solutions, except Step 1 co-varied out solution time (RT) for correct neutral fragments (instead of correct solutions for neutral fragments).

For the updating analysis, the full model was significant $F(4, 93) = 7.21, p<.001, R^2= .24$. The average correct solution time for neutral fragments predicted a significant amount of the variance, $B = 0.56, t(96) = 4.99, p< .001$. Prime condition did not predict correct solution times for music-misleading fragments, $B = -3.55, t(94) = -0.04, p = .97$, nor did the updating factor, $B = -9.38, t(94) = -0.20, p = .84$, but the two-way interaction of prime condition x updating trended toward significance, $B = 176.42, t(93) = 1.93, p = .06, \Delta R^2 = .03$, as non-experts with higher updating scores tended to take longer when they correctly completed the fragments in the misleading prime condition.

For the retrieval-induced forgetting analysis, the full model was significant $F(4, 93) = 6.52, p<.001, R^2= .22$. Correct solution times on neutral fragments predicted a significant amount of the variance in correct solution times on music-misleading fragments, $B = 0.56, t(96) = 4.99, p<.001$, but prime condition did not, $B = -5.63, t(94) = -0.07, p = .94$, nor did retrieval-induced forgetting, $B = -363.19, t(94) = -1.08, p = .29$. There was also no prime condition x retrieval-induced forgetting interaction, $B = 446.82, t(93) = 0.63, p = .53, \Delta R^2 = .00$.

For the restraint analysis, the full model was significant $F(4, 93) = 6.27, p<.001, R^2= .21$. Correct solution times on neutral fragments predicted a significant amount of the variance in correct solution times on music-misleading fragments, $B = 0.56, t(96) = 4.99, p<.001$, but prime condition did not, $B = -15.19, t(94) = -0.19, p = .85$, nor did restraint, $B = -0.84, t(94) = -0.72, p$
= .47. There was no prime condition x restraint interaction, \( B = -1.15, r(93) = -0.49, \ p = .63, \ \Delta R^2 = .00.\)

**Intrusions.** Simple correlations between intrusions for music-misleading fragments, the updating factor, retrieval-induced forgetting, and restraint are shown in Table 5 for the no prime condition and Table 6 for the misleading prime condition. Figure 4 shows intrusions as a function of updating, retrieval-induced forgetting, and restraint in each prime condition, with lines showing the best fitting linear regression.
Hierarchical regressions were again conducted to explore the main and interactive effects of individual differences and prime condition on the proportion of intrusions during music-misleading fragments. The regressions followed the same steps as the regressions examining correct solutions.

For the updating analysis, the full model was significant $F(4, 102) = 7.13, p<.001, R^2 = .22$. Correct solutions on neutral fragments predicted a significant amount of the variance in the proportion of intrusions on misleading-music fragments, $B = -0.07, t(105) = -1.95, p=.05$, as did prime condition, $B = 0.05, t(103) = 4.48, p< .001$, but updating did not, $B = -0.01, t(103) = -1.00, p=.32$. The two-way interaction of prime condition x updating, $B= -0.02, t(102) = -1.84$. 

*Figure 4.* Average proportion of music-related primes given as responses (intrusions) as a function of updating (top left panel), retrieval-induced forgetting (top right panel), and restraint (bottom panel) in both the no prime and misleading prime conditions. Positive retrieval-induced forgetting indicates more forgetting. Larger restraint scores represent more restraint.
\[ p = .07, \Delta R^2 = .03, \] approached significance as non-experts with higher updating scores tended to make fewer intrusions in the misleading prime condition, but there was no difference in the no prime condition.

For the retrieval-induced forgetting analysis, the full model was significant \( F(4, 102) = 7.74, p < .001, R^2 = .23. \) The proportion of neutral fragments solved predicted a significant amount of the variance the proportion of intrusions on misleading music fragments, \( B = -0.07, t(105) = -1.95, p = .05, \) as did prime condition, \( B = 0.04, t(103) = 4.36, p < .001. \) Both the effect for retrieval-induced forgetting, \( B = 0.07, t(103) = 1.82, p = .07, \) and the prime condition x retrieval-induced forgetting interaction, \( B = 0.14, t(102) = 1.73, p = .09, \Delta R^2 = .02, \) approached significance as non-experts who showed more retrieval-induced forgetting made more intrusions, especially in the misleading prime condition.

For the restraint analysis, the full model was significant \( F(4, 102) = 7.16, p < .001, R^2 = .22. \) The proportion of neutral fragments solved predicted a significant amount of the variance in intrusions on music misleading fragments, \( B = -0.07, t(105) = -1.95, p = .05, \) as did prime condition, \( B = 0.04, t(103) = 4.47, p < .001. \) Restraint did not predict a significant amount of the variance in intrusions, \( B = 0.00, t(103) = 1.00, p = .32. \) The prime condition x restraint interaction approached significance, \( B = 0.00, t(102) = 1.86, p = .07, \Delta R^2 = .03, \) as non-experts who showed better restraint made more intrusions in the misleading prime condition.

**Conclusions**

Replicating prior work (e.g., Smith & Tindell, 1997; Koppel & Storm, 2012), participants solved fewer music-misleading fragments in the misleading prime condition than in the no prime condition. That is, participants demonstrated a memory blocking effect from experimentally-induced fixation. Participants also experienced more intrusions in the misleading prime
condition than in the baseline condition despite being warned that the solutions were not music-related. This is consistent with other research that has shown that a warning can have ironic effects, and can fail to reduce intrusions, and can even increase them, during problem solving (see similar results in RAT problem solving in Wiley, 1998). No differences in solution times were seen due to misleading primes in this study.

As predicted, updating scores were generally related to problem solving success (except for trend towards a negative effect on solution times in misleading prime conditions), whereas restraint scores generally were not (except for a trend towards solvers with higher restraint scores offering increased numbers of intrusions). With respect to retrieval-induced forgetting, the results were more mixed. While retrieval-induced forgetting was not related to solution success in the no prime condition, in the misleading prime condition, non-experts who showed more retrieval-induced forgetting trended toward solving fewer music-misleading fragments, and generating more intrusions. This result was unexpected because other work (e.g., Storm & Angello, 2010; Storm, et al., 2011; Koppel & Storm, 2014) has consistently demonstrated a positive relationship between retrieval-induced forgetting and problem solving under fixated conditions. One possible explanation for this result is that it might be due to the specific warning that was used that informed the solver that the solutions would not be music-related. The possibility that this result was obtained because of the warning that was given will be revisited in relation to Experiment 3.
V. EXPERIMENT 2

The second experiment explored the effects of individual differences in the three measures of executive functioning on overcoming fixation that is both experimentally-induced and from prior knowledge using a more expert sample. Participants in Experiment 2 were selected to have six or more years of music experience. The materials and procedure were the same as Experiment 1, except musicians were recruited from the UIC subject pool, and from the community via flyers and ads on the UIC campus, in the city of Chicago, and on Craigslist. Participants recruited from the community were paid $30 for their participation.

Based on the results of Ricks et al. (2007), the updating factor might predict performance on neutral items, but should not predict performance of music experts on the music-misleading items. If domain knowledge is causing fixation in participants with music expertise, participants with higher updating scores may focus too much on incorrect answers when they are misled by prior knowledge.

Because previous work on retrieval-induced forgetting has only shown how it benefits problem solving in the context of experimentally-induced fixation, retrieval-induced forgetting might also be unrelated to problem-solving success for music-misleading items when experts are being fixated by prior knowledge. However, retrieval-induced forgetting may be positively related to problem-solving success when fixation is also induced experimentally in the misleading prime condition. Retrieval-induced forgetting should not predict performance on the neutral items which are not being fixated. This predicts an interaction between retrieval-induced forgetting and fixation condition.

The ability to restrain prepotent, dominant responses (as measured by the restraint task) should be related to problem solving performance for music-misleading items. Experts who are more effective at restraint should solve more music-misleading fragments than experts who are
less effective at restraint. Restraint should not predict performance on the neutral items which would not be fixated by prior knowledge.

Method

Participants. The final sample included 84 experts. Fifty-seven undergraduates from the Introductory Psychology subject pool at UIC received partial course credit for participation, and 27 experts from the community who responded to flyers or ads received $30 for participation. There were originally 87 participants who were classified as having at least 6 years of experience singing or playing an instrument. Three participants who had music familiarity or music quiz scores in the bottom 2% of the distribution were also removed because their scores appeared extremely low for experts. The final sample sizes for number of solution analyses included $n=42$ in the misleading prime condition, and $n=42$ in the no prime condition. The final sample sizes for solution time analyses included $n=42$ for neutral fragments in the no prime condition and the misleading prime condition, $n=41$ for music-misleading fragments in the no prime condition, and $n=40$ for music-misleading fragments in the misleading prime condition.
VI. RESULTS

Equivalence of Conditions

To test for equivalence of conditions on individual difference measures, t-tests compared the variables in both conditions (descriptive statistics and t-statistics in Table 8). Individual difference measures did not differ between the misleading prime and no prime conditions, although a pattern was seen in music familiarity that experts were more familiar with the music terms in the misleading prime condition than in the no prime condition. With exception of restraint scores in the misleading prime condition, music familiarity did not significantly correlate with individual difference measures, misleading-music fragments solved, or neutral fragments solved, in either condition (correlations seen in Table 9).
Table 8

Descriptive statistics and \( t \)-statistics for demographics and individual difference measures by prime condition.

<table>
<thead>
<tr>
<th>Prime Condition</th>
<th>No Prime</th>
<th>Misleading Prime</th>
<th>( t )-statistic</th>
<th>( p )</th>
<th>( d )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>19.23 (2.37)</td>
<td>19.85 (3.15)</td>
<td>( t(79) = -1.01 ), ( p = .31 ), ( d = -0.23 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACT composite</td>
<td>25.62 (4.72)</td>
<td>26.45 (3.88)</td>
<td>( t(75) = -0.85 ), ( p = .40 ), ( d = -0.20 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native English speakers</td>
<td>.88 (.33)</td>
<td>.93 (.26)</td>
<td>( t(82) = -0.74 ), ( p = .46 ), ( d = -0.16 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years Instrument</td>
<td>8.69 (5.15)</td>
<td>8.83 (5.86)</td>
<td>( t(82) = -0.12 ), ( p = .91 ), ( d = -0.03 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years Sang</td>
<td>5.36 (5.83)</td>
<td>4.71 (5.53)</td>
<td>( t(82) = 0.52 ), ( p = .61 ), ( d = 0.11 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Music Familiarity</td>
<td>4.48 (1.06)</td>
<td>4.84 (1.19)</td>
<td>( t(82) = -1.49 ), ( p = .14 ), ( d = -0.33 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Music Quiz</td>
<td>12.62 (2.61)</td>
<td>12.60 (1.95)</td>
<td>( t(82) = 0.05 ), ( p = .96 ), ( d = 0.01 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Individual Difference</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIF</td>
<td>.07 (.13)</td>
<td>.09 (.12)</td>
<td>( t(82) = -0.78 ), ( p = .44 ), ( d = -0.17 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Updating Factor</td>
<td>-0.05 (.96)</td>
<td>-0.01 (1.00)</td>
<td>( t(82) = -0.18 ), ( p = .86 ), ( d = -0.04 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restraint</td>
<td>-45.94 (48.94)</td>
<td>-51.75 (37.04)</td>
<td>( t(82) = 0.61 ), ( p = .54 ), ( d = 0.13 )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. RIF=retrieval-induced forgetting. Music familiarity uses a 1-7 Likert scale where 7=highly familiar, and the music quiz is scored out of 18.*
Table 9

Correlation table between music familiarity, individual difference measures, and performance measures in both prime conditions.

<table>
<thead>
<tr>
<th>Measure</th>
<th>RIF</th>
<th>Updating</th>
<th>Restraint</th>
<th>Neutral Fragments</th>
<th>Music Fragments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Music Familiarity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Prime</td>
<td>.21</td>
<td>.15</td>
<td>.11</td>
<td>.14</td>
<td>.12</td>
</tr>
<tr>
<td>Misleading Prime</td>
<td>.13</td>
<td>-.07</td>
<td>.32*</td>
<td>.05</td>
<td>.03</td>
</tr>
</tbody>
</table>

*Note. RIF= retrieval-induced forgetting.

* p<.05.

There was a negative correlation between music familiarity and restraint scores in both conditions, but it was stronger in the misleading prime condition. To see whether the difference in relationships was statistically significant, a hierarchical regression was conducted with restraint scores as the outcome. Condition and music familiarity were entered in Step 1, and the condition x music familiarity was entered in Step 2. Condition x music familiarity was not significant, $B = -5.08, t(80) = -0.60, p = .55$, thus, experts with more music familiarity had larger restraint scores, but the stronger relationship in the misleading prime condition was not statistically different than the relationship in the no prime condition.

**Manipulation Check for Fixation**

The differences between conditions in correct solutions and solution times for neutral fragments and music-misleading fragments, and differences in intrusions for the music-misleading fragments, are shown in Table 10. A 2 (Fragment type) X 2 (Prime condition) repeated-measures ANOVA was run on correct responses, and then on response time. The
ANOVA for correct responses showed a two-way interaction. As expected, experts solved fewer music fragments in the misleading prime condition than in the no prime condition, $t(82)=3.08$, $p=.003^{**}$, $d=0.68$, but there was no difference in the number of neutral fragments solved between the conditions, $t(82)=-0.33$, $p=.74$, $d=-0.07$. Experts also experienced more intrusions in the misleading prime condition than in the no prime condition. There was no two-way interaction for solution time, and no differences were seen in solution times due to prime condition.

**Table 10**

Descriptive statistics and $t$-statistics for performance measures by prime condition.

