THE FORGETTING FIXATION ACCOUNT OF CREATIVE INCUBATION

A Dissertation

by

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Submitted to the Graduate and Professional School of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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December 2021

Major Subject: Psychology

ABSTRACT

8 experiments were conducted to examine forgetting fixation in creative incubation. First, the strength and nature of fixation was studied. Experiments 1 and 2 found that both repetition and context reinstatement of the encoding context for misleading red herrings affect creative problem solving negatively, more repetition and the reinstatement of the study context for the misleading solutions made it more difficult to solve Remote Associates Test problems. Exposure to multiple different red herrings also impaired problem solving. In Experiments 3 and 4, the number of red herrings was manipulated in a Word Fragment Completion task. The more similar, but incorrect, answers participants were exposed to, the less they were likely to solve subsequent word fragment problems. In the second set of experiments, factors that might eliminate fixation during an incubation period were studied. Experiments 5 and 6 showed that both additional incubation time and the change of the fixating context might assist in alleviating fixation in a creative problem solving task. The last two experiments looked at adaptive forgetting processes in eliminating fixation. Experiment 7 established a new method to study problem solving induced forgetting using the *guess* method and Experiment 8 showed that neural correlates for problem solving induced forgetting are similar to those indicated in the memory process called retrieval induced forgetting. The results inform us about ways to eliminate fixation in order to assist creative problem solving, and provide additional support for the ties between cognitive processes of memory and creativity.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Professor Smith, and my committee members, Dr. Anderson, Dr. Orr, and Prof. Tassinary, for their guidance and support throughout the course of this research.

Thanks also go to my friends and colleagues and the department faculty and staff for all their help at Texas A&M University.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a dissertation committee consisting of Professors Steven M Smith, Brian Anderson, and Joseph Orr of the Department of Psychological and Brain Sciences and Professor Louis Tassinary of the Department of Visualization

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Beda, Z., & Smith, S. M. (2018). Chasing red herrings: Memory of distractors causes fixation in creative problem solving. *Memory & Cognition*, *46*(5), 671–684. https://doi.org/10.3758/s13421-018-0799-3

Contributions to this work include experimental design, build, running, scoring, analysis, interpretation and the writing of the paper in co-operation with the second author.

Smith, S. M., & Beda, Z. (2020). Old problems in new contexts: The context-dependent fixation hypothesis. *Journal of Experimental Psychology: General*, *149*(1), 192–197. https://doi.org/10.1037/xge0000615

Contributions to this work include design, build, running, scoring, analysis, interpretation and the writing of the Method and Results sections of the paper.

Smith, S. M., Beda, Z., & Hernandez, A. (2020). Entrenchment: effects of multiple red herrings on memory blocks in word fragment completion. *Memory, 28*(6), 830–836. https://doi.org/10.1080/09658211.2020.1769137

Contributions to this work include concept, design, build, analysis and interpretation of both experiments, and the running, scoring, and writing of the Method and Results sections of Experiment 3 (Group Study).

All other work conducted for the thesis (or) dissertation was completed by the student independently.

Funding Sources

Experiment 8 was supported by a T3 grant from Texas A&M University under Grant number 247082 and Grant Title: *Neural mechanisms underlying detecting and resolving memory blocks in creative cognition*.

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INTRODUCTION

Preface

Human creativity is an elusive and fairly vague concept. It has no clear definitions, and can be approached from multiple angles. The diversity of creativity among various individuals, cultures, domains, and historic eras would make creativity a daunting subject of scientific inquiry, provided there were some clearly defined boundaries to adhere to. Using the creative cognition approach (Finke et al., 1992) research can focus on experimental studies of cognitive processes that are important components of creative thinking. These component processes are the same as those used in other mental activities, such as memory and problem solving. In the present dissertation effects of *mental fixation* and how to alleviate fixation using an *incubation period* will be examined.

Fixation and Incubation

When a thinker gets stuck, or *fixated*, during a creative endeavor a period of *incubation*, a time when the problem is put aside and no conscious thinking is performed to solve it, has been shown to help speed up the thinking process (Sio & Ormerod, 2009). Cognitive mechanisms suggested to be in play during incubation include *unconscious thinking* (Dijksterhuis & Meurs, 2006; Dijksterhuis & Nordgren, 2006; Gilhooly, 2016), *mind wandering* (Mooneyham & Schooler, 2013; Smallwood & Schooler, 2006), and *opportunistic assimilation* (Seifert et al., 1995; Seifert & Patalano, 2001). These mechanisms all have one thing in common, they all assume that some kind of additional cognitive work is performed during incubation.

Additional Work in the Incubation Period: Unconscious Thinking

Theories that suggest active thinking processes behind incubation periods state that during incubation, covert thinking operates and continues to go on while people are occupied with something else. Once this hidden thinking is completed, the result becomes known as an insight (Dijksterhuis & Meurs, 2006; Dijksterhuis & Nordgren, 2006; Gilhooly, 2016). This is a very appealing explanation that is difficult to disprove, however, because findings attributed to unconscious thought can be also explained with theories that do not involve any additional special processes. The main evidence that characterizes theories of unconscious thinking is that, for an incubation period to be effective, there is no need for an initial attempt for solution before the incubation period. Proponents of the unconscious thinking hypothesis provide participants an incubation period directly following the introduction to the problem, without asking for a solution attempt beforehand. According to the unconscious thinking hypothesis, covert thinking on the problem operates regardless of whether an attempt was made to solve a problem before incubation or not. Theories of unconscious thinking, however, disregard the existence of quick automatic answers that would come as soon as participants receive the problem. Ironically, some of the evidence of quick automatic solutions comes from one of the proponents of the unconscious thinking explanation (Gilhooly et al., 2007). In their think-aloud paradigm for the Alternative Uses Task (AUT), Gilhoolly et al. performed a verbal protocol analysis. One of their findings was that during the AUT one of the strategies participants used was to retrieve memories based on their past experience. As they wrote in their general discussion: "This type of retrieval appears to be relatively automatic, rapid and not heavily loaded of executive capacity. (Gilhooly et al., 2007 pg. 623)" Not asking someone to give a solution does not necessarily mean that there is not one already in mind, as initial solutions do tend to come quickly and automatically.

Additional Work in the Incubation Period: Mind Wandering

Another suggested cognitive process is that of *mind wandering* (Mooneyham & Schooler, 2013; Smallwood & Schooler, 2006). When discussing mind wandering and its opposing construct *mindfulness* (Mrazek et al., 2012) as facilitators in the creative thinking process, it is important to mention the two distinct approaches to solving a creative problem. When a problem is approached in an *analytical* manner, the thinking process is carried out step-by-step gradually approaching the solution. On the contrary, when the *insightful* approach is chosen, people usually just ‘stare at nothing’ and wait for a sudden awareness of the solution, an insight to arrive. These two approaches also involve different cognitive processes as evidenced by the different neural signatures they entail (e.g., Kounios et al., 2008). In their study, Zedelius and Schooler (2015) examined relations between levels of trait mindfulness and performance of problem solving in Remote Associates Test problems (RAT, Mednick, 1962). Problems in RAT are unique from this perspective, as they can be solved both in an analytical (trial and error) and insightful manner. Zedelius and Schooler found that trait high mindfulness facilitated analytical problem solving, but hindered solutions that came in an insightful manner. The study suggests that when insightful solutions are needed mindfulness presents an obstacle, and mind wandering might be beneficial during the thinking process.

Mind wandering is a mental state in which attentional processes decouple from the external environment and turn inward (Schooler et al., 2011). Mind wandering might assist human creativity by heightening accessibility of goal-relevant stimuli (Klinger, 1999), or by conceptual manipulation of relevant information (Binder et al., 1999). Incubation periods with tasks that have low processing demands might encourage mind wandering and assist in the solution of unsolved problems.

Additional Work in the Incubation Period: Reactivation of Failed Solution Attempt

Theories that explain effects of incubation with the reactivation of the failed attempt to solve a problem propose that an incubation period does nothing with being fixated, but instead provides thinkers with a hint towards the solution. The theory implies that the incubation period, or rather the activity done during the incubation period, might provide some kind of a hint that will take the thinkers immediately to the solution. This process would require remembering the problem when coming across this accidental hint and also connecting these two together. The idea of *opportunistic assimilation* (Seifert et al., 1995; Seifert & Patalano, 2001) is a direct descendent of the intention-superiority effect from prospective memory studies (e.g., Goschke & Kuhl, 1993; Mäntyla, 1993), and has been around since computational theories (Hayes-Roth & Hayes-Roth, 1979). An important element of the theory is the *predictive encoding model* of goal representation. The predictive encoding model says that when people fail to solve a certain problem, its main characteristics become sensitized, or flagged in their memories. Once solutions are accidentally encountered these sensitized characteristics activate the problem and the solution becomes apparent (Seifert et al., 1995). Another important detail in the theory is that solution plans should be considered at the beginning of the thinking process to be able to recognize opportunities that might come along subsequently. Patalano and Seifert (1997) gave goals to achieve to their participants. In the planning phase participants received a list of goals they had to reach along with some plans to achieve them (e.g., the goal was to obtain an elastic band from the top shelf and the plan was to somehow find a chair to stand on to be able to get the elastic band). In the second phase of the experiment, the reminding phase, a set of objects were given to the participants some of which were helpful to achieve their goals and some were neutral. Finally, at the recall phase everyone had to recall as many goals from the original list as possible. Manipulated variables were the existence of a plan to achieve the goals and whether this plan was presented to participants or generated. The study found that participants were reminded to their goals by the appearing clues if they prepared themselves for those clues by planning ahead. This finding is not surprising in the light of the generation effect (Slamecka & Graf, 1978), that says participants will remember stimuli better if they generate them themselves compared to when they just have to read them. Another finding of Patalano and Seifert (1997) was that reminders had to be very specific and that semantically related clues would not work well with opportunistic assimilation (for example, if at the original goal plan *Vaseline* was mentioned as a potential lubricant, a bar of *soap* did not work well as a reminder of the goal). This latter finding is also unsurprising, considering the relatively short effect of semantic priming (Meyer & Schvaneveldt, 1971) and the principle of encoding specificity (Tulving & Thomson, 1973). Opportunistic assimilation can certainly complement to incubation effects, however there are situations in which it would not be able to explain the findings (see Experiments 3 and 4 in Chapter 2).

Another explanation for incubation effects is the *forgetting fixation* account. For the remainder of the dissertation, the forgetting fixation theory and its suggested mechanisms will be discussed in detail. The forgetting fixation theory mainly revolve around the reason for why the thinking process gets stuck and ways of eliminating the block that caused the stoppage. In the following pages mental fixation and potential reasons for mental fixation will be considered.

CHAPTER 2

MENTAL FIXATION

Mental fixation was described by Woodworth and Schlosberg (1954) as a “groove” resulting from a false start in the thinking process from which it is difficult to escape (p.841). A great deal of literature exists on mental fixation. One type of mental fixation is *functional fixedness*, in which people get stuck on the original function of an object and fail to realize other ways it could be used (Duncker, 1945; Maier, 1931). In Duncker’s classic experiment participants received a candle, a book of matches, and a box of thumbtacks. The task was to fix the candle on the wall, and light it so it would not drip on the table below, using only the objects received. The crucial move in the solution was to use the box the tacks arrived in as a holder for the candle, and attach the box to the wall. The difficulty in finding the solution is that people tend to be functionally fixated, and regard the box in its original function as a holder for the tacks, and not as a candle stand. If the set of thumbtacks is presented to the participants separately, outside of their box, the problem is solved relatively quickly (Duncker, 1945).

Similar to functional fixedness is *mental set*, or Einstellung, in which people, after continuous exposure, get stuck on a method or heuristic for solving a problem and fail to realize that there is a simpler and more obvious solution to the same problem. In another classic experiment, Luchins and Luchins (1959) presented a problem to their participants in which the contents of three imaginary water jars of different sizes had to be combined to reach a target amount. This target amount had to be obtained by a linear combination of the three jars. In the first five problems the solution formula was always the same (B-A-2C). In the sixth and seventh problems the original formula still worked, however, a simpler solution also existed (A-C). In the eighth and final problem only the simple solution (A-C) led to the correct target amount. Luchins and Luchins found that most participants could not find the simpler solution after having trained to use the longer and more complicated formula. Even more surprising was that several of those participants who continued to use the well-learned heuristic or mental set thought the final problem was unsolvable. Fixation can be persistent and difficult to escape (Wegner, 1994).