<table>
<thead>
<tr>
<th>Condition</th>
<th>No Prime</th>
<th>Misleading Prime</th>
<th>Test Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$ ($SD$)</td>
<td>n</td>
<td>$M$ ($SD$)</td>
</tr>
<tr>
<td>Neutral Fragments</td>
<td>.39 (.13)</td>
<td>42</td>
<td>.40 (.12)</td>
</tr>
<tr>
<td>Music Fragments</td>
<td>.33 (.13)</td>
<td>42</td>
<td>.24 (.14)</td>
</tr>
<tr>
<td>Neutral Fragment RT</td>
<td>2100.27 (496.20)</td>
<td>42</td>
<td>2135.01 (487.52)</td>
</tr>
<tr>
<td>Music Fragment RT</td>
<td>2035.95 (387.93)</td>
<td>41</td>
<td>2042.78 (407.04)</td>
</tr>
<tr>
<td>Music Intrusions</td>
<td>.02 (.04)</td>
<td>42</td>
<td>.07 (.11)</td>
</tr>
</tbody>
</table>

*Note. RT stands for response time, indicating solution times in ms.*

* $p<.05$, **$p<.01$, ***$p<.001$.

**Main Analysis: Individual Differences as Predictors of Performance**

**Correct Solutions.** Simple correlations between correct solutions for neutral fragments, correct solutions for music-misleading fragments, updating, retrieval-induced forgetting, and
restraint are shown in Table 11 for the no prime condition and Table 12 for the misleading prime condition. Figure 5 shows the adjusted means for the proportion of music-misleading fragments solved as a function of updating, retrieval-induced forgetting, and restraint by prime condition, with lines showing the best fitting linear regression.

**Table 11**
Correlation table for no prime condition.

<table>
<thead>
<tr>
<th>Measure</th>
<th>RIF</th>
<th>Updating</th>
<th>Restraint</th>
<th>Neutral Fragments</th>
<th>Music Fragments</th>
<th>Neutral Fragment RT</th>
<th>Music Fragment RT</th>
<th>Music Intrusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIF</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Updating</td>
<td>-.10</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Restraint</td>
<td>-.17</td>
<td>.32*</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neutral Fragments</td>
<td>.17</td>
<td>.32*</td>
<td>.14</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Music Fragments</td>
<td>-.13</td>
<td>.27</td>
<td>.06</td>
<td>.33*</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neutral Fragment RT</td>
<td>.07</td>
<td>-.47**</td>
<td>.14</td>
<td>-.12</td>
<td>-.25</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Music Fragment RT</td>
<td>.02</td>
<td>-.47**</td>
<td>.30</td>
<td>-.13</td>
<td>-.04</td>
<td>.61***</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Music Intrusions</td>
<td>.14</td>
<td>-.15</td>
<td>-.18</td>
<td>-.10</td>
<td>-.18</td>
<td>-.11</td>
<td>-.24</td>
<td>1</td>
</tr>
</tbody>
</table>

*Note. RIF= retrieval-induced forgetting.*

* p<.05, **p<.01, ***p<.001.
Table 12
Correlation table for misleading prime condition.

<table>
<thead>
<tr>
<th>Measure</th>
<th>RIF</th>
<th>Updating</th>
<th>Restraint</th>
<th>Neutral Fragments</th>
<th>Music Fragments</th>
<th>Neutral Fragment RT</th>
<th>Music Fragment RT</th>
<th>Music Intrusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIF</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Updating</td>
<td>-.07</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Restraint</td>
<td>.24</td>
<td>.01</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neutral Fragments</td>
<td>.10</td>
<td>.19</td>
<td>.15</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Music Fragments</td>
<td>-.24</td>
<td>.27</td>
<td>.29</td>
<td>.21</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neutral Fragment RT</td>
<td>-.01</td>
<td>-.23</td>
<td>-.09</td>
<td>-.27</td>
<td>.01</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Music Fragment RT</td>
<td>.25</td>
<td>-.37*</td>
<td>-.20</td>
<td>-.25</td>
<td>-.17</td>
<td>.60***</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Music Intrusions</td>
<td>.08</td>
<td>-.57***</td>
<td>-.02</td>
<td>-.19</td>
<td>-.14</td>
<td>.18</td>
<td>.45**</td>
<td>1</td>
</tr>
</tbody>
</table>

Note. RIF= retrieval-induced forgetting.

* p<.05, **p<.01, ***p<.001.
Hierarchical regressions examined the main and interactive effects of individual differences and condition on the proportion of music-misleading fragments solved. One regression examined the variance predicted by updating, another for retrieval-induced forgetting (centered), and a third for restraint (centered). Performance on neutral fragments was always covaried out in the first step to control for problem solving ability. Next, prime condition (no prime or misleading prime), and the individual difference score (update, retrieval-induced forgetting, or restraint) were entered to evaluate the main effect of each on performance. The
third step included condition x individual difference scores that represented the two-way interaction.

For the updating analysis, the full model was significant $F(4, 79) = 5.13, p=.001, R^2 = .21$. The proportion of neutral fragments solved predicted a significant amount of the variance in the proportion of music-misleading fragments solved, $B = 0.27, t(82) = 2.23, \ p = .03$, as did prime condition, $B = -0.10, t(80) = -3.35, \ p = .001$, and the updating factor, $B = 0.03, t(80) = 1.98, \ p = .05$. The two-way interaction was not significant, $B= 0.01, t(79) = 0.22, \ p = .82, \Delta R^2= .00$.

Updating scores generally related to improved problem solving.

For the retrieval-induced forgetting analysis, the full model was significant $F(4, 79) = 5.42, p=.001, R^2 = .22$. The proportion of neutral fragments solved predicted the proportion of music-misleading fragments solved, $B = 0.27, t(82) = 2.23, \ p = .03$, as did prime condition, $B = -0.09, t(80) = -3.15, \ p = .002$, and retrieval-induced forgetting, $B = -0.24, t(79) = -2.13, \ p = .04$. The two-way interaction was not significant, $B= -0.13, t(79) = -0.58, \ p = .56, \Delta R^2= .003$.

Retrieval-induced forgetting scores negatively predicted problem solving success. People who showed more retrieval-induced forgetting did worse.

For restraint, the full model was significant $F(4, 79) = 4.90, p=.001, R^2 = .20$. The proportion of neutral fragments solved predicted a significant amount of the variance the proportion of music-misleading fragments solved, $B = 0.27, t(82) = 2.23, \ p = .03$, as did prime condition, $B = -0.09, t(80) = -3.18, \ p = .002$. Restraint did not predict a significant amount of the variance in music-misleading fragments solved, $B = 0.00, t(80) = 1.15, \ p = .25$. The condition x restraint interaction, $B= 0.00, t(79) = 1.33, \ p = .19, \Delta R^2= .01$, showed a pattern such that experts with higher restraint scores tended to solve more music-misleading fragments in the misleading prime condition, but there was no relationship in the no prime condition.
**Solution times.** Simple correlations between solution times for correct responses (neutral fragments and music-misleading fragments), the updating factor, retrieval-induced forgetting, and restraint are shown in Table 11 for the no prime condition and Table 12 for the misleading prime condition. Figure 6 shows adjusted mean solution times for correctly-solved music-misleading fragments as a function of updating scores, retrieval-induced forgetting, and restraint by prime condition, with line showing best fitting linear regression.
Figure 6. Adjusted mean solution time/response time (RT) for correctly-solved music-misleading fragments solved (after controlling for neutral RT) as a function of updating (top left panel), retrieval-induced forgetting (top right panel), and restraint (bottom panel). Positive retrieval-induced forgetting indicates more forgetting. Larger restraint scores represent more restraint.

Hierarchical regressions again were used to examine the main and interactive effects of individual differences and prime condition on solution time for correct music-misleading fragments.

For updating, the full model was significant $F(4, 76) = 13.53$, $p<.001$, $R^2 = .42$. Solution times on neutral fragments predicted a significant amount of the variance in music-misleading solution times, $B = 0.49$, $t(79) = 6.76$, $p< .001$. Prime condition did not predict variance in solution time for music-misleading fragments, $B = 0.07$, $t(77) = 0.00$, $p = .99$. The updating factor did predict solution times, $B = -93.75$, $t(77) = -2.52$, $p = .01$. The two-way interaction of condition x updating was not significant, $B = -22.55$, $t(76) = -0.32$, $p = .75$, $\Delta R^2 = .001$. Higher updating scores generally predicted faster correct solution times.

For retrieval-induced forgetting, the full model was significant $F(4, 76) = 12.60$, $p<.001$, $R^2 = .40$. Correct solution times for neutral fragments predicted variance in music-misleading fragment solution times, $B = 0.49$, $t(79) = 6.76$, $p<.001$, but prime condition did not, $B = -9.32$, $t(77) = -0.13$, $p = .90$, nor did retrieval-induced forgetting, $B = 335.08$, $t(77) = 1.20$, $p = .23$. The two-way interaction between prime condition and retrieval-induced forgetting showed a
trend, \( B = 892.24, t(76) = 1.61, \ p = .11, \Delta R^2 = .02 \), such that experts who showed more retrieval-induced forgetting were slower in the misleading prime condition than experts who showed less retrieval-induced forgetting, but this relationship did not exist in the no prime condition.

In the restraint analysis, the full model was significant \( F(4, 76) = 12.30, \ p < .001, \ R^2 = .39 \). Correct solution times for neutral fragments predicted a significant amount of the variance in correct solution times for music-misleading fragments, \( B = 0.49, t(79) = 6.76, \ p < .001 \), but prime condition did not, \( B = 0.46, t(77) = 0.01, \ p = .99 \), nor did restraint, \( B = 0.65, t(77) = 0.79, \ p = .43 \). The two-way interaction between prime condition and restraint showed a trend, \( B = -2.79, t(76) = -1.63, \ p = .11, \Delta R^2 = .02 \), such that experts who had better restraint tended to solve faster in the misleading prime condition, with the opposite pattern in the no prime condition.

**Intrusions.** Simple correlations between intrusions for music-misleading fragments, the updating factor, retrieval-induced forgetting, and restraint are shown in Table 11 for the no prime condition and Table 12 for the misleading prime condition. Figure 7 shows intrusions as a function of updating, retrieval-induced forgetting, and restraint by prime condition, with line showing best fitting linear regression.
Figure 7. Average proportion of music-related primes given as responses (intrusions) as a function of updating (top left panel), retrieval-induced forgetting (top right panel), and restraint (bottom panel) in the no prime condition and misleading prime condition. Positive retrieval-induced forgetting indicates more forgetting. Larger restraint scores represent more restraint.

Hierarchical regressions were again conducted to explore the main and interactive effects of individual differences and prime condition on the proportion of intrusions for music-misleading fragments.

For updating, the full model was significant $F(4, 79) = 10.70, p<.001, R^2 = .35$. Correct solutions on neutral fragment accuracy did not predict intrusions on music-misleading fragments, $B = 0.00, t(82) = 0.90, p = .37$. Prime condition predicted variance in intrusions, $B = 0.05, t(80) = 3.01, p = .004$, as did the updating factor, $B = -0.04, t(80) = -4.17, p<.001$, and the two-way condition x updating interaction was significant, $B = -0.06, t(79) = -3.52, p = .001, \Delta R^2 = .10$. For the two-way interaction, experts with higher updating scores experienced fewer intrusions.
than experts with lower updating scores in the misleading prime condition, while there was no relationship between updating and success in the no prime condition.

For retrieval-induced forgetting, the full model trended toward significance, \( F(4, 79) = 2.06, p = .09, R^2 = .09 \). The proportion of neutral fragments solved did not predict a significant amount of the variance in intrusions for music-misleading fragments, \( B = 0.00, t(82) = 0.90, p = .37 \), nor did retrieval-induced forgetting, \( B = 0.05, t(80) = 0.76, p = .45 \). Prime condition predicted a significant amount of the variance, \( B = 0.05, t(80) = 2.53, p = .01 \). There was no condition x retrieval-induced forgetting interaction, \( B = 0.04, t(79) = 0.29, p = .77, \Delta R^2 = .001 \).

For the restraint analysis, the full model approached significance, \( F(4, 79) = 1.98, p = .11, R^2 = .09 \). Correct solutions on neutral fragments did not predict variance in music-misleading fragment intrusions, \( B = 0.00, t(82) = 0.90, p = .37 \), and neither did restraint, \( B = 0.00, t(80) = -0.54, p = .59 \). However, prime condition predicted a significant amount of the variance in intrusions, \( B = 0.05, t(80) = 2.56, p = .01 \). There was no prime condition x restraint interaction, \( B = 0.00, t(79) = 0.28, p = .78, \Delta R^2 = .001 \).

**Conclusions**

Experts solved fewer music-misleading fragments in the misleading prime condition than in the no prime condition, and experienced more intrusions. There was no difference in solution times for correctly-solved fragments between the no prime condition and misleading prime condition.

Similar to the non-experts in Experiment 1, updating scores generally related to improved problem solving. In this experiment, higher updating scores predicted more correct solutions, faster solution times, and fewer intrusions. On the other hand, retrieval-induced forgetting tended to negatively affect problem solving performance, leading to fewer correct solutions and
slower solution times in the misleading prime condition. Finally, although not significant, there was a tendency for experts who had better restraint to solve more fragments than experts who had less restraint in the music-misleading prime condition, with no relationship between restraint and success in the no prime condition.
VII. EXPERIMENT 3

The third experiment examined whether removing the warning before problem solving would alter relationships between individual differences in the three measures of executive functioning, and overcoming fixation when it is experimentally-induced in a novice sample. The materials and procedure were the same as Experiment 1, except for removal of the warning.

Based on the results of the first two experiments, the updating factor could be predicted to positively relate to the number of correct solutions in all conditions if updating is related to better retrieval from long-term memory. However, it may be important that the participants in the earlier experiments were given a warning that solutions would not be related to music. If the positive relationship between updating and performance seen in the earlier experiments is related to goal maintenance and being better at remembering the warning (Unsworth, Redick, Spillers, & Brewer, 2012), then removing the warning may eliminate the relationship between the updating factor and the number of correct solutions in the misleading prime condition.

Based on Storm and Angello (2010), it was predicted that retrieval-induced forgetting should positively predict performance for non-experts in the misleading prime condition, but have no relationship with performance in the no prime condition. However, an unexpected negative relation between retrieval-induced forgetting and performance on misleading fragments was found in the prior studies. The question tested here is whether removing the warning will eliminate this effect.