Fixation and Impasse

Getting stuck during a memory search might eventually be the cause to give up the search process completely, an *impasse*, or to keep returning to the same item over and over again (cf. with earworms from Beaman & Williams, 2010; and the theory of ironic mental control from Wegner, 1994). The recall process was characterized by Rundus (1973) as memory sampling with replacement in which previously retrieved items may be re-retrieved. With each retrieval the retrieval probability of the retrieved items is increased, and if retrieval is competition dependent already retrieved items will prevent new items from being retrieved after a while. When the number of consecutive failed retrievals reaches a criterion, set by the individual, the sampling process stops. This stopping criterion represents the point of time when the participant decides that the search is not productive anymore because no new items can be retrieved. The process, when already retrieved items block participants from retrieving new ones is called *output interference*. As output interference builds up over time at the recall process, reaching the end of the finite capacity results in an impasse, which Raaijmakers and Shiffrin refer to as a *biased retrieval set* (1981).

One explanation of fixation is the possibility that new information is processed in a biased way, due to prior experience. Data that are in some way relevant to a belief seem not to be processed in an impartial manner. During a memory search in problem solving, prior knowledge about a topic might cause biased assimilation of new information, putting more weight on the evidence that confirms previous belief and thus potentially derailing the thinking process (Lord et al., 1979). The *attentional bias explanation* of the Einstellung effect states that intake of perceptual cues might be biased by previous, familiar knowledge and hijack attentional resources towards objects or notions that are related to memories activated during the thinking process (Bilalić et al., 2008a, 2008b). Bilalic et al. installed eye-tracking devices to participants when they had to solve various chess problems. One of the problems they gave to their expert participants had two possible solutions: a familiar sequence that is taught to all young chess players (smothered mate) solving the problem in five moves, and a less familiar one that could deliver a checkmate in three moves. Eye movement analysis of the players showed that even though after finding the longer solution players said they were looking for a shorter possibility (that most of them could not find), their eye gazes on the chess board were mostly directed to the squares that are important to the longer, sub-optimal solution. This finding illustrates one way mental fixation might work by focusing attentional resources on already discovered but sub-optimal or misleading solutions.

Contextual elements of the thinking process other than those in relation to attention also greatly influence memory and problem solving. One of the basic assumptions of the memory retrieval process is that one or more cues that are already stored in memory are linked to the to-be-retrieved memory trace and retrieval is the progress from these cues to the target items via associative links. Cues might be elements or features of the target memory, concepts associated with them, or even mental states in which the memory was encoded (M. C. Anderson & Neely, 1996). In this respect, environmental elements are all potential retrieval cues that might assist or hinder the retrieval process by biasing it one way or the other.

It seems like prior experience, and automatic retrieval of memories are key in the development of fixation. An important factor in fixation might be the relative strength of the fixation effect itself, that is the memory strength or the number of intruding blockers. In the first set of four experiments, effects of the strength of blocking were examined.

Memory Strength of Intruding Blockers in Fixation[1]

If fixation in creative problem solving can be increased by making intruding blockers (or *red herrings*) more retrievable, then we can think of creative problem solving as a type of indirect memory measure, and retrieval-induced fixation as analogous to other types of negative transfer effects. Our retrieval-induced fixation hypothesis states that factors that make red herrings more retrievable should reduce creative problem solving performance, as measured with Remote Associate Test (RAT) problems.

Several studies have shown that pre-exposure to various types of red herrings can cause subsequent fixation or conformity effects in creative problem solving, creative idea generation and memory retrieval, however none of these studies has provided a test of the retrieval-induced fixation hypothesis, which states that the memory strengths of red herrings determine the magnitude of a fixation effect. Alternatively, strengthening the retrievability of a red herring might *decrease* fixation effects if faster retrieval of red herrings allows them to be rejected more quickly. The faster one can put aside a wrong answer, the more able one will be to devote more mental resources to searching for the correct answer. We conducted the present experiments to test the different possible outcomes of increasing retrievability of red herrings.

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Experiment 1: Fixation Strength with More Practice of Red Herrings

In the present experiments a fixation effect was elicited using previously studied red herrings, to make it difficult for participants to solve Remote Associate Test (RAT) problems (Mednick, 1962). In the RAT, often used as a measure of creative ability (e.g., Benedek & Neubauer, 2013), there are three test words in each problem (e.g., COTTAGE - SWISS - CAKE.) The task is to find a single word that can be used to make a compound word or a two word phrase with each of the three test words. The solution for this particular test item is CHEESE (COTTAGE CHEESE, SWISS CHEESE, CHEESECAKE.) To elicit a fixation effect, paired associates were assigned to each of the three test words. These paired associates were conceptually related to the test words, but were not related to the solution. For example, for the RAT problem COTTAGE - SWISS - CAKE the red herring associates made the pairs COTTAGE - hut, SWISS - chocolate, CAKE - icing. We predicted that when the red herrings are made easier to recall, the observed fixation effect would be greater.

Numerous factors can affect the accessibility of events, including encoding and test manipulations. In the present study, we tested our retrieval-induced fixation hypothesis by manipulating an encoding variable: number of practice trials, and a test variable: context reinstatement. If the red herrings are repeated and practiced more, then more of them should be retrieved when a triad of RAT words are presented. Repetition improves both recollection and automatic retrieval of items in memory (e.g., Jacoby & Dallas, 1981). Therefore, lower solution rates were expected when there were more repetitions and practice trials of red herring words, as compared with less practice. Similarly, the context manipulation was predicted to affect retrieval of red herrings on RAT trials: when the initial encoding context was reinstated, more red herrings were expected to be retrieved (e.g., Smith, 1979; Smith et al., 2014; Smith & Manzano, 2010; Smith & Vela, 2001), causing solution rates to suffer for those RAT problems. Several studies have reported context reinstatement effects with indirect memory measures (e.g., Parker et al., 1999; Smith et al., 1990), but whether such effects are caused by automatic retrieval or conscious recollection may still be in question (see Mulligan, 2011; Smith et al., 2018). We expect to find context dependent fixation regardless of whether our manipulations of context affect conscious recollection, automatic retrieval, or both types of retrieval processes.

The method in the present experiments used a particularly robust paradigm for context-dependent memory effects, including the use of perceptually rich contexts (photo backgrounds of various environments), small context-to-item fans (only three words per context), and intentional encoding of items (red herrings, in our case) with their associated contexts (see Smith, 2013). Thus, we expected context reinstatement of red herrings, relative to non-reinstatement, to cause poorer performance on associated RAT problems, and we expected that more practice with red herrings, relative to less practice, would cause poorer RAT solution rates.

Participants in Experiment 1 were given four tasks that were aimed at making sure that the photo contexts were well encoded (the context encoding task), that red herrings were associated with RAT test words (the paired associates encoding task), and that test word-red herring associations were strengthened (the retrieval practice task). After the red herrings, contexts, and RAT test words were encoded, the Remote Associates Test was given; each critical RAT triad was tested by being superimposed over a test context, which either reinstated the encoding contexts of red herrings, or presented a different context than the one seen for that triad at encoding. It was predicted that more practice with red herrings, relative to less practice, and context reinstatement at test, relative to non-reinstatement, would both decrease performance on critical RAT problems, because practice and context reinstatement should improve retrieval of red herrings. Our context reinstatement prediction, however, was predicated on the assumption that the three word-word associations created for each RAT triad would not outshine (or overpower) the weaker context-to-word associations (Smith & Vela, 2001).

Method

Participants. Based on an a priori power analysis, our experiment needed approximately 72 participants to detect a medium sized effect (Cohen's d=.5) with $\alpha = .05$ and $1 - \beta = .95$. Participants were undergraduate psychology students volunteering as participants to fulfill a course requirement. They could enroll for the particular time slots via a computerized database. The sessions were conducted with 3-15 participants at a time. Altogether we had 133 participants with 30, 32, 35 and 36 in four counterbalancing groups. The numbers of participants in the counterbalancing groups varied because participants could enroll themselves in any session of the experiment, and experiment sessions were randomly assigned to the counterbalancing conditions.

Design and Materials. A total of 36 RAT problems were used in Experiment 1. A RAT problem consists of three words, and the solution is a single word that is strongly associated with each of the three test words (e.g., COTTAGE - SWISS - CAKE, solution - CHEESE). The problems were selected from the Compound Remote Associate Problem compendium published by Bowden and Jung-Beeman (2003), using problems with high normed levels of solution rates. The RAT problems used can be found in Appendix F. For each triad of RAT words, red herrings were generated, one red herring word for each of the three test words, resulting in three paired associates for each RAT problem (e.g., COTTAGE-hut, SWISS-chocolate, CAKE-icing). Test words, solution words, and red herring words were unique within our set of materials; none were repeated in other problems. All of the RAT test words were presented in capital letters and all of the red herrings in lowercase letters throughout the experiment. RAT problems, their solutions and their associated red herrings are shown in the Appendix. The items were presented as a PowerPoint slideshow shown on a large screen in clear view of the participants.

A total of 72 photo contexts, or photographs of places, were used in Experiment 1. The photos showed familiar types of places, such as an airport or a restaurant, but the specific places were likely not known to our participants. A sample of the background photo contexts used can be found in Appendix G. Each photo context was assigned at random to a RAT problem, except that obvious pre-experimental associations of words and accompanying photos was avoided in each pairing. Stimulus words were shown in a red font and outlined with a yellow border, and they were superimposed over their accompanying photo contexts. On retrieval practice trials, the encoding contexts accompanying paired associates were the same contexts paired with those items at encoding. On the RAT, triads were tested either with the photo context of the red herrings' encoding, or with a new photo, that is, a photo not seen before in the experiment.

A 2 (reinstatement, reinstated or new contexts at the test phase, a within-subjects variable) x 2 (repetition, zero or two retrieval practices, a within-subjects variable) x 4 (counterbalancing, a between-subjects variable) mixed design was used. The 36 RAT triads were randomly divided into four sets of nine triads, sets A, B, C, and D. In the first counterbalancing group (CB-1), items from set A were used for the zero-practice new-context condition, set B was used for the two-practice new-context condition, set C for the zero-practice reinstated-context condition, and set D for the two-practice reinstated-context condition. In CB-2, CB-3, and CB-4, each set of items was assigned to a different condition, so that across the four counterbalancing groups, each item was used in each treatment condition. The proportion of correctly solved RAT problems in the final phase of the experiment served as our dependent measure. Strict scoring was used, that is, no alternative solutions to the RAT problems were accepted. The experimental design for Experiments 1 and 2 can be found in Appendix H.

Procedure. The PowerPoint slideshow had four sections corresponding to the experimental tasks, context encoding, paired associates encoding, paired associates retrieval practice, and finally, the Remote Associates Test. Participants were initially told that they would complete several different tasks during the experiment and that they would receive instructions when it was time for each task. Each task consisted of 36 slides, one for each of the critical items, that were presented in an order randomized in blocks of six.

For the first task, context encoding, participants gave relatedness ratings on a 1-10 scale between each set of three red herring words and their background context. The backgrounds were not conceptually related to the red herrings in any obvious way. Participants had 8-sec to look at the screen, and write down their ratings.

For the next task, paired-associates encoding, participants tried to memorize triads of paired-associates consisting of the three test words each linked with its red herring word. Each triad of paired-associates was superimposed over the same photo context that had been seen with the triad’s red herring words at encoding. Each study trial of the paired-associates encoding task was 5-sec.

Following paired-associates encoding was the paired-associates retrieval practice task. For half of the items, on each trial of the retrieval practice task, participants were shown the three RAT words superimposed over their encoding context (only for items in the two-retrieval practices condition), and they tried to recall and write down the three words that had been the responses (the red herrings.) Participants had 10-sec for each practice trial. After 10-sec, the correct responses were displayed, and participants either circled their response if they got it right, or they wrote down the solutions they could not remember. This self-correction procedure took an additional 10-sec. There were two retrieval practice trials for each item in this condition; the two practice trials were evenly distributed, with at least 8-10 slides between the two trials.

The final task was the Remote Associates Test. For each problem, participants had 15-sec to think of the solution. The word triads were superimposed over either the encoding background for the associated red herrings (reinstated context condition) or a different context that had not been seen previously in the experiment (new context condition.) The order of the three words was never the same on the RAT task as it had been on the encoding or the retrieval practice tasks. No mention was made of the previous tasks in the instructions. The method of Experiment 1 is shown on Figure 1.