As in Experiment 1, there should be no relationship with restraint in either the no prime or the misleading prime conditions for non-experts. Restraint should only predict problem solving when participants must reduce the activation of dominant responses from prior knowledge.
Method

Participants. The final sample included 101 undergraduates from the Introductory Psychology subject pool at UIC, who participated for partial course credit. There were originally 107 non-experts total, classified as having less than 5 years of music experience. One participant who did not solve any word fragments was removed. Participants who had music familiarity or music quiz scores in the top 2% of the distribution (5 participants) were also removed because their scores appeared extreme for non-experts. The final sample sizes for correct solution analyses were \( n = 48 \) in the no prime condition, and \( n = 53 \) in the misleading prime condition. For solution time analyses the final sample sizes were \( n = 48 \) the no prime condition, and \( n = 51 \) for the misleading prime condition.
VIII. RESULTS

Equivalence of Conditions

To test for equivalence of conditions on individual difference measures, \( t \)-tests compared the variables in the misleading prime condition and the no prime condition (descriptive statistics are shown in Table 13). Individual difference measures did not differ between the misleading prime and no prime conditions.

Manipulation Check for Fixation

The differences between conditions in solution rates and solution times for neutral fragments and music-misleading fragments, and differences in intrusions for the music-misleading fragments, are found in Table 14. A 2 (Fragment type) X 2 (Prime condition) repeated-measures ANOVA was run on correct responses, and then on response time. There was a two-way interaction for correct responses. Replicating prior work, non-experts solved fewer music fragments in the misleading prime condition than in the no prime condition, \( t(99)=4.52, p=0.00***, d=0.91 \), but there was no difference in the number of neutral fragments solved in both conditions, \( t(99)=0.92, p=0.36, d=0.18 \). Non-experts also experienced more intrusions in the misleading prime condition than in the no prime condition. There was no two-way interaction for response time; there was no difference in solution times for the neutral fragments and the music-misleading fragments due to prime condition.
Table 13

Descriptive statistics and t-statistics for demographics and individual difference measures by prime condition.

<table>
<thead>
<tr>
<th>Prime Condition</th>
<th>No Prime</th>
<th></th>
<th>Misleading Prime</th>
<th></th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>n</td>
<td>M (SD)</td>
<td>n</td>
<td></td>
</tr>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>19.00 (1.17)</td>
<td>39</td>
<td>19.26 (2.00)</td>
<td>46</td>
<td>t(83)=-0.72, p=.48, d=-0.16</td>
</tr>
<tr>
<td>ACT composite</td>
<td>23.02 (5.98)</td>
<td>46</td>
<td>24.20 (4.72)</td>
<td>51</td>
<td>t(95)=-1.08, p=.28, d=-0.22</td>
</tr>
<tr>
<td>Native English speakers</td>
<td>.63 (.49)</td>
<td>48</td>
<td>.64 (.48)</td>
<td>53</td>
<td>t(99)=-0.17, p=.87, d=-0.03</td>
</tr>
<tr>
<td>Years Instrument</td>
<td>0.85 (1.47)</td>
<td>48</td>
<td>0.55 (1.15)</td>
<td>53</td>
<td>t(99)=1.17 p=.24, d=0.24</td>
</tr>
<tr>
<td>Years Sang</td>
<td>0.08 (0.58)</td>
<td>48</td>
<td>0.09 (0.56)</td>
<td>53</td>
<td>t(99)=-0.10, p=.92, d=-0.02</td>
</tr>
<tr>
<td>Music Familiarity</td>
<td>3.50 (1.12)</td>
<td>48</td>
<td>3.76 (1.03)</td>
<td>53</td>
<td>t(99)=-1.21, p=.23, d=-0.24</td>
</tr>
<tr>
<td>Music Quiz</td>
<td>9.84 (1.85)</td>
<td>48</td>
<td>9.57 (2.06)</td>
<td>53</td>
<td>t(99)=0.71 p=.48, d=0.14</td>
</tr>
<tr>
<td>Individual Difference</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIF (positive)</td>
<td>.06 (0.13)</td>
<td>48</td>
<td>.04 (0.13)</td>
<td>53</td>
<td>t(99)=0.75, p=.45, d=0.15</td>
</tr>
<tr>
<td>Updating Factor</td>
<td>0.19 (1.04)</td>
<td>48</td>
<td>0.09 (1.19)</td>
<td>53</td>
<td>t(99)=0.45, p=.66, d=0.09</td>
</tr>
<tr>
<td>Restraint</td>
<td>44.09 (49.86)</td>
<td>48</td>
<td>39.46 (43.37)</td>
<td>53</td>
<td>t(99)=-0.50, p=.62, d=-0.10</td>
</tr>
</tbody>
</table>

*Note. RIF=retrieval-induced forgetting. Music familiarity uses a 1-7 Likert scale where 7=highly familiar, and the music quiz is scored out of 18.*
**Table 14**

Descriptive statistics and *t*-statistics for performance measures by prime condition.

<table>
<thead>
<tr>
<th>Condition</th>
<th>No Prime</th>
<th>Misleading Prime</th>
<th>Test Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>n</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Neutral Fragments</td>
<td>0.37 (0.13)</td>
<td>48</td>
<td>0.34 (0.15)</td>
</tr>
<tr>
<td>Music Fragments</td>
<td>0.30 (0.11)</td>
<td>48</td>
<td>0.20 (0.12)</td>
</tr>
<tr>
<td>Neutral Fragment RT</td>
<td>2106.33 (389.02)</td>
<td>48</td>
<td>2170.35 (426.09)</td>
</tr>
<tr>
<td>Music Fragment RT</td>
<td>2145.56 (442.16)</td>
<td>48</td>
<td>2176.92 (557.07)</td>
</tr>
<tr>
<td>Music Intrusions</td>
<td>0.01 (0.02)</td>
<td>48</td>
<td>0.10 (0.13)</td>
</tr>
</tbody>
</table>

*Note.* RT stands for response time, indicating solution times in ms.

* *p* < .05, ** *p* < .01, *** *p* < .001.

**Main Analysis: Individual Differences as Predictors of Performance**

**Correct solutions.** Simple correlations between word fragments solved (neutral and music-misleading), updating, retrieval-induced forgetting, and restraint are shown in Table 15 for the no prime condition and Table 16 for the misleading prime condition. Figure 8 shows the adjusted mean for the proportion of music-misleading fragments solved as a function of updating, retrieval-induced forgetting, and restraint by prime condition, with line showing best fitting linear regression.
Table 15

Correlation table for no prime condition.

<table>
<thead>
<tr>
<th>Measure</th>
<th>RIF</th>
<th>Updating</th>
<th>Restraint</th>
<th>Neutral Fragments</th>
<th>Music Fragments</th>
<th>Neutral Fragment RT</th>
<th>Music Fragment RT</th>
<th>Music Intrusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIF</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Updating</td>
<td>-12</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Restraint</td>
<td>.02</td>
<td>.19</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neutral</td>
<td>.04</td>
<td>.30*</td>
<td>-.03</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fragments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Music</td>
<td>-.01</td>
<td>.24</td>
<td>-.09</td>
<td>.57***</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Fragments</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>-.12</td>
<td>-.08</td>
<td>-.10</td>
<td>.03</td>
<td>-.15</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fragment RT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Music</td>
<td>-.08</td>
<td>-.03</td>
<td>-.20</td>
<td>-.11</td>
<td>-.11</td>
<td>.29*</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Fragment RT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Music Intrusions</td>
<td>-.16</td>
<td>-.29*</td>
<td>.13</td>
<td>-.18</td>
<td>-.03</td>
<td>-.07</td>
<td>-.01</td>
<td>1</td>
</tr>
</tbody>
</table>

Note. RIF= retrieval-induced forgetting.

*p<.05, **p<.01, ***p<.001.
Table 16
Correlation table for misleading prime condition.

<table>
<thead>
<tr>
<th>Measure</th>
<th>RIF</th>
<th>Updating</th>
<th>Restraint</th>
<th>Neutral Fragments</th>
<th>Music Fragments</th>
<th>Neutral Fragment RT</th>
<th>Music Fragment RT</th>
<th>Music Intrusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIF</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Updating</td>
<td>-.22</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Restraint</td>
<td>.02</td>
<td>-.03</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neutral Fragments</td>
<td>.25</td>
<td>-.22</td>
<td>-.12</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Music Fragments</td>
<td>.06</td>
<td>.03</td>
<td>-.07</td>
<td>.34*</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Neutral Fragment RT</td>
<td>-.30*</td>
<td>-.08</td>
<td>-.19</td>
<td>-.32*</td>
<td>-.19</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Music Fragment RT</td>
<td>-.12</td>
<td>-.13</td>
<td>-.11</td>
<td>-.54***</td>
<td>-.25</td>
<td>.54***</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Music Intrusions</td>
<td>.18</td>
<td>.09</td>
<td>.03</td>
<td>-.16</td>
<td>-.39**</td>
<td>.02</td>
<td>.26</td>
<td>1</td>
</tr>
</tbody>
</table>

*Note. RIF= retrieval-induced forgetting.

*p<.05, **p<.01, ***p<.001.
Figure 8. Adjusted means for proportion of music-misleading fragments solved (after controlling for neutral performance) as a function of updating (top left panel), retrieval-induced forgetting (top right panel), and restraint (bottom panel). Positive retrieval-induced forgetting indicates more forgetting. Larger restraint scores represent more restraint.

Hierarchical regressions examined the main and interactive effects of individual differences and prime condition on the proportion of music-misleading fragments solved. The first regression examined the variance predicted by updating, the second for retrieval-induced forgetting (centered), and the third for restraint (centered). The first step always co-varied out performance on neutral fragments to control for problem solving ability. In the second step, prime condition (no prime or misleading prime), and the individual difference score (updating, retrieval-induced forgetting, or restraint) were entered to assess the main effect of each on performance. The third step included condition x individual difference scores that represented the two-way interaction.
For the updating analysis, the full model was significant $F(4, 96) = 12.37$, $p=.001$, $R^2=.34$. The proportion of neutral fragments solved predicted a significant amount of the variance the proportion of music-misleading fragments solved, $B = 0.38$, $t(99) = 4.75$, $p<.001$, as did prime condition, $B = -0.09$, $t(97) = -4.49$, $p<.001$. There was no overall effect of the updating factor, $B = 0.01$, $t(97) = 1.40$, $p = .16$, and the two-way interaction was not significant, $B= 0.00$, $t(96) = 0.00$, $p = .99$, $\Delta R^2=.00$.

For the retrieval-induced forgetting analysis, the full model was significant $F(4, 96) = 11.72$, $p<.001$, $R^2=.33$. The proportion of neutral fragments solved predicted the proportion of music-misleading fragments solved, $B = 0.38$, $t(99) = 4.75$, $p<.001$, as did prime condition, $B = -0.09$, $t(97) = -4.53$, $p<.001$. The main effect of retrieval-induced forgetting was not significant, $B = -0.03$, $t(97) = -0.42$, $p = .68$, nor was the two-way interaction, $B= -0.03$, $t(96) = -0.16$, $p = .88$, $\Delta R^2=.001$.

For restraint, the full model was significant $F(4, 96) = 11.76$, $p<.001$, $R^2=.33$. The proportion of neutral fragments solved predicted a significant amount of the variance the proportion of music-misleading fragments solved, $B = 0.38$, $t(99) = 4.75$, $p<.001$, as did prime condition, $B = -0.09$, $t(97) = -4.49$, $p<.001$. Restraint did not predict a significant amount of the variance in music-misleading fragments solved, $B = 0.00$, $t(97) = -0.49$, $p = .63$, nor did the two-way interaction, $B= 0.00$, $t(96) = 0.27$, $p = .79$, $\Delta R^2=.001$.

**Solution times.** Simple correlations between solution times for correct responses (neutral fragments and music-misleading fragments), the updating factor, retrieval-induced forgetting, and restraint are shown in Table 15 for the no prime condition and Table 16 for the misleading prime condition. Figure 9 shows adjusted mean solution times for correctly-solved music-
misleading fragments as a function of updating scores, retrieval-induced forgetting, and restraint by prime condition, with line showing best fitting linear regression.

*Figure 9.* Adjusted mean solution time/response time (RT) for correctly-solved music-misleading fragments solved (after controlling for neutral RT) as a function of updating (top left panel), retrieval-induced forgetting (top right panel), and restraint (bottom panel). Positive
retrieval-induced forgetting indicates more forgetting. Larger restraint scores represent more restraint.

Hierarchical regressions again examined the main and interactive effects of individual differences and prime condition on solution time for correct music-misleading fragments.

For the updating analysis, the full model was significant $F(4, 95) = 5.93, p < .001, R^2 = .21$. Solution times on neutral fragments predicted a significant amount of the variance in music-misleading solution times, $B = 0.48, t(93) = -0.61, p < .001$. Prime condition did not predict variance in music-misleading fragments, $B = -53.71, t(93) = -0.61, p = .54$, nor did the updating factor, $B = -46.79, t(93) = -1.14, p = .26$. The two-way interaction of condition x updating was not significant, $B = -88.32, t(92) = -1.08, p = .28, \Delta R^2 = .01$.

For retrieval-induced forgetting, the full model was significant $F(4, 92) = 5.19, p = .001, R^2 = .18$. Correct solution times for neutral fragments predicted variance in music-misleading fragment solution times, $B = 0.49, t(95) = 4.59, p < .001$, but prime condition did not, $B = -46.34, t(93) = -0.22, p = .60$, nor did retrieval-induced forgetting, $B = -75.85, t(93) = -0.22, p = .83$. The two-way interaction of condition x retrieval-induced forgetting was not significant, $B = 50.64, t(92) = 0.07, p = .94, \Delta R^2 = .00$.

For the restraint analysis, the full model was significant $F(4, 92) = 6.01, p < .001, R^2 = .21$. Correct solution times for neutral fragments predicted a significant amount of the variance in music-misleading solution times, $B = 0.49, t(95) = 4.59, p < .001$, but prime condition did not, $B = -38.50, t(93) = 1.64, p = .66$. The main effect for restraint showed a trend toward predicting variance in correct solution times for music-misleading fragments, $B = -1.57, t(93) = -1.64, p =
.10, as non-experts with more restraint tended to take less time to respond than non-experts with less restraint. The two-way interaction between prime condition and restraint was not significant, \( B = -0.47, \ t(92) = -0.24, \ p = .81, \ \Delta R^2 = .001. \)

**Intrusions.** Simple correlations between intrusions for music-misleading fragments, the updating factor, retrieval-induced forgetting, and restraint are shown in Table 15 for the no prime condition and Table 16 for the misleading prime condition. Figure 10 shows intrusions as a function of updating scores, retrieval-induced forgetting, and restraint by prime condition, with line showing best fitting linear regression.

![Graphs showing intrusions as a function of updating scores, retrieval-induced forgetting, and restraint by prime condition.](image)
**Figure 10.** Average proportion of music-related primes given as responses (intrusions) as a function of updating (top left panel), retrieval-induced forgetting (top right panel), and restraint (bottom panel) in the no prime condition and the misleading prime condition. Positive retrieval-induced forgetting indicates more forgetting. Larger restraint scores represent more restraint.

Hierarchical regressions were again conducted to assess the main and interactive effects of individual differences and prime condition on the proportion of intrusions for music-misleading fragments.

For the updating analysis, the full model was significant $F(4, 96) = 6.70, p < .001, R^2 = .22$. There was a trend that correct solutions on neutral fragment accuracy predicted intrusions on music-misleading fragments, $B = -0.13, t(99) = -1.72, p = .09$. Prime condition predicted variance in intrusions, $B = 0.09, t(97) = 4.79, p < .001$. The updating factor did not predict
variance in intrusions, $B = 0.03$, $t(97) = 0.36$, $p = .72$, nor did the two-way interaction of condition x updating, $B= 0.01$, $t(96) = 0.63$, $p = .53$, $\Delta R^2 = .003$.

For retrieval-induced forgetting, the full model was significant, $F(4, 96) = 7.94$, $p < .001$, $R^2 = .25$. There was a trend that the proportion of neutral fragments solved predicted variance in intrusions for music-misleading fragments, $B = -0.13$, $t(99) = -1.72$, $p=.09$. Prime condition predicted a significant amount of the variance, $B = 0.10$, $t(97) = 4.89$, $p< .001$. Trends were seen for both the main effect of retrieval-induced forgetting, $B = 0.10$, $t(97) = 1.31$, $p=.19$, and the condition x retrieval-induced forgetting interaction, $B= 0.24$, $t(96) = 1.64$, $p = .11$, $\Delta R^2 = .02$, such that non-experts who showed more retrieval-induced forgetting tended to make more intrusions in the misleading prime condition compared to non-experts who showed less retrieval-induced forgetting, but the opposite happened in the no prime condition.

For the restraint analysis, the full model was significant, $F(4, 96) = 6.56$, $p < .001$, $R^2 = .22$. There was a trend that correct solutions on neutral fragments predicted variance in intrusions on music-misleading fragments, $B = -0.13$, $t(99) = -1.72$, $p=.09$, and prime condition predicted variance in music-misleading fragment intrusions, $B = 0.09$, $t(97) = 4.76$, $p< .001$. There was no main effect of restraint, $B = 0.00$, $t(97) = -0.28$, $p =.78$, and no condition x restraint interaction, $B= 0.00$, $t(96) = 0.01$, $p = .99$, $\Delta R^2 = .00$.

**Conclusions**

Non-experts solved fewer music-misleading fragments in the misleading prime condition than in the no prime condition, and experienced more intrusions. There was no difference in solution times for correctly-solved music-misleading fragments between the no prime condition and misleading prime conditions.
No significant effects on problem solving were found for any of the individual differences in this study. These results seem to suggest two differences from earlier findings: one in updating and one in retrieval-induced forgetting. Updating was no longer a significant predictor of problem solving performance across conditions. In this study, the positive relation between updating and solution success seemed to be limited to the no prime condition, suggesting that updating scores related to better performance in prime conditions in the earlier studies with a warning because of goal maintenance. A second difference in results was that the removal of the warning seemed to eliminate the negative relation between retrieval-induced forgetting and performance on the misleading fragments. These potential cross-experiment conclusions are further explored in the final section.
IX. PATH ANALYSES COLLAPSING ACROSS EXPERIMENTS

The previous experiments suggest distinct roles for updating, retrieval-induced forgetting, and restraint depending on whether participants were in the prime condition, received a warning, or had expertise. Three path analysis models were used to test whether 1) for participants who received the warning, if being in a primed condition increased the unique variance in correct solutions explained by retrieval-induced forgetting, 2) receiving a warning increased the unique variance in correct solutions explained by retrieval-induced forgetting and the updating factor, and, 3) expertise increased the unique variance in correct solutions explained by restraint. Path analysis is an extension of multiple regression, and tests the relationships between manifest variables. All of the predictors are entered into one model simultaneously to explore each predictor’s unique variance while controlling for the others. Path analyses were run with the lavaan package in R, and were estimated using maximum likelihood. Each model included the updating factor (which was created from backwards digit span, running span, and LNS), retrieval-induced forgetting (centered), restraint (centered), and the proportion of neutral fragments solved. (Tasks that loaded onto the updating factor will not be discussed for the purpose of simplicity.) The second model (for warning) also included prime condition as a predictor, because the role for retrieval-induced forgetting seemed to increase when participants were fixated.

The first path analysis explored whether variance predicted by retrieval-induced forgetting was affected by being in a not primed or primed condition among participants who were given a warning that no solutions would be related to music. The overall model fit for the collapsed conditions was $\chi^2(8, N = 191) = 71.97, p < .001$. CFI = 1.00 and RMSEA < .001 both passed their respective cutoffs indicative of a good fit (above .95 for CFI, and below .05 for
RMSEA according to Hu & Bentler, 1999). As can be seen in Table 17 below, retrieval-induced forgetting predicted unique variance in correct solutions in the prime condition (N=94), but not in the no prime condition (N=97). When primed, participants who showed more retrieval-induced forgetting had fewer correct solutions. 

Table 17

Path analysis task loadings on correct solutions by prime condition for participants receiving a warning.

<table>
<thead>
<tr>
<th></th>
<th>No Prime Condition</th>
<th>Prime Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>Std. Err</td>
</tr>
<tr>
<td>Updating</td>
<td>0.18</td>
<td>0.01</td>
</tr>
<tr>
<td>Retrieval-Induced Forgetting</td>
<td>-0.15</td>
<td>0.09</td>
</tr>
<tr>
<td>Restraint</td>
<td>0.09</td>
<td>0.00</td>
</tr>
<tr>
<td>Neutral Fragments</td>
<td>0.44</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Note. β represents standardized regression coefficients.

*p<.05.

The second path analysis assessed whether a warning affected the amount of unique variance predicted by the updating factor, and retrieval-induced forgetting. The overall model fit for the collapsed conditions was $\chi^2(10, N = 292) = 124.82, p<.001$, with CFI = 1.00 and RMSEA <.001 (CFI and RMSEA both passed the thresholds indicative of a good fit, Hu & Bentler, 1999). As seen in Table 18 below, the updating factor predicted a significant amount of the variance in correct solutions when participants were warned (N=191), but did not predict unique variance when participants were not warned (N=101). When warned, participants with higher updating scores also had more correct solutions. Similarly, retrieval-induced forgetting predicted unique variance in correct solutions when participants were warned, but did not predict unique variance when they were not warned. When warned, participants who showed more retrieval-
induced forgetting had fewer correct solutions.

The third path analysis assessed whether expertise (and warning) affected the amount of unique variance predicted by restraint. The overall model fit for the collapsed conditions was $\chi^2(12, N = 293) = 93.49, p < .001$, with CFI = 1.00 and RMSEA < .001 (both CFI and RMSEA passed the cutoffs indicative of a good fit, Hu & Bentler, 1999). As seen in Table 19 below, restraint approached significance in predicting variance in correct solutions for experts ($N=84$), but not for novices in both the hard warning ($N=107$) and no warning ($N=102$) conditions, indicating that experts with more restraint tended to find more correct solutions.
Table 18

Path analysis task loadings on correct solutions by warning condition.

<table>
<thead>
<tr>
<th></th>
<th>No Warning</th>
<th></th>
<th></th>
<th>Warning</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>Std. Err</td>
<td>p-value</td>
<td>β</td>
<td>Std. Err</td>
<td>p-value</td>
</tr>
<tr>
<td>Updating</td>
<td>0.11</td>
<td>0.01</td>
<td>0.18</td>
<td>0.01</td>
<td>0.01</td>
<td>0.004</td>
</tr>
<tr>
<td>Retrieval-Induced Forgetting</td>
<td>-0.01</td>
<td>0.08</td>
<td>0.89</td>
<td>-0.17</td>
<td>0.07</td>
<td>0.004</td>
</tr>
<tr>
<td>Restraint</td>
<td>-0.03</td>
<td>0.00</td>
<td>0.72</td>
<td>0.08</td>
<td>0.00</td>
<td>0.20</td>
</tr>
<tr>
<td>Neutral Fragments</td>
<td>0.39</td>
<td>0.07</td>
<td>&lt;.001</td>
<td>0.44</td>
<td>0.06</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Prime Condition</td>
<td>0.37</td>
<td>0.02</td>
<td>&lt;.001</td>
<td>0.24</td>
<td>0.02</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*Note. β represents standardized regression coefficients. Prime condition represents being the no prime condition (referent is prime condition). *

*p<.05.

Table 19

Path analysis task loadings on correct solutions by expertise level.

<table>
<thead>
<tr>
<th></th>
<th>Novices Hard Warning</th>
<th></th>
<th>Experts Hard Warning</th>
<th></th>
<th>Novices No Warning</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>Std. Err</td>
<td>p-value</td>
<td>β</td>
<td>Std. Err</td>
<td>p-value</td>
</tr>
<tr>
<td>Updating</td>
<td>0.13</td>
<td>0.01</td>
<td>0.11</td>
<td>0.22</td>
<td>0.02</td>
<td>0.04</td>
</tr>
<tr>
<td>Retrieval-Induced Forgetting</td>
<td>-0.12</td>
<td>0.08</td>
<td>0.11</td>
<td>-0.21</td>
<td>0.11</td>
<td>0.04</td>
</tr>
<tr>
<td>Restraint</td>
<td>0.07</td>
<td>0.00</td>
<td>0.38</td>
<td>0.18</td>
<td>0.00</td>
<td>0.07</td>
</tr>
<tr>
<td>Neutral Fragments</td>
<td>0.57</td>
<td>0.06</td>
<td>&lt;.001</td>
<td>0.18</td>
<td>0.12</td>
<td>0.09</td>
</tr>
</tbody>
</table>

*Note. β represents standardized regression coefficients. *

*p<.05.
X. DISCUSSION

Prior knowledge guides our thinking when we encounter a new situation or problem. But using prior knowledge as a springboard means that sometimes inappropriate information gets in the way. Fixation induced by prior knowledge feels like it needs to be overcome by different means than experimentally-induced fixation, and the results of the current experiments start to provide empirical support for this idea. That is, different “flavors” of executive functioning help to overcome fixation, depending on the way that fixation is induced. When warned that solutions would not be related to music, correct solutions were positively predicted by updating. Correct solutions also tended to be positively predicted by restraint, particularly among participants with musical experience in the misleading prime condition. And, when participants were negatively primed with music-misleading solutions, retrieval-induced forgetting negatively predicted overcoming fixation.

**Experimentally-induced fixation and updating**

There was a tendency for participants with higher updating scores to get more correct solutions, but removing the warning reduced the relationship between the updating factor and the proportion of correct solutions. This result suggests a more nuanced way that updating benefits problem solving other than improved retention approaches, which is via goal maintenance.

One reason why better updating could benefit word-fragment completion is because it helps individuals generate viable solutions by aiding search or retrieval of words from long-term memory (Rosen & Engle, 1997; Ricks, et al., 2007; Unsworth, 2009) and/or by selectively maintaining only relevant information in the focus of attention (Hasher, Lustig, & Zacks, 2007; Unsworth & Engle, 2007). However, this reasoning would predict improved performance across conditions. The fact that updating contributed more strongly to performance when a warning was present suggests that updating may be playing a role in another way.
An alternative explanation is that updating is improving performance via improved goal maintenance during problem solving. This view has support in a number of recent studies. Kane and colleagues (McVay & Kane, 2009, 2010; see also, Unsworth & McMillan, 2014) have explored how higher working memory capacity allows for ready access to and maintenance of task goals, and works to guide top-down processes in searching memory. Recent work assessing the relationship between working memory capacity and mind wandering has examined the use of attentional control for the purpose of maintaining task goals, which in turn, restricts attentional focus to remain on goal-related thoughts. Goal neglect may also arise from temporarily forgetting the task goal due to attentional lapses, in which case, prepotent responses guide behavior. Goal neglect is especially high in contexts that fail to consistently reinforce the task goal. For example, Kane and Engle (2003) found that individuals with lower working memory capacity made more errors on the color-word Stroop when the task included larger amounts of congruent trials (for example, 75%), and incongruent trials (GREEN in the color red) were relatively infrequent. By contrast, when the Stroop task included fewer congruent trials (0%-25%), working memory did not predict accuracy because incongruent trials were relatively common and the goal was easier to maintain. Kane and Engle theorized that Stroop conditions with more incongruent trials consistently reinforced the goal of ignoring the word, leading to less goal neglect and improving performance.