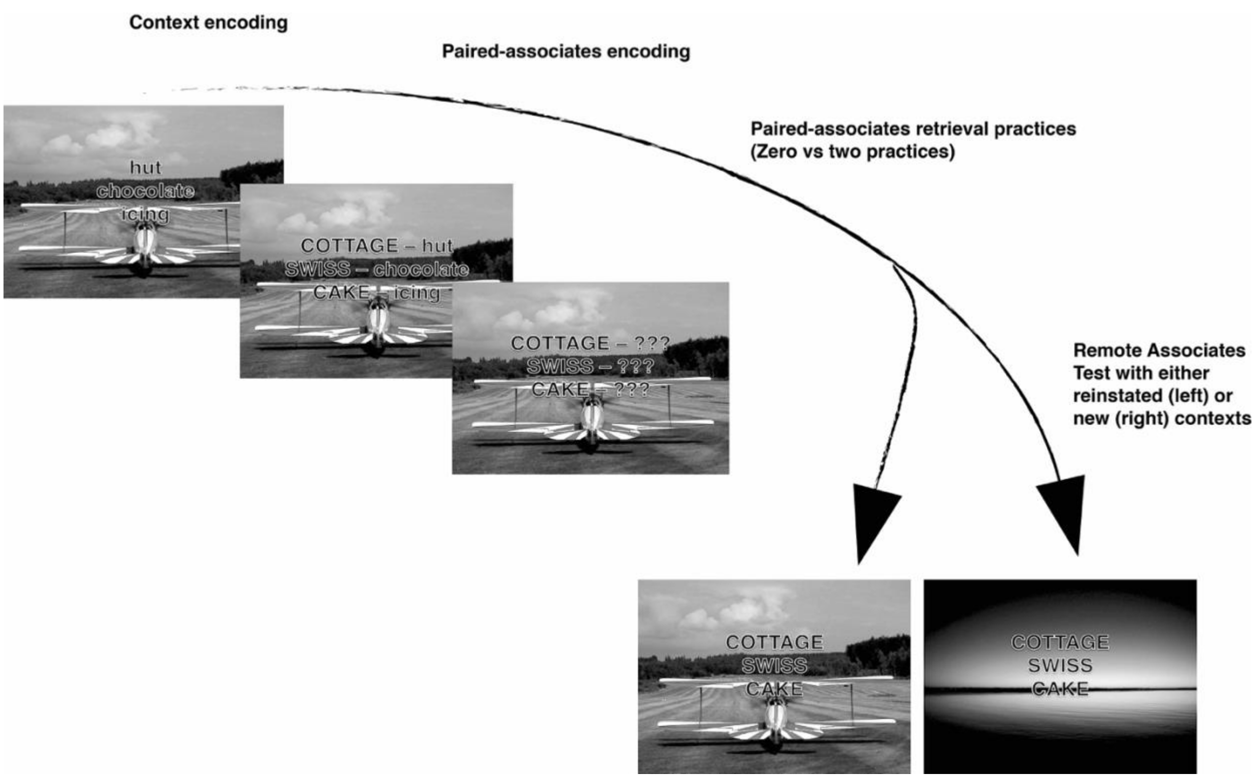

Figure 1 Experiment 1 Method (Reprinted with permission from Memory & Cognition, Lic. No 5119411426401)

Results

A 2 (*context*: reinstated, new context; a within-subjects variable) x 2 (*repetition*: zero, two; a within-subjects variable) analysis of variance (ANOVA) was computed with the proportion of RAT problems solved as the dependent variable[2]. The main effect of repetition was significant [F (1, 132) = 5.167, p = .025, *partial* $\eta 2$ = .038]; items that had two retrieval practices with red herrings, relative to items with no practice trials, had lower solution rates, as predicted by the retrieval-induced fixation hypothesis. The main effect of context was not significant [F (1, 132) < 1, p = .541, *partial* $\eta 2$ = .003]; although, numerically, the reinstated context condition was slightly worse than the new context condition, as predicted, the difference was small. The context X repetition interaction was not significant [F (1, 132) = 3.029, p = .084, *partial* $\eta 2$ = .022]. Figure 2 shows the means for the four conditions. The proportion correctly solved was .44 (*SD* = .19) in the reinstated-zero practice condition, .38 in the reinstated-two repetition condition (*SD* = .2), .42 in the new-zero repetition condition (*SD* = .19), and .41 in the new-two repetition condition (*SD* = .18). Post-hoc paired comparisons of reinstated vs new context conditions were not significant in either the zero [t(132) = .69, p = .49] or two retrieval practice [t(132) = 1.61, p = .11] condition. Mean relatedness rating on a 1-10 scale between the context pictures and the red herrings, in which 1 meant extremely unrelated and 10 meant highly related, was 2.85 (*SD* = 1.6). A paired-samples t-test showed that participants during the second retrieval practice trial (*M* = .78, *SD* = .2) remembered the red herrings significantly better [t(255) = 37.37, p < .001, d =

[2] The inclusion of counterbalancing in a mixed ANOVA as a between-subjects measure showed no differences between the four counterbalancing groups [F(3.129) < 1, p = .547, *partial* $\eta 2$ = .016], therefore the between-subjects factor was removed from the calculation.

2.34] than during the first retrieval practice trial

(*M* = .46, *SD* = .18).

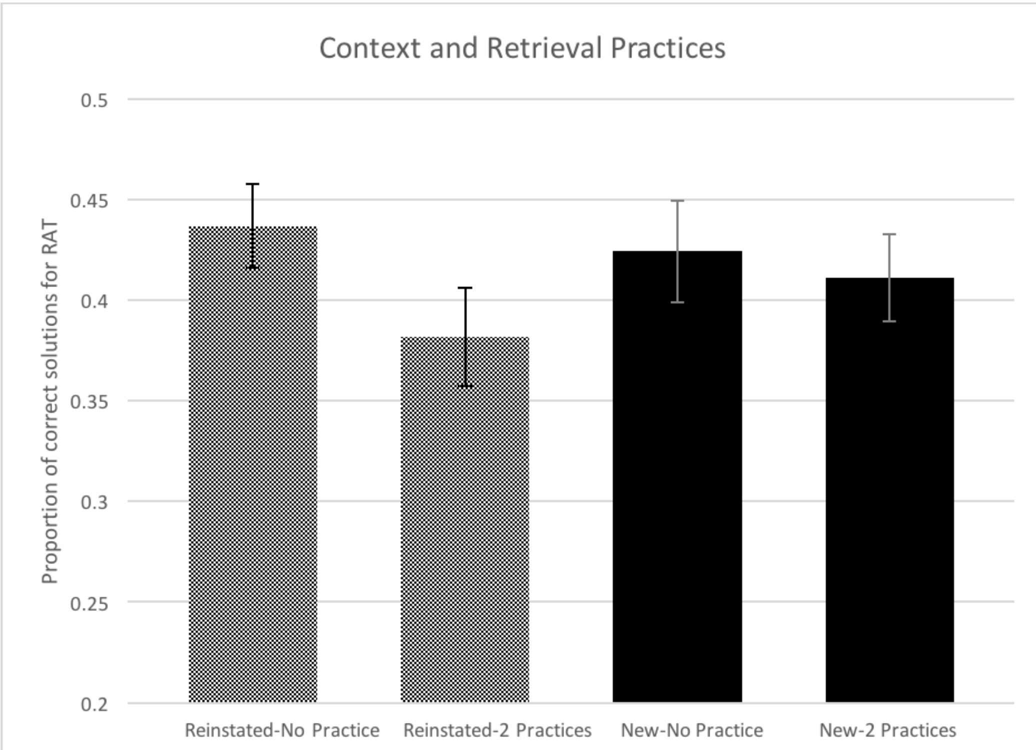

Figure 2 Mean proportion of correct solutions for the RAT as a function of the four conditions in Experiment 1. The error bars represent 95% within-subjects CI. (Reprinted with permission from Memory & Cognition, Lic. No 5119411426401)

Discussion

Experiment 1 tested whether repetition and context reinstatement would modulate the strength of the fixation effect caused by presentation of red herrings. As predicted, with more retrieval practices of the red herrings, solution rates for the RAT items suffered. Two extra retrieval practice trials decreased solution rates by 4%, an effect size of

partial $\eta 2$ = .038. Because Experiment 1 did not include an unprimed baseline condition, it is not clear how this effect compares with the overall fixation effect that may have occurred. Experiment 2 included an unprimed condition.

The main effect of context reinstatement was not significant. The methods that we used to observe context-dependent fixation have been shown to produce robust context-dependent memory effects (e.g., Smith, 2013). The context stimuli that we used were photographs of real places, making them "rich" enough to yield robust effects. There were only three paired-associates per context, a small contextual fan size. Our context encoding task ensured that items and contexts had been directly associated. These methods have yielded robust context-dependent memory effects for tests of free recall (Smith et al., 2014; Smith & Manzano, 2010), recognition (Shahabuddin & Smith, 2016), and paired-associates recall (Smith et al., 2014; Smith & Handy, 2014, 2016). Why, then, was the effect of context reinstatement not significant in Experiment 1?

One possible reason for our failure to detect context reinstatement-enhanced fixation, is, of course, that there may not be an effect of context reinstatement on experimentally-induced fixation effects. Alternatively, context reinstatement may truly influence fixation, but effect size may be much smaller than what we observed in Experiment 1 for the effect of repetition on fixation, and we may have had insufficient power to detect the effect. We suspected a different reason, however, based on the types of associations between contexts and red herrings, and between test words and red herring words. Whereas the associations between contexts and red herrings were purely arbitrary and episodic (e.g., a photo of an airfield and the red herring word *hut*), the associations between test words and red herrings were semantic and meaningful (e.g., COTTAGE-*hut*). The stronger semantic associations, which existed even before participants enrolled in the experiment, were further strengthened in Experiment 1 by the paired-associates encoding task and the retrieval practice task. Thus, when the three test words on a RAT problem appeared, the presence of the strong word-word associates at test obscured the weaker effects of contextual stimuli, a phenomenon known as an *outshining* effect (e.g., McDaniel et al., 1989;

Smith & Vela, 1986, 2001). An alternative to outshining might be that because of the strong association of the paired-associates, the contexts were never even encoded. The strongly associated red herrings *overshadowed* the arbitrary contexts at encoding (Pavlov, 1927 p.141).

Although the main effect of context and the context X repetition interaction were not significant in Experiment 1, the non-significant trend ($p = .084$) suggests that greater effects of context manipulations may occur with more retrieval practice trials in a given context. This possibility is supported by the reasoning that more context-item practice strengthens not only the items themselves, but also the item-context associations, making memory of items more dependent upon the context. Therefore, in addition to mitigating potential outshining effects in Experiment 2, we also tried to maximize the likelihood of finding context-dependent fixation effects by using two context-item retrieval practice trials for all items.

Experiment 2: Fixation Strength with Reinstatement of Encoding Context

In Experiment 1, triads of paired-associates, made from each RAT test word paired with its red herring (e.g., COTTAGE-hut, SWISS-chocolate, CAKE-icing), had been studied in association with photo contexts (e.g., a photo of an airfield). In Experiment 2, to avoid an outshining effect from powerful word cues, we instead paired the three red herrings for a subsequent problem (e.g., hut, chocolate, icing) with a photo context (e.g., an airfield). Participants were told that for each trial of a subsequent memory test, they would see a photograph, and they were to recall the three words that had been paired with the photo. Following two practice trials in which participants tried to recall the three words for each photo context (with post-trial corrective feedback), participants were given a test of RAT problems. A third of the RAT problems were displayed on the photo context that was paired with red herring words at encoding (primed-reinstated context), a third were shown superimposed over a new context (primed- new context), and a third did not correspond to any red herrings shown in the experiment (unprimed items). The red herring retrieval hypothesis predicted that the unprimed RAT problems would have the highest solution rate, the primed-new context problems would have the next highest solution rate, and RAT problems in the primed-reinstated context condition would have the lowest solution rate.

Furthermore, following an analysis of solution rates of RAT problems from Experiment 1, 12 of the original set of 36 RAT items were excluded from Experiment 2 because their solution rates were too low to show significantly decreased performance in the fixation conditions. For Experiment 1, we selected items with high solution rates from the Bowden and Jung-Beeman (2003) norms (above 33% in the 15 seconds per problem condition), because we expected our fixation manipulations to decrease solution rates. In Experiment 1, twelve of the RAT items had mean solution rates below 10%, a base rate too low to observe effects of fixation. Therefore we eliminated those 12 items from the stimulus materials used in Experiment 2. The remaining items in the Bowden and Jung-Beeman (2003) norm had baseline solution rates that were too low to observe fixation effects, therefore we used the reduced set of 24 items with high solution rates in Experiment 2.

Method

Participants. An a priori power analysis indicated a desired total sample size of 84 to detect a medium-sized (Cohen's d = .5) effect with an alpha level of .25 and power of .95. Participants were undergraduate psychology students volunteering as participants to fulfill part of a course requirement. They could enroll for time slots via a computerized database. The sessions were conducted with 3–15 participants at a time. There was a total of 89 participants in Experiment 2: 30 in CB-1, 31 in CB-2 and 28 in CB-3.