In the present work, Experiment 3 removed the warning, and participants no longer needed resources to maintain the goal of ignoring music-misleading information. In contrast, Experiments 1 and 2 required participants’ controlled attention to remember to ignore music-related information. Participants with lower updating scores may have had more attentional lapses and may have temporarily forgotten the warning, thereby increasing the number of
intrusions they had because, 1) intrusions were prepotent responses recently activated in
memory, and, 2) they forgot the goal to ignore music-misleading information. It makes sense,
then, that goal maintenance could be the driving force behind the positive relationship between
updating and performance on music-misleading fragments in the warning condition. The other
benefits of working memory capacity may certainly influence the positive relationship between
updating and correct solutions (as evidenced by the positive relationship between updating and
neutral fragments in Experiment 1, and the tendency in the no warning condition for individuals
with higher updating scores to have more correct solutions), but the role for goal maintenance
may have a bigger role when a warning is included as part of the problem-solving task.

Although goal maintenance provides a plausible explanation for the results, it cannot
account for the negative relationship between updating and correct responses on neutral
fragments in Experiment 3 (no warning). In Experiments 1 and 2 there is a consistent positive
relationship between updating and both kinds of word fragments across conditions. This
relationship remains in the no prime condition of Experiment 3. By contrast, there is no
relationship for music-misleading fragments in the misleading prime condition, and the
relationship reverses for neutral fragments. In the no prime condition of Experiment 3, novices
may feel like they are just solving a difficult task and updating helps them for the
aforementioned reasons. Exposing participants to the music-misleading primes without a
warning may confuse them and lead them to rely on the music-misleading primes before they
realize that they are harmful. This explanation makes more sense in the context of the
presentation order; participants view all of the neutral fragments before the block of music-
misleading fragments. When participants start to solve the neutral fragments they might rely on
the music-misleading primes because they don’t know to avoid them. Participants with higher
updating scores would be better at retrieving the music-misleading fragments, thus impairing performance for neutral fragments. As participants progress through the task they realize that the music-misleading primes do not help them, eliminating the relationship between updating and correct responses for music-misleading fragments. Using a think-aloud protocol, or asking about problem-solving strategy during debriefing could shed light on these theories.

Although participants’ performance after a warning was contrasted with performance without a warning, this comparison does not elucidate the particular conditions under which updating predicts problem-solving performance. At what point does a warning no longer elicit goal maintenance? Kane and Engle (2003) explored how task difficulty changed the role for goal maintenance in the Stroop, and ultimately the role of working memory. The same investigation should be conducted for problem solving, to see which manipulations or problem-solving tasks create more interference during problem solving. Something seemingly small, like the order in which the fragments are solved (fragments could be interleaved instead of blocked by type) could alter the resources needed to maintain the warning. Interleaving the fragments may make it harder to maintain the warning because participants are altering between solving neutral fragments and music-misleading fragments, increasing the role for goal maintenance. Interleaving the fragments may also attenuate the negative relationship between updating and neutral fragment performance (seen in Experiment 3) if presentation order is the root of the negative relationship. What kinds of manipulations, or tasks, increase inference and elicit the goal maintenance function of updating?

**Expertise and restraint**

The most striking difference between experts and novices was that the relationship between restraint and correct solutions on music-misleading fragments approached significance
for experts, but was not related for novices. As predicted, restraint tended to positively predict
the number of correct solutions for experts. It can be inferred that experts not only used restraint
to suppress their prior music knowledge in the no prime condition, but that the misleading primes
heightened the activation of music-misleading information in music-related schemas. These
results add to the incubation finding in Wiley (1998) which benefitted novices more than experts.
At the same time, these results related to restraint are necessarily limited by the lack of relation
among the three measures that were intended to measure this construct, but it is not uncommon
for studies to find that tasks assumed to measure restraint are uncorrelated (see Eide, Kemp,

The results also seem consistent with several studies that have shown that restraint may
help solvers avoid perseveration on misleading prior knowledge when completing Alternate Uses
Tasks (AUTs). Benedek, Jauk, Sommer, Arendasy, and Neubauer (2014; see Groborz & Necka,
2003 for similar results) found a relationship between color-word Stroop effects (average
response time for neutral trials minus incongruent trials) and creativity in divergent thinking.
Benedek et al. suggested that restraint helped to suppress dominant response tendencies, thus
reducing the number of dominant, common ideas and facilitating originality. Individuals must
overcome prior knowledge to think of creative ideas in the AUT, as measured by originality and
appropriateness, just like experts must overcome dominant prior knowledge to solve the music-
misleading word fragments. Novices in our experiments do not have highly-activated prior
music knowledge to overcome, and thus do not benefit from restraint. Although Stroop
measures did not predict performance in the present studies, Stroop may predict AUT creativity
better than word fragment completion because there are an infinite number of answers in the
AUT, but only a limited number of correct answers (often, one) for the word fragments. After restraining prior knowledge in the word-fragment completion task one continues to search memory for the few correct solutions, which may involve cognitive mechanisms other than restraint.

Despite a lack of correspondence among the originally-proposed restraint tasks, the results suggest that restraint may be needed on problem solving tasks that require overcoming prior knowledge in order to think of other viable options. Moreover, the finding adds something unique to the literature by looking at the role of restraint in a problem-solving task where individuals have varying levels of prior knowledge. Other studies that examine individual differences in executive functioning typically examine the effects of prior knowledge by using problem-solving tasks in which prior knowledge makes solving problems more difficult for everybody (e.g., divergent thinking, AUT, or insight puzzles), but prior knowledge is not manipulated. In the AUT, for example, everybody comes in with prior knowledge about typical uses for a brick, or a paperclip, and knowing common uses make thinking of novel uses more difficult. The present experiments (as did Wiley, 1998, and Ricks et al., 2007) sought participants with varying levels of prior knowledge, to see how a change in prior knowledge affected the role for different executive functions.

**Experimentally-induced fixation and retrieval-induced forgetting**

When participants were warned that solutions would not be related to music, retrieval-induced forgetting was unexpectedly negatively related to overcoming fixation. As predicted, no relationship existed between retrieval-induced forgetting and neutral fragments, or the music-misleading fragments in the no prime condition. This result presumably occurred because neutral fragments, and fragments in the no prime condition, have fewer strong competitors that
need to be pushed down. In contrast to our predictions, participants who were warned and showed more retrieval-induced forgetting had fewer correct solutions (and sometimes this was accompanied by more intrusions) than participants who showed less retrieval-induced forgetting in the misleading prime condition. Once the warning was removed, no relationships were seen in any condition with retrieval-induced forgetting.

Previous work by Storm and colleagues (e.g., Storm & Angello, 2010; Storm, Angello, & Bjork, 2011; Storm & Patel, 2014; Koppel & Storm, 2014) have repeatedly demonstrated positive relationships between retrieval-induced forgetting and problem solving. Typically, when competition arises in memory, the processes underlying retrieval-induced forgetting are recruited to attenuate interference and increase accessibility to other viable solutions. Several possibilities may underlie the discrepancy between the present experiments and findings in the literature.

The first possibility is that the warning may have altered the retrieval dynamics involved in problem solving. One explanation could be that the warning decreased the activation of music-misleading primes for individuals who showed less retrieval-induced forgetting, but increased the activation for individuals who showed more retrieval-induced forgetting. When people receive the warning that the solutions are not music-related they may try to forget what they just viewed. In this case the warning would act like a list-method directed forgetting instruction (for a review see MacLeod, 1998). Koppel and Storm (2012) showed that a forget instruction improved word fragment completion rates when presented after the misleading primes (similarly, a forget instruction before retrieval practice reduced retrieval-induced forgetting in Storm, Bjork, & Bjork, 2007). However, Delaney and Sahakyan (2007) demonstrated that individuals with more working memory capacity benefited more from a forget
instruction than individuals with less working memory capacity (for similar results see Aslan, Zellner, & Bauml, 2010, and Soriano & Bajo, 2007). Brewin and Beaton (2002) also showed that individuals with high working memory capacity were better at suppressing topics when told to stop thinking about them. The present experiments found a tendency for a negative relationship between working memory capacity and retrieval-induced forgetting. If the warning acts like a forget instruction, and individuals with more working memory capacity benefit more from a forget instruction, then misleading primes should be less salient for individuals who exhibit less retrieval-induced forgetting. This would increase the proportion of music-misleading fragments solved for participants who show less retrieval-induced forgetting.

Another (almost opposite) explanation is that participants who showed more retrieval-induced forgetting may have actively pushed down the music-related information more after receiving the warning, compared to participants who showed less retrieval-induced forgetting. For participants who showed less retrieval-induced forgetting, the music-related information may have passively dissipated while they tried to solve the first 18 neutral fragments (much like an incubation period may differentially help individuals who show more or less retrieval-induced forgetting during RAT problem solving, Koppel & Storm, 2014). When the music-misleading word fragments appeared half way through the task, participants who showed less retrieval-induced forgetting would have degraded representations of the music-related primes and would not be able to recall them, decreasing intrusions and increasing the number of correct solutions. Participants who showed more retrieval-induced forgetting, on the other hand, may experience a release of inhibition if the fragments remind them of the music-related primes (Bjork & Bjork, 1996), increasing the salience of the music-misleading primes and reducing the number of correct solutions. This theory is bolstered by the finding that retrieval-induced forgetting
negatively predicted performance when participants saw the misleading primes in conjunction with a warning, but the relationship disappeared when the warning was removed.

In either warning-related possibility, it seems there is something about the warning is that differentially altering the competitiveness of the music-misleading primes, which would result in different patterns of relations with retrieval-induced forgetting. Research should explore the boundary conditions for the positive effects of retrieval-induced forgetting in problem solving, especially in relation with warnings to ignore certain kinds of information.

Placing the retrieval-practice paradigm last in the study, and the brief nature of the problem-solving task are two methodological issues that may have influenced the negative relationship between retrieval-induced forgetting and correct solutions. Storm and Angello (2010), and Koppel and Storm (2014) found positive relationships between retrieval-induced forgetting and problem solving, but retrieval-induced forgetting was the first measure participants completed in their studies. Making the retrieval-practice paradigm the last task in a series of long, demanding assessments may make it a less reliable, less pure measure of inhibition. By that point, retrieval-induced forgetting could also reflect attentional processes, effort, fatigue, or other non-inhibitory mechanisms and characteristics. The retrieval-practice paradigm might measure something different when it is given to participants last compared to when it is given to participants first.

The nature of the word-fragment completion task is also different than the nature of the RAT problem-solving tasks from previous experiments. Storm and Angello (2010) gave participants 18 min to complete 20 RAT problems on a sheet of paper. Participants could work on problems as long as they liked, and they could return to a problem after working on other problems. Koppel and Storm (2014) gave participants 1 min to solve each RAT problem. Both
experiments gave participants more time than the 7 sec allotted for a given word fragment. The nature of the word-fragment completion task was very brief, especially compared to Koppel and Storm, and did not provide extended attempts like Storm and Angello. The retrieval-practice phase that assessed retrieval-induced forgetting gave participants three attempts to generate new exemplars for each category-two-letter stem cue (and three separate attempts to select against competing information). The extended nature of the retrieval-practice phase maps better onto the nature of RAT than it does word fragment completion. Participants who show more retrieval-induced forgetting may be better at selecting against competing information over several attempts, but not necessarily during one short, brief attempt. In fact, Murayama et al. (2014) found that participants who were given less time during retrieval practice actually showed more retrieval-induced forgetting. If participants were given more time to solve the word fragments, or several, spaced out attempts, the results of these studies may be reversed and more closely resemble prior studies.

An additional possibility is that retrieval-induced forgetting is not a stable individual difference to the same extent as updating and restraint. If retrieval-induced forgetting is a consequence of competition in a specific context at test, then it would be expected to fluctuate based on the amount of competition experienced in a specific moment (Murayama et al., 2014). As it stands, retrieval-induced forgetting is not a pure measure of inhibition—it may result from both inhibitory-based and competition-based mechanisms based on the structure of the paradigm used (Murayama et al., 2014; Storm & Levy, 2012). The reliance of retrieval-induced forgetting on contextually-based competition, and the fact that retrieval-induced forgetting is not a pure measure of inhibition, may be why its relations with other measures of executive control and problem solving are variable.
Where executive functioning fits into the cognitive process model for novices and experts

The results suggest that the three “flavors” of executive functioning may play a role at different steps in the cognitive process model for novices and experts. For novices, there was a tendency that those with higher updating scores solved more problems overall in the warning condition. Those who showed less retrieval-induced forgetting also solved more problems, but only after being exposed to misleading primes in the warning condition. Updating may shift novices’ focus of attention away from the music-misleading primes prior to problem solving, which would increase the probability of choosing the correct solution at the beginning of the search process. If the warning acts like a forget instruction, or if the warning causes novices who show more retrieval-induced forgetting to actively push down the music-misleading primes (and experience a later release of inhibition), the processes underlying retrieval-induced forgetting are only playing a role prior to problem solving. When the novice tries their first response option and it does not fit the fragment, updating can help retrieve other viable solutions during the iterative process (which is why there was a positive relationship between updating and neutral fragments), or focus attention away from already-guessed, incorrect responses. The positive relationship between updating and correct solutions in the warning condition suggests that updating may also help novices stay on task during solution generation to keep remembering the warning.

Removing the warning removes the benefits of updating when novices see music-misleading primes. Novices need to know that they should avoid using the music-misleading primes, otherwise they may try to use the music-misleading primes to solve the fragments and better updating then impairs problem solving. The shift from a negative relationship with updating in the first half of problem solving to no relationship with updating in the second half of
problem solving supports this idea. The shifting relationship with updating in the no warning condition also bolsters the argument that updating works online during the generation process and not just prior to problem solving, which it may also do in the warning condition. On the other hand, retrieval-induced forgetting plays no role in problem solving in the absence of a warning. A warning may trigger the processes underlying retrieval-induced forgetting to act prior to problem solving, so removing the warning eliminates the role for retrieval-induced forgetting.

Experts may go through a similar problem-solving process as novices, except executive functioning plays a much larger role for experts than does their typical search process, and restraint has a place in their model. Like novices, experts may benefit from updating before and during problem solving, and the processes that underlie retrieval-induced forgetting may act before problem solving. However, experts had a positive relationship between restraint and correct solutions after seeing music-misleading primes, and a tendency to benefit from restraint in all conditions. Restraint, as measured by word categorization, would act to push down competing items that are grounded in domain knowledge after they pop up. Therefore, when domain knowledge becomes activated, restraint may work during solution generation to push down the strong, prepotent responses. It should also be emphasized that updating, retrieval-induced forgetting, and restraint were more predictive of experts’ success than they were for novices, and neutral fragment solutions failed to predict music-misleading solutions for experts, but not for novices. Both pieces of evidence intimate that while experts and novices go through similar steps during problem solving, experts experience a different kind of fixation that sometimes requires more, or additional executive function processes to overcome. Fixation induced by prior knowledge may be more difficult to overcome, increasing the role for executive
functioning in problem solving, or the highly organized structure of experts’ domain knowledge may allow executive functioning to operate more efficiently/precisely. In fact, executive functioning predicted experts’ ability to solve music-misleading fragments more than their general problem-solving ability—a result that was not close to emerging for novices. Music-misleading fragments strongly activate domain knowledge, and experts’ ability to solve the fragments relies more on their ability to overcome fixation than it does their normal problem-solving plan. That is, while novices’ performance relies more on their typical iterative search process than it does overcoming fixation due to recently-primed information, experts’ performance relies more on overcoming fixation than it does their typical iterative search process. Thus, while experts and novices follow the same steps to solve a problem, the role of executive functioning is much more important for experts.
XI. CONCLUDING COMMENTS

Fixation constrains the scope of our thinking in memory and problem solving. Individuals may become fixated during simple tests of memory, or during more complex problem-solving tests because of prior knowledge, or recently-primed information in the environment. The findings in the present studies lend support to the idea that there are qualitatively different kinds of fixation. Individuals need different means to overcome fixation that is induced by long-term, prior knowledge than they would experimentally-induced fixation. One may assume that we employ special cognitive processes when we solve problems, but the same retrieval dynamics that underlie everyday cognition also shape thinking and problem solving (Smith & Ward, 2012). If we want to become better problem solvers and thinkers, we need to understand the very normal retrieval dynamics that support these activities. The nature of the problem-solving task, however, alters the memory dynamics involved and better executive functioning—be it updating, retrieval-induced forgetting, or restraint—is not always helpful.

It is important to look at the unique variance accounted for by multiple individual differences, but this could also be done by examining different stages of problem solving for certain kinds of insight problems (see also, Ash & Wiley, 2006). For example, Lv (2015) showed that working memory capacity (updating) was beneficial in an initial search phase, but that restraint (as measured by number Stroop effects) played a complex role during the restructuring phase. Specifically, Lv found that the effects of restraint on restructuring were contradictory in verbal versus spatial insight problem solving. Although an individual differences approach alone is informative, analyzing the role of individual differences in various phases of problem solving may tell us even more about what goes on during problem solving.

Taking an individual differences approach to problem solving is valuable because it
directly tests the mechanisms that are thought to be responsible for the memory search processes and cognitive strategies underlying problem solving. There are countless individual differences beyond the three studied in this experiment, and future research can continue to explore the role for these potential mechanisms. For example, DeYoung, Flanders, and Peterson (2008) found a positive relationship between insight problem solving and performance on the anomalous card task (Bruner & Postman, 1949), which assessed individual differences in breaking frame. Breaking frame is similar to overcoming functional fixedness or a context-induced set (Schooler & Melcher, 1995). In the anomalous card task, participants quickly label the color and suit of playing cards, before seeing an anomalous card (like a black seven of hearts). Individual differences are measured by looking at the number of trials before the participant notices the anomalous card. Breaking frame could be one of multiple determinants of problem-solving success (others include task switching, spatial abilities, or fluency, to name a few), and there are many more individual differences to be explored (e.g., Gilhooly & Fioratou, 2009; Benedek et al., 2014; Dorfman, Martindale, Gassimova, & Vartanian, 2008). Examining individual differences in updating, restraint, and retrieval-induced forgetting only tell part of the story of the relationship between executive functioning and problem solving.

Problem solving success is determined by what the situation calls for, and this interacts with characteristics of the problem solver themselves. To optimize problem solving, one must weigh the costs and benefits for different cognitive mechanisms.
References


Appendix A

**Automated Running Span (Broadway & Engle, 2010):**
Participants are told to remember the last few letters in a series of letters, which appear on the screen one at a time. After the last letter in the series disappears, participants recall the last few letters. For example, participants may be instructed to type the last three letters on the screen for the following series.

R K F S J W

**Backwards Digit Span (Unsworth & Engle, 2007):**
Participants see a string of numbers on the screen, one at a time. After the last number in the series disappears, participants are asked to type them in reverse order.

5 3 1 6

**WAIS Letter-Number Sequencing (Wechsler, 1997):**
Participants see a string of numbers and letters on the screen, one at a time. After the last item disappears, participants are asked to type the numbers in ascending order, followed by the letters alphabetically.

5 J 3 C 8

**Word Categorization (Amit, Algom, & Trope, 2009; Arieh & Algom, 2002)**
Participants see a picture of fruit (e.g., apple, banana, cherry, lemon) or furniture (e.g., table, piano, vase, stool) on the center of the screen with the name of a fruit or furniture overlaid on top of the picture. Participants must ignore categorizing the picture, and instead indicate the category of the word.
Appendix B

Fragments with music-misleading primes

<table>
<thead>
<tr>
<th>Misleading Prime</th>
<th>Target</th>
<th>Word Fragment</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAGPIPE</td>
<td>BARGAIN</td>
<td>BA _ G _ I _</td>
</tr>
<tr>
<td>BASSOON</td>
<td>BLOSSOM</td>
<td>B _ _ SSO _</td>
</tr>
<tr>
<td>BAROQUE</td>
<td>BOUQUET</td>
<td>BO _ QUE _</td>
</tr>
<tr>
<td>CADENZA</td>
<td>CANTEEN</td>
<td>CA _ _ E _ N</td>
</tr>
<tr>
<td>CALYPSO</td>
<td>CARPOOL</td>
<td>CA_P_O _</td>
</tr>
<tr>
<td>CHAMBER</td>
<td>COBBLER</td>
<td>C__B_ER</td>
</tr>
<tr>
<td>CANTATA</td>
<td>CONTACT</td>
<td>C _ NTA _ T</td>
</tr>
<tr>
<td>CONDUCT</td>
<td>CONTEST</td>
<td>CONT_ _ _</td>
</tr>
<tr>
<td>CHORALE</td>
<td>COURAGE</td>
<td>CO _ RA _ E</td>
</tr>
<tr>
<td>DICTION</td>
<td>DESTINY</td>
<td>D _ _ TIN _</td>
</tr>
<tr>
<td>MARIMBA</td>
<td>MARTIAN</td>
<td>MAR_IA _</td>
</tr>
<tr>
<td>MUSICAL</td>
<td>MASCARA</td>
<td>M_ SCA _ _</td>
</tr>
<tr>
<td>PRELUDE</td>
<td>PARSLEY</td>
<td>P _ R _ LE _</td>
</tr>
<tr>
<td>PERFORM</td>
<td>PERFUME</td>
<td>PERF _ M _</td>
</tr>
<tr>
<td>PIANIST</td>
<td>PLANTER</td>
<td>P _ ANT _ _</td>
</tr>
<tr>
<td>SOLOIST</td>
<td>SHELTER</td>
<td>S _ _LT _ _</td>
</tr>
<tr>
<td>TIMPANI</td>
<td>TRIPLET</td>
<td>T_IP _ _</td>
</tr>
<tr>
<td>VIBRATO</td>
<td>VIBRANT</td>
<td>VIBRA _ T</td>
</tr>
</tbody>
</table>
## Appendix C

Neutral fragments

<table>
<thead>
<tr>
<th>Target</th>
<th>Word Fragment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALLERGY</td>
<td>A_L_ _GY</td>
</tr>
<tr>
<td>APRICOT</td>
<td>A_R_ _OT</td>
</tr>
<tr>
<td>CUSHION</td>
<td>CUS_I_N</td>
</tr>
<tr>
<td>EPISODE</td>
<td>EP_SO_ _</td>
</tr>
<tr>
<td>FAILURE</td>
<td>F_I_URE</td>
</tr>
<tr>
<td>FOLIAGE</td>
<td>F_ _L_GE</td>
</tr>
<tr>
<td>GRAMMAR</td>
<td>GR_ <em>MA</em></td>
</tr>
<tr>
<td>HISTORY</td>
<td>H_ST_R_</td>
</tr>
<tr>
<td>PAGEANT</td>
<td>P_GE_ _T</td>
</tr>
<tr>
<td>REALITY</td>
<td>REA_ <em>T</em></td>
</tr>
<tr>
<td>SHAMPOO</td>
<td>S_A_PO_</td>
</tr>
<tr>
<td>SHINGLE</td>
<td>S_ING_E</td>
</tr>
<tr>
<td>SUPPORT</td>
<td>SUP_ _T</td>
</tr>
<tr>
<td>TERRAIN</td>
<td>T_R_ _IN</td>
</tr>
<tr>
<td>TRAGEDY</td>
<td>TR_G_ _Y</td>
</tr>
<tr>
<td>VILLAIN</td>
<td>V_L_A_N</td>
</tr>
<tr>
<td>VINEGAR</td>
<td>VIN_G_ _</td>
</tr>
<tr>
<td>VOLTAGE</td>
<td>VO_ _AGE</td>
</tr>
</tbody>
</table>
Appendix D

How familiar are you with the following terms on a scale of 1 (NOT familiar at all) to 7 (VERY familiar)? When rating the word, consider how often you ENCOUNTER these terms in a typical week.

Please write 1 (not familiar at all), 2, 3, 4, 5, 6, or 7 (very familiar) on the line next to each term.

1. BAGPIPE _____
2. BASSOON _____
3. BAROQUE _____
4. CADENZA _____
5. CALYPSO_____ 
6. CHAMBER _____
7. CANTATA _____
8. CONDUCT _____
9. CHORALE _____
10. DICTION _____
11. MARIMBA ___
12. MUSICAL _____
13. PRELUDE _____
14. PERFORM _____
15. PIANIST _____
16. SOLOIST _____
17. TIMPANI _____
18. VIBRATO _____
Please circle the option that best describes each term. After circling an option, write how confident you are in your answer on a scale of 1 (not confident at all) to 7 (very confident).

1. Bagpipe
   a. a small flute sounding an octave higher
   b. a musical instrument made from a row of short pipes of varying length fixed together
   c. a musical instrument that is played especially in Scotland
   d. a woodwind instrument with a double-reed mouthpiece, and holes stopped by keys
   **How confident are you in the answer you circled (1-7)? _____**

2. Bassoon
   a. a brass instrument with a coiled tube, valves, and a wide bell
   b. a guitar with six strings that has the lowest pitch
   c. a woodwind instrument with a single-reed mouthpiece
   d. a bass instrument of the oboe family with a double reed
   **How confident are you in the answer you circled (1-7)? _____**

3. Baroque
   a. orchestral music of the early 20th century
   b. style of Western art music made between the 17th and 18th centuries; invented tonality
   c. European music from the Late Middle Ages, which advanced concepts of rhythm
   d. 19th century Cuban dance music
   **How confident are you in the answer you circled (1-7)? _____**

4. Cadenza
   a. instrumental music played by a small ensemble, with one player to a part
   b. a virtuoso solo passage inserted into a movement in a concerto, typically near the end
   c. a composition in which a short melody is introduced by one part and successively taken up by others and developed by interweaving the parts
   d. a musical passage to be performed with all voices or instruments together
   **How confident are you in the answer you circled (1-7)? _____**

5. Calypso
   a. a kind of West Indian (originally Trinidadian) music in syncopated African rhythm
   b. music heavily influenced by Chinese forms, emerging in the 1980s
   c. southern Indian classical music
   d. Argentine popular music that spread internationally in the 1920s
   **How confident are you in the answer you circled (1-7)? _____**
6. Chamber
   a. a musical composition for a keyboard instrument designed to show the performer's technique
   b. a musical composition usually composed in three movements, in which one solo instrument is accompanied by an orchestra
   c. a medium-length narrative piece of music for voices with instrumental accompaniment
   d. instrumental music played by a small ensemble, with one player to a part
   **How confident are you in the answer you circled (1-7)? _____**

7. Cantata
   a. the quality of a musical sound or voice as distinct from its pitch and intensity
   b. a wavering effect in a musical tone, typically produced by rapid reiteration of a note
   c. a medium-length narrative piece of music for voices with instrumental accompaniment
   d. a composition for an instrumental soloist, often with a piano accompaniment
   **How confident are you in the answer you circled (1-7)? _____**

8. Conduct
   a. to direct the performance of a piece of music
   b. the degree of highness or lowness of a tone
   c. the lower female or unbroken male voice
   d. music between the acts of a play or opera
   **How confident are you in the answer you circled (1-7)? _____**

9. Chorale
   a. a flourish of trumpets or other similar instruments
   b. the five lines generally used in music notation
   c. a musical composition consisting of a harmonized version of a simple, stately hymn tune
   d. the simultaneous sounding of two or more notes
   **How confident are you in the answer you circled (1-7)? _____**

10. Diction
    a. a sign that shows that a note should be lowered by a semitone
    b. the style of enunciation in singing
    c. a direction to performers, meaning becoming softer
    d. unaccompanied choral singing
    **How confident are you in the answer you circled (1-7)? _____**
11. Marimba
   a. a musical percussion instrument having a set of tuned metal pieces
   b. a fast-paced, Brazilian dance
   c. a large musical instrument having rows of tuned pipes sounded by compressed air
   d. a deep-toned xylophone of African origin
   **How confident are you in the answer you circled (1-7)? _____**

12. Musical
   a. a play or movie in which singing and dancing play an essential part
   b. an indication of tempo and mood, meaning slow and serious
   c. divisions of the tone smaller than the semi-tone
   d. the exactness of pitch or lack of it in playing or singing
   **How confident are you in the answer you circled (1-7)? _____**

13. Prelude
   a. an introductory piece of music, most commonly the first movement of a suite
   b. a composer or publisher's directive to repeat the previous part of music
   c. the ending of a piece of music
   d. a night-piece, music that evokes a nocturnal mood
   **How confident are you in the answer you circled (1-7)? _____**

14. Perform
   a. orchestral music of the early 20th century
   b. a small flute sounding an octave higher
   c. present (a form of entertainment) to an audience
   d. an introductory piece of music, most commonly the first movement of a suite
   **How confident are you in the answer you circled (1-7)? _____**

15. Pianist
   a. a person who plays percussion, especially professionally
   b. a person who plays the piano, especially professionally
   c. a person who plays the flute, especially professionally
   d. a person who sings, especially professionally
   **How confident are you in the answer you circled (1-7)? _____**
16. Soloist
   a. a singer or other musician who performs alone
   b. instrumental music played by a small ensemble, with one player to a part
   c. a medium-length narrative piece of music for voices with instrumental accompaniment
   d. the style of enunciation in singing
   **How confident are you in the answer you circled (1-7)? _____**

17. Timpani
   a. a cylindrical drum with two drumheads, the upper of which is struck
   b. a small keyboard instrument in which felted hammers strike a row of steel plates
   c. a percussion instrument resembling a shallow drum with small metal disks in slots around the edge
   d. a set of two or three large kettledrums
   **How confident are you in the answer you circled (1-7)? _____**

18. Vibrato
   a. a rapid, slight variation in pitch in singing or playing some musical instruments
   b. a pause of unspecified length on a note or rest
   c. a person who is highly skilled in music
   d. a melody announced by one voice or instrument is imitated by one or more other voices or instruments
   **How confident are you in the answer you circled (1-7)? _____**
Musicianship Questionnaire

Are you a musician? (circle one): Serious musician Casual musician Non-musician

Are you an instrumental musician? YES NO

How many years have you been an instrumental musician (currently or in the past)? _____ years.