Design and Materials. Test condition (primed-reinstated context, primed-new context and unprimed) was a within-subjects measure, and counterbalancing (CB-1, CB-2 and CB-3) was a between- subjects measure. There were 24 items distributed in each test condition. In Experiment 2, the set of items (i.e., 8 RAT problems with their accompanying red herrings) in the primed-reinstated context condition in CB-1 were in the primed-new context condition in CB-2, and the unprimed (baseline) condition in CB-3. The other two sets of 8 items were similarly counterbalanced among the three counterbalancing groups. The proportion of RAT problems solved was the dependent measure.

Procedure. The procedure used in Experiment 2 was the same as described for Experiment 1, with the following exceptions. On the context encoding task in Experiment 2, participants were instructed to memorize each set of 3 words appearing together on the screen (i.e., the 3 red herrings for a RAT problem) in association with the context photos.

For each trial of the retrieval practice task in Experiment 2, participants were shown one of the encoded photo contexts as a cue, and they tried to recall the three words that they had encoded on the previous task. Participants wrote these responses on paper, with 10-sec per retrieval practice trial. After 10-sec, the correct responses were shown on the screen, participants either circled the responses that they got correct on that trial, or they wrote down the responses they could not remember. This self-correction procedure took another 10-sec per trial. All 16 of the encoded items were tested in this way twice. The method of Experiment 2 is shown on Fig. 3.

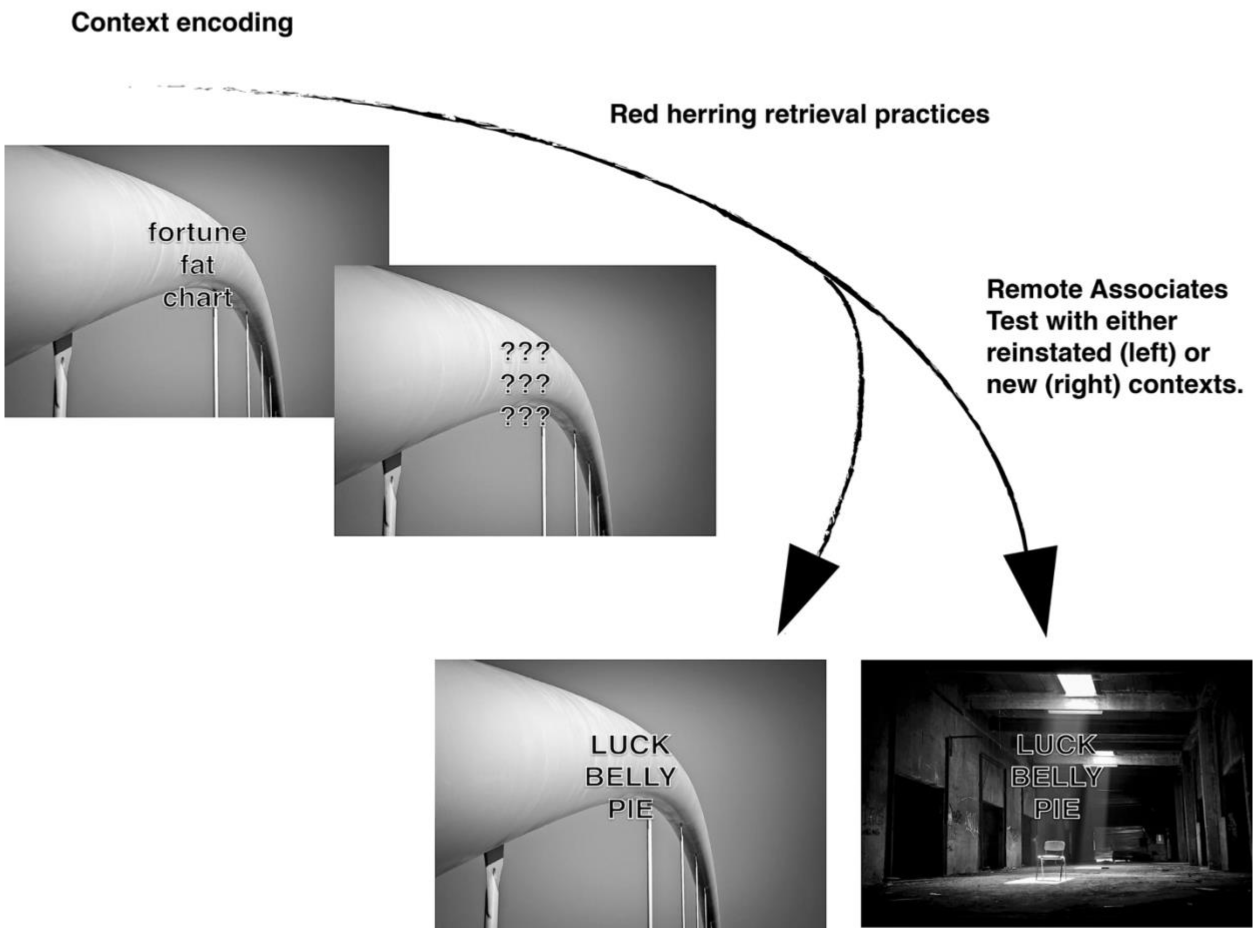

Figure 3 Experiment 2 Method (Reprinted with permission from Memory & Cognition, Lic. No 5119411426401)

Results

A repeated measures one-way ANOVA was computed, to test the effects of test position (unprimed, primed-reinstated context, primed-new context), using the proportion of RAT problems solved as a dependent variable[3]. There was a significant difference among the three conditions [$F(2,176) = 8.127$, $p < .001$, *partial* $\eta 2 = .085$] Post-hoc pairwise comparisons with a

[3] The inclusion of counterbalancing in a mixed ANOVA as a between-subjects measure showed no significant differences between the three counterbalancing groups [$F(2, 86) = 1.025$, $p = .363$, *partial* $\eta 2$ - .023], therefore the between-subjects factor was removed from the calculation.

Bonferroni correction revealed, that compared to the unprimed condition (*M* = .539, *SD* = .195), solutions for the RAT problems were significantly worse when the encoding contexts of red herrings at the test phase were reinstated (*M* = .456, *SD* = .205) [$t(88) = 4.011$, $p < .001$, d = .425]. We also found that compared to the new context condition (*M* = .506, *SD* = .205) there was a significant decline in correct solutions if the encoding contexts of red herrings was reinstated at test [$t(88) = 2.585$, $p = .034$, $d = .274$]. The difference between the unprimed and primed- new context conditions was not significant [$t(88) = 1.517$, $p = .399$, $d = .161$] (Fig. 4). A paired-samples t-test showed that participants during the second retrieval practice trial (*M* = .58, *SD* = .24) remembered the red herrings significantly better [$t(169) = 21.64$, $p < .001$, d = 1.66] than during the first retrieval practice trial (*M* = .22, *SD* = .15).