What instrument(s) do you play (and for how many years)? (i.e., Piano, 10 years)

_____________________________________________________

Do you currently take private lessons for an instrument? YES NO

If you have ever taken private lessons, how many years did you do so? _______ years.

Are you currently making instrumental music in a structured setting? YES NO

If you currently do/did in the past, what is the setting? (school band, church group, etc.)

_____________________________________________________

If you have ever made instrumental music in a structured setting, for how many years have you done so? _______ years.

If you do not currently make instrumental music in a structured setting, but used to, how many years has it been since you’ve played in a structured setting? _______ years.

How many hours outside of a structured setting do/did you practice instrumental music each week (on average) _______ hours.

Are you a vocal musician? YES NO

How many years have you been a vocal musician? _______ years.

Do you currently take private vocal lessons? YES NO

If you have ever taken private lessons, how many years did you do so? _______ years.

Are you currently singing in a structured setting? YES NO

If you currently do/did in the past, what is the setting? (school band, church group, etc.)

_____________________________________________________

If you have ever sung in a structured setting, for how many years have you done so? _______ years.
If you do not currently sing in a structured setting, but used to, how many years has it been since you’ve sang in a structured setting? __________ years.

How many hours outside of a structured setting do/did you practice vocal music each week (on average) ________ hours.

How many times have you composed an original musical work? (best estimate) _______

How many times have you arranged or transcribed music? (best estimate) ______

How often do you improvise when performing music?

1 2 3 4 5 6 7
Never All the time

How many college or graduate level music courses have you taken? ________ courses.

Do you have any music experiences not covered by the above questions? If so, explain below.
INSTITUTIONAL REVIEW BOARD APPROVAL FORM

UNIVERSITY OF ILLINOIS
AT CHICAGO

Office for the Protection of Research Subjects (OPRS)
Office of the Vice Chancellor for Research (MC: 672)
203 Administrative Office Building
1737 West Polk Street
Chicago, Illinois 60612-7227

November 15, 2013

Rebecca Koppel, BA
Psychology
Psychology
1007 W Harrison, M/C 285
Chicago, IL 60612
Phone: (703) 220-5117

RE: Protocol #2010-1018
“Problem Solving and Memory”

Dear Ms. Koppel:

Your Continuing Review was reviewed and approved by the Expedited review process on November 15, 2013. You may now continue your research.

Please note the following information about your approved research protocol:

Approved Subject Enrollment #: 3400 (2276 subjects enrolled)

Additional Determinations for Research Involving Minors: The Board determined that this research satisfies 45CFR46.404, research not involving greater than minimal risk. Therefore, in accordance with 45CFR46.408, the IRB determined that only one parent's/legal guardian's permission/signature is needed. Wards of the State may not be enrolled unless the IRB grants specific approval and assures inclusion of additional protections in the research required under 45CFR46.409. If you wish to enroll Wards of the State contact OPRS and refer to the tip sheet.

Performance Site: UIC
Sponsor: None

Research Protocol:
a) Problem Solving and Memory (no footer)

Recruitment Materials:
a) Pre-Screening Form; Version 3; 11/14/2012
b) Print Ad; Version 4; 11/14/2012
c) Flyer; Version 4; 11/14/2012
d) Internet Ad; Version 4; 11/14/2012

Phone: 312-996-1711 http://www.uic.edu/depts/ovcr/oprs/ FAX: 312-413-2929
Informed Consents:

a) Problem Solving and Memory; Version 4; 11/14/2012
b) Waiver of Signed Consent Document granted under 45 CFR 46.117 for Pre-Screening Only
c) Debriefing Form (no version number, no date)

Parental Permission:

a) A waiver of parental permission has been granted under 45 CFR 46.116(d) and 45 CFR 46.408(c); however, as per UIC Psychology Subject Pool policy, at least one parent must sign the Blanket Parental Permission document prior to the minor subject's participation in the UIC Psychology Subject Pool.

Your research meets the criteria for expedited review as defined in 45 CFR 46.110(b)(1) under the following specific category:

(7) Research on individual or group characteristics or behavior (including but not limited to research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Please note the Review History of this submission:

<table>
<thead>
<tr>
<th>Receipt Date</th>
<th>Submission Type</th>
<th>Review Process</th>
<th>Review Date</th>
<th>Review Action</th>
</tr>
</thead>
</table>

Please remember to:

→ Use your research protocol number (2010-1018) on any documents or correspondence with the IRB concerning your research protocol.

→ Review and comply with all requirements on the enclosure, "UIC Investigator Responsibilities, Protection of Human Research Subjects" (http://tigger.uic.edu/depts/over/research/protocolreview/irb/policies/0924.pdf)

Please note that the UIC IRB has the right to seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Please be aware that if the scope of work in the grant/project changes, the protocol must be amended and approved by the UIC IRB before the initiation of the change.

We wish you the best as you conduct your research. If you have any questions or need further help, please contact OPRS at (312) 996-1711 or me at (312) 355-2764. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.
Sincerely,

Betty Mayberry, B.S.
IRB Coordinator, IRB #2
Office for the Protection of Research Subjects

Enclosures:

1. Informed Consent Documents:
   a) Problem Solving and Memory; Version 4; 11/14/2012
   b) Debriefing Form (no version number, no date)

2. Recruiting Materials:
   a) Pre-Screening Form; Version 3; 11/14/2012
   b) Print Ad; Version 4; 11/14/2012
   c) Flyer; Version 4, 11/14/2012
   d) Internet Ad; Version 4; 11/14/2012

cc: Michael E. Ragozzino, Psychology, M/C 285
    Jennifer Wiley, Faculty Sponsor, Psychology, M/C 285
Approval Notice

Amendment to Research Protocol and/or Consent Document – Expedited Review

UIC Amendment # 2

February 6, 2014

Rebecca Koppel, BA
Psychology
Psychology
1007 W Harrison, M/C 285
Chicago, IL 60612
Phone: (703) 220-5117

RE: Protocol # 2010-1018
“Problem Solving and Memory”

Dear Ms. Koppel:

Members of Institutional Review Board (IRB) #2 have reviewed this amendment to your research and/or consent form under expedited procedures for minor changes to previously approved research allowed by Federal regulations [45 CFR 46.110(b)(2)]. The amendment to your research was determined to be acceptable and may now be implemented.

Please note the following information about your approved amendment:

Amendment Approval Date: February 3, 2014

Amendment:

Summary: UIC Amendment #2 dated January 24, 2014 (received 1/27/14) is an investigator-initiated amendment regarding the following:
(1) Revise the protocol to include recruitment of expert musicians from the UIC community (revised initial review application pages 5-6, 8-11, 15-16; revised Protocol (no footer);
(2) Submit new and revised recruitment and consent documents reflecting the above (Problem Solving and Memory, v6, 1/24/14; Expert Pre-Screening Form, v1, 1/24/14; Expert Print Ad, v1, 1/24/14; Expert Internet Ad, v1, 1/24/14; Expert Flyer, v1, 1/24/14; Print Ad, v1, 1/24/14; Internet Ad, v1, 1/24/14; Problem Solving and Memory Study Flyer, v1, 1/24/14);
(3) Add Erin Sovansky as key research personnel (Appendix P and training completion report included)

**Approved Subject Enrollment #:** 3400  
**Performance Sites:** UIC  
**Sponsor:** None  
**Research Protocol:**  
  a) Problem Solving and Memory (no Footer)

**Recruiting Materials:**  
  a) Expert Pre-Screening Form Version 1, 01/24/2014  
  b) Expert Print Ad Version 1, 01/24/2014  
  c) Expert Internet Ad Version 1, 01/24/2014  
  d) Memory Expert Flyer Version 1, 01/24/2014  
  e) Memory Study Print Ad Version 1, 01/24/2014  
  f) Memory Study Internet Ad Version 1, 01/24/2014  
  g) Memory Study Flyer Version 1, 01/24/2014

**Informed Consent:**  
  a) Problem Solving and Memory; Version 6, 01/24/2014

Please note the Review History of this submission:

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Please be sure to:

➤ Use only the IRB-approved and stamped consent document enclosed with this letter when enrolling subjects.

➤ Use your research protocol number (2010-1018) on any documents or correspondence with the IRB concerning your research protocol.

➤ Review and comply with all requirements on the enclosure, "UIC Investigator Responsibilities, Protection of Human Research Subjects"[http://tigger.uic.edu/depts/ovcr/research/protocolreview/irb/policies/0924.pdf](http://tigger.uic.edu/depts/ovcr/research/protocolreview/irb/policies/0924.pdf)

Please note that the UIC IRB #2 has the right to seek additional information, or monitor the conduct of your research and the consent process.

Please be aware that if the scope of work in the grant/project changes, the protocol must be amended and approved by the UIC IRB before the initiation of the change.

We wish you the best as you conduct your research. If you have any questions or need further help, please contact the OPRS at (312) 996-1711 or me at (312) 355-2764. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.
Sincerely,

Betty Mayberry, B.S.
IRB Coordinator, IRB # 2
Office for the Protection of Research Subjects

Enclosures:

1. **Informed Consent Document:**
   a) Problem Solving and Memory; Version 6, 01/24/2014

2. **Recruiting Materials:**
   a) Expert Pre-Screening Form Version 1, 01/24/2014
   b) Expert Print Ad Version 1, 01/24/2014
   c) Expert Internet Ad Version 1, 01/24/2014
   d) Memory Expert Flyer Version 1, 01/24/2014
   e) Memory Study Print Ad Version 1, 01/24/2014
   f) Memory Study Internet Ad Version 1, 01/24/2014
   g) Memory Study Flyer Version 1, 01/24/2014

cc: Jennifer Wiley, Faculty Sponsor, Psychology, M/C 285
    Michael E. Ragozzino, Psychology, M/C 285
November 21, 2014

Rebecca Koppel, BA
Psychology
1007 W. Harrison, M/C 285
Chicago, IL 60612
Phone: (703) 220-5117

RE: Protocol # 2010-1018
“Problem Solving and Memory”

Dear Ms. Koppel:

Your Continuing Review was reviewed and approved by the Expedited review process on November 20, 2014. You may now continue your research.

Please note the following information about your approved research protocol:

**Protocol Approval Period:** December 10, 2014 - December 10, 2015

**Approved Subject Enrollment #:** 7,400 (2,982 subject enrolled)

**Additional Determinations for Research Involving Minors:**
The Board determined that this research satisfies 45CFR46.404 research not involving greater than minimal risk. Therefore, in accordance with 45CFR46.408, the IRB determined that only one parent’s/legal guardian’s permission/signature is needed. Wards of the State may not be enrolled unless the IRB grants specific approval and assures inclusion of additional protections in the research required under 45CFR46.409. If you wish to enroll Wards of the State contact OPRS and refer to the tip sheet.

**Performance Sites:** UIC

**Sponsor:** None

**PAF#:** Not applicable

**Research Protocol:**
- a) Problem Solving and Memory (no Footer)

**Recruitment Materials:**
- a) Print Ad; Version 4; 11/14/2012
- b) Pre-Screening Form; Version 3; 11/14/2012
Informed Consents:
  a) Problem Solving and Memory; Version 6, 01/24/2014
  b) Waiver of Signed Consent Document granted under 45 CFR 46.117 for Pre-Screening Only
  c) Debriefing Form (no version number, no date)

Parental Permissions:
  a) A waiver of parental permission has been granted under 45 CFR 46.116(d) and 45 CFR
     46.408(c); however, as per UIC Psychology Subject Pool policy, at least one parent must sign the
     Blanket Parental Permission document prior to the minor subject’s participation in the UIC
     Psychology Subject Pool.

Your research meets the criteria for expedited review as defined in 45 CFR 46.110(b)(1) under the
following specific category:

(7) Research on individual or group characteristics or behavior (including but not limited to research on
perception, cognition, motivation, identity, language, communication, cultural beliefs or practices and
social behavior) or research employing survey, interview, oral history, focus group, program evaluation,
human factors evaluation, or quality assurance methodologies.

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Please remember to:

➔ Use your research protocol number (2010-1018) on any documents or correspondence with
  the IRB concerning your research protocol.

➔ Review and comply with all requirements on the OPRS website under:
  "UIC Investigator Responsibilities, Protection of Human Research

Please note that the UIC IRB has the right to seek additional information, require further
modifications, or monitor the conduct of your research and the consent process.

Please be aware that if the scope of work in the grant/project changes, the protocol must be
amended and approved by the UIC IRB before the initiation of the change.
We wish you the best as you conduct your research. If you have any questions or need further help, please contact OPRS at (312) 996-1711 or me at (312) 996-9299. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.

Sincerely,

Anna Bernadska, M.A.
IRB Coordinator, IRB # 2
Office for the Protection of Research Subjects

Enclosures:

1. **Informed Consent Documents:**
   a) Problem Solving and Memory; Version 6, 01/24/2014
   b) Debriefing Form (no version number, no date)

2. **Recruiting Materials:**
   a) Print Ad; Version 4; 11/14/2012
   b) Pre-Screening Form; Version 3; 11/14/2012
   c) Internet Ad; Version 4; 11/14/2012
   d) Flyer; Version 4; 11/14/2012
   e) Memory Study Print Ad Version 1, 01/24/2014
   f) Memory Study Internet Ad Version 1, 01/24/2014
   g) Memory Expert Flyer Version 1, 01/24/2014
   h) Expert Internet Ad Version 1, 01/24/2014
   i) Memory Study Flyer Version 1, 01/24/2014
   j) Expert Pre-Screening Form Version 1, 01/24/2014
   k) Expert Print Ad Version 1, 01/24/2014

cc: Michael E. Ragozzino, Psychology, M/C 285
    Jennifer Wiley, Faculty Sponsor, Psychology, M/C 285
VITA

Rebecca H. Koppel, Ph.D.
University of Illinois at Chicago
Department of Psychology (M/C 285)
1007 W. Harrison St.
Phone: (703)220-5117
rkoppe2@uic.edu

EDUCATION

Ph.D. 2015
University of Illinois at Chicago
Major: Cognitive Psychology
Minor: Statistics, Methods, and Measurement
Advisor: Jennifer Wiley, Ph.D.
Advisor: Benjamin C. Storm, Ph.D.

M.A. 2011
University of Illinois at Chicago
Major: Cognitive Psychology

B.A. 2009
College of William and Mary, Williamsburg, VA
Major: Psychology
Major: French
Summa Cum Laude, High Honors

AWARDS AND HONORS

UIC Undergraduate Mentoring Award for Graduate Students Honorable Mention (Spring 2013)
UIC Liberal Arts and Sciences PhD Travel Award (Fall 2014, Fall 2013, Fall 2012, Fall 2011)
UIC Psychology Department Travel Award (Fall 2014, Fall 2013, Spring 2012, Fall 2010, Fall 2009)
UIC Graduate Student Council Travel Award (Fall 2013, Fall 2011, Fall 2010, Fall 2009)
Phi Beta Kappa Membership (Spring 2009)
Psi Chi (Inducted Fall 2007)
Dean’s List, College of William and Mary (Fall 2005-Spring 2009)
Robert C. Byrd Honors Scholarship, State of Virginia (Fall 2005-Spring 2009)
French House Resident, College of William and Mary (Fall 2006-Spring 2007)

PUBLICATIONS


**CONFERENCE PRESENTATIONS**


RESEARCH EXPERIENCE

Dissertation: Understanding different kinds of mental fixation through executive functioning (Spring 2014-Spring 2015)
Committee: Jennifer Wiley, Ph.D. (Chair), Benjamin C. Storm, Ph.D., Steve M. Smith, Ph.D., James W. Pellegrino, Ph.D., Eric D. Leshikar, Ph.D.
Mental fixation can be induced by domain knowledge, or recently-primed information. This study explores whether the fixation experienced in both of these cases is qualitatively different by exploring the kinds of inhibitory functioning that may be needed to overcome each kind of fixation.

Assessing executive functions in bilingual populations (Fall 2014-Spring 2015)
Collaborators: Marta Mielicki & Jennifer Wiley, Ph.D., University of Illinois at Chicago, Chicago, IL
Supervised an honors capstone project by Gabriela Valencia exploring the effects of oral and visual presentation of the Letter Number Sequencing Task on working memory scores for monolingual and bilingual individuals.

Wait, wait, don’t tell me!: Tip-of-the-tongue and retrieval-induced forgetting (Spring 2012-Fall 2013)
Advisors: Jennifer Wiley, Ph.D., University of Illinois at Chicago, Chicago, IL, & Benjamin C. Storm, Ph.D., University of California, Santa Cruz, Santa Cruz, CA
Tip-of-the-tongue (TOT) states are retrieval failures accompanied by feelings of imminent recall. The inability to access correct answers is thought to be due to competition between relevant and irrelevant information during the retrieval attempt (Smith, 1994). Across two experiments, we investigated whether retrieval-induced forgetting (RIF), a phenomenon believed to reflect the ability to inhibit competing memory traces, predicted a person’s propensity to experience TOTs. Participants first rated TOTs for general knowledge questions and then took a recognition test to verify that they indeed knew the answers. When an incorrect answer (blocker) was provided before each trivia question, a negative linear relationship was observed such that participants who exhibited less RIF experienced more false TOTs than did participants who exhibited more RIF. In the absence of blockers, however, this relationship between RIF and false TOTs disappeared. These results suggest that the memory processes underlying RIF may play an important role in determining whether, and when, someone experiences TOTs.

**Toy Design Novelty and Inhibitory Functioning (Summer 2013)**
Advisors: Jennifer Wiley, Ph.D., University of Illinois at Chicago, Chicago, IL, & Benjamin C. Storm, Ph.D., University of California, Santa Cruz, Santa Cruz, CA

Two previous experiments examined the relationship between toy generation, stop-signal performance, and conformity effects under baseline conditions and fixated conditions (instructed participants to diverge from previously-seen toy examples). This project explored the relationship between creativity as measured by the uncommonness, remoteness, and cleverness of toy designs and individual differences in stop-signal performance.

**Consequences of contextual change on mental fixation (Spring 2012-Spring 2013)**
Advisors: Jennifer Wiley, Ph.D., University of Illinois at Chicago, Chicago, IL, & Benjamin C. Storm, Ph.D., University of California, Santa Cruz, Santa Cruz, CA

Old and inappropriate information can impair problem solving by causing mental fixation (Smith & Blankenship, 1991). In the present study, we examined whether this type of mental fixation can be reduced by simply changing the context prior to problem solving. Moreover, how does this affect problem solving success and problem-solving-induced forgetting (Storm, Angello, & Bjork, 2012)?

**Retrieval-induced forgetting and remembering stereotypical information (Spring 2012)**
Advisor: Benjamin C. Storm, Ph.D., University of Illinois at Chicago, Chicago, IL, & Mary C. Murphy, Ph.D., Indiana University

Individuals who demonstrate better inhibitory functioning, as measured by retrieval-induced forgetting (RIF), are more successful at updating irrelevant information in memory. One way to quickly and efficiently update memory is to rely on heuristics; stereotypes are one kind of heuristic that we employ to remember more information. This experiment examines whether individuals who exhibit more retrieval-induced forgetting are actually more susceptible to remembering stereotypical information.

**Master’s Thesis Research: Incubation moderates the relationship between retrieval-induced forgetting and overcoming fixation (Fall 2010-Fall 2011)**
Advisor: Benjamin C. Storm, Ph.D., University of Illinois at Chicago, Chicago, IL

Storm and Angello (2010) demonstrated that individuals with better inhibitory functioning, as measured by retrieval-induced forgetting, had superior performance on the Remote Associates Task under fixated conditions (RAT; Mednick, 1962). We examined whether an incubation period moderates the effects of retrieval-induced forgetting on RAT performance under fixated conditions.

**Examining the validity of selective directed forgetting (Fall 2010-Fall 2011)**
Advisor: Benjamin C. Storm, Ph.D., University of Illinois at Chicago, Chicago, IL
Across three experiments, we failed to find any evidence that participants can selectively forget a subset of to-be-learned information via directed forgetting. This finding has important implications for theoretical accounts of directed forgetting and contradicts recent work which has suggested that selective directed forgetting is possible.

**Does a dual task exacerbate fixation in problem solving? (Fall 2010-Spring 2011)**
Advisor: Benjamin C. Storm, Ph.D., University of Illinois at Chicago, Chicago, IL
Many problems are difficult to solve because old and inappropriate ideas cause fixation, thus interfering with our ability to generate new and appropriate ideas. Using the Remote Associates Task, we examined whether engaging in a concurrent task makes problem solvers more susceptible to this form of fixation.

**Research Apprenticeship: The blocking and unblocking of memory (Fall 2009-Spring 2010)**
Advisor: Benjamin C. Storm, Ph.D., University of Illinois at Chicago, Chicago, IL
The memory blocking effect (Smith & Tindell, 1997) is the result of implicit memory and, subsequently, very difficult to eliminate. We examined whether the inhibition of negative primes via retrieval-induced forgetting or directed forgetting can reduce, or even eliminate, the memory blocking effect. These experiments provide important implications for theoretical accounts of retrieval-induced forgetting, directed forgetting and the memory blocking effect.

**Senior Honors Thesis: Rapid eye movement effects on traumatic memories: A test of the working memory hypothesis (Fall 2008-Spring 2009)**
Advisor: Christopher T. Ball, Ph.D., College of William and Mary, Williamsburg, VA
Examined two working memory hypotheses proposed to explain how rapid eye movements affect the vividness, emotionality and completeness of traumatic memories. Researched procedures, created six working memory tasks and EMDR procedures on SuperLab, compiled and analyzed data.

**Research Assistant: The cognitive advantage of percussive auditory information (Spring 2009)**
Advisor: Jeanine K. Stefanucci, Ph.D., College of William and Mary, Williamsburg, VA
Processed participants and administered trials for various experiments examining episodic memory encoding and retrieval, and the link between emotion and perception.

Supervisor: Brigitte Schay, Ph.D., Assessment Services Branch (ASB), Washington, D.C.
Applied I/O psychology in the Human Resources Products and Services Division. Revised proposals and evaluations, proofed data reports, created crosswalks, and cleaned and analyzed comments. Researched the ROI of change initiatives, concentrating on the five high-impact dimensions, specifically targeting fairness and treatment of others. Organized raw data, and generated and analyzed corresponding statistics for a Government-wide pre-pilot program. Helped plan a strategic training retreat and constructed group activities for ASB, comprised of 15+ Personnel Research Psychologists.

**Research Assistant, Human Cognition Lab (Spring 2007-Fall 2007)**
Advisor: Christopher T. Ball, Ph.D., College of William and Mary, Williamsburg, VA
Studied the relationship between working memory and schizophrenic tendencies. Processed participants and administered trials for automatic n-back tasks (short term memory assessments). Orally administered scripted recall testing and collected questionnaire data. Organized and analyzed information for entry into the SPSS statistical data analysis program.
SUMMARY OF TEACHING EXPERIENCE

**PSCH 343 Statistics in Behavioral Science**
Instructor (Summer 2015, Summer 2014, Spring 2014)
Teaching Assistant (Spring 2015, Fall 2013, Summer 2013, Fall 2012)

**PSCH 242 Research Methods in Behavioral Science**
Teaching Assistant (Spring 2013)

**PSCH 321 Lab in Developmental Psychology**
Teaching Assistant (Fall 2014)

**PSCH 352 Cognition and Memory**
Teaching Assistant (Spring 2013, Fall 2012, Spring 2012, Summer 2011, Spring 2011, Fall 2010, Summer 2010, Spring 2010)

**PSCH 353 Lab in Cognition and Memory**
Teaching Assistant (Fall 2014, Fall 2011, Fall 2010)

**Fairfax County Public Schools**
Substitute Teacher (Spring 2007–Fall 2008)
Responsible for instruction according to teacher plans and maintaining a safe and orderly environment.
Accountable for knowing where students were and what they were engaged in at all times.

MENTORING EXPERIENCE

**Awards:**
Allison Heise (Fall 2012): Awarded Honors College Undergraduate Research Grant ($700)
MPA Research Presenter Award

Sabrina Spikes (Spring 2013): Awarded Chancellor's Undergraduate Research Award ($3000)

Aimee Fizor (Fall 2013): Awarded Honors College Undergraduate Research Grant ($1000)
Awarded Hirschberg Memorial Grant for Undergraduate Research ($130)
MPA Research Presenter Award, Honors Council Award

Gabriela Valencia (Fall 2014): Awarded Chancellor's Undergraduate Research Award ($3000)
Awarded Hirschberg Memorial Grant for Undergraduate Research ($150)
Awarded Chancellor’s Student Service and Leadership Award
MPA Research Presenter Award, Honors Council Award ($405)
Awarded Hirschberg Memorial Grant Best Paper Award

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<td>Esther Grimaldo</td>
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<td>Bradley Bassen</td>
<td>Spring 2015</td>
<td>Domain Knowledge and Fixation</td>
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**PROFESSIONAL SERVICES & AFFILIATIONS**

Ad Hoc Reviewer
- Creative Problem Solving
- Memory
- Quarterly Journal of Experimental Psychology
- Psychological Research
- The Journal of Problem Solving

Professional Memberships (alphabetical order)
- Association for Psychological Science Student Affiliation
- Midwestern Psychological Association Graduate Student Member
Phi Eta Sigma Academic Honor Society
Psi Chi Psychology Honor Society
The Psychonomic Society Member

UIC Cognitive Psychology, Division Assistant (Spring 2013, organized visiting day)

ADDITIONAL SKILLS & EXPERIENCE

SPSS Data Analysis, SAS, R, Mplus, STATA, E-Prime 2.0, Super Lab 4.0, MS Suite
Moderate Risk Government Security Clearance, Certified June 2008

Language Skills: Fluent in French
Study Abroad: Université Paul-Valéry Montpellier III, Montpellier, France (Spring 2008)