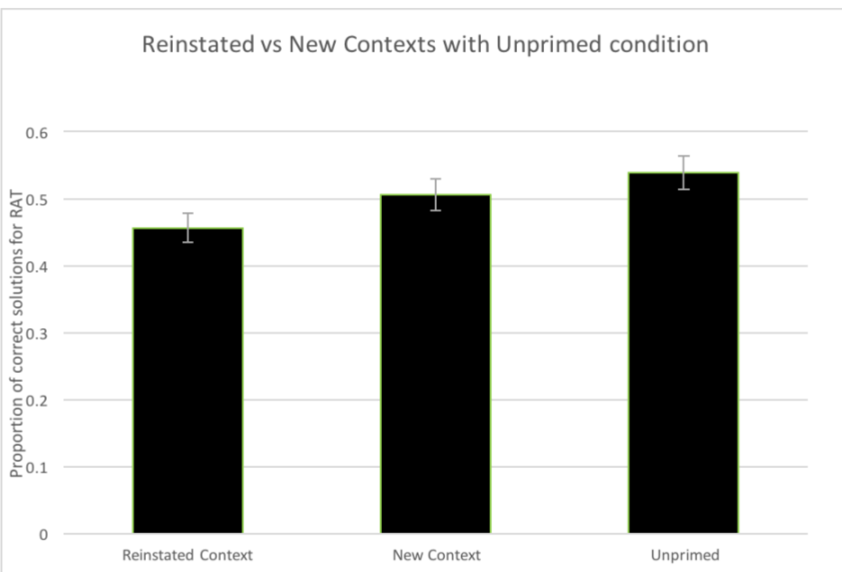

Figure 4 Mean proportion of correct solutions for the RAT as a function of the three context conditions in Experiment 2. The error bars represent 95% within-subjects CI. (Reprinted with permission from Memory & Cognition, Lic. No 5119411426401)

Discussion

In contrast with the results of Experiment 1, there was a clear context-dependent fixation effect observed in Experiment 2. The RAT problems tested with the encoding contexts of corresponding red herrings (i.e., the primed-reinstated context items), relative to RAT problems tested with new contexts (i.e., the primed-new context items), were solved at a significantly lower rate. The primary difference between the procedures used in Experiments 1 and 2 was that in Experiment 1, both RAT test words and photo contexts were practiced in association with red herrings, whereas in Experiment 2, only photo contexts were practiced with red herrings. In Experiment 1, the strong semantic associations between RAT test words and red herring words were made even stronger because they were practiced together. The presence of those strong verbal cues at test, regardless of the test context, caused an outshining effect (e.g., Smith, 1988) in Experiment 1. Because the associations between test words and red herrings were practiced in Experiment 1, but not Experiment 2, the verbal cues were much stronger in Experiment 1 than in Experiment 2. As a result, the cuing effects of photo contexts were not outshone by the stronger cuing effects of RAT test words in Experiment 2, as they were in Experiment 1. In addition, all items received one presentation trial and two retrieval practice trials before the critical RAT problems, based upon the suggestion in the results of Experiment 1 that multiple context-item repetitions may strengthen the context-red herring associations, making them more context-dependent.

In Experiment 2, we included a baseline control condition (i.e., the unprimed condition) in which there were no corresponding red herrings that had been encoded and practiced before the RAT was given. The percentage of RAT problems solved in the primed-reinstated context condition, relative to the unprimed condition, was 8% lower, a fixation effect size (d = .43) in the medium range (Cohen, 1977). In contrast, the 3% fixation effect in the primed-new context condition did not rise to significance, with a very small effect size (d = .16). In addition to showing that a test manipulation, context reinstatement, affects the magnitude effect, the present findings suggest that trying to solve creative problems in new contexts may be a way to relieve fixation.

In conclusion, we have shown that creative problem solving is impeded by manipulations of factors that improve memory of red herrings for those problems. In Experiment 1, repeated practice of associations between problems and red herrings caused greater fixation. In Experiment 2, practice of associations between contexts and red herrings caused greater fixation for problems tested in those practiced contexts. The fact that retrieval of fixating ideas can be triggered by problems or by contexts shows that there can be multiple sources of fixation in creative problem solving, and indicates that efforts to reduce or overcome fixation might focus on memory cues provided by problems and/or by problem solving contexts.

Number of Intruding Blockers in Fixation[4]

In Experiments 3 and 4, we asked whether priming a greater number of red herrings would cause a greater fixation effect in word fragment completion. We have decided to use word fragment completion, a problem solving task, because of the better control over the task due to it only containing a single semantic element, and the stronger and more reliable effect sizes reported. Researchers have investigated effects of fixating stimuli in fragment completion in some of the same ways that effects of positively priming stimuli have been studied. Smith and Tindell (1997), for example, examined the perceptual modality and the level of processing at encoding of red herrings in fragment completion, finding results analogous to effects of positive word primes, that is, a transfer appropriate processing pattern (e.g., Morris et al., 1977; H. L. Roediger & Blaxton, 1987). For the variable number of different priming stimuli, however, there

[4] Reprinted with permission from *Memory* (Smith et al., 2020)

is no analogous finding from the positive priming literature, because there cannot be multiple versions of a single correct solution; the only positive priming word for the fragment A_L_ _GY, for example, is the solution, ALLERGY. In fixation, or negative priming, there can be multiple incorrect responses that orthographically resemble the one correct solution, such as ANALOGY, ANATOMY, ANGRY, ANTHOLOGY, and ANXIETY. Although it is known that the number of times a single positive priming stimulus is repeated, the greater its positive priming effect (e.g., Greene, 1990; H. L. Roediger & Challis, 1992), and the more repetitions of a red herring, the greater the fixation effect (Chapter 2, Experiments 1-2), it is not clear whether or not priming more red herrings related to a single word fragment will cause a greater fixation effect. In Experiments 3 and 4, after priming with varying numbers of red herrings prior to word fragment completion, we tested the entrenchment hypothesis by comparing fragment completion for varying numbers of red herrings, predicting that greater numbers of red herrings would cause greater entrenchment, and poorer word fragment completion.

Experiment 3: Fixation Strength with Multiple Red Herrings (Group Study)

In Experiment 3, the number of red herrings (0, 1, 3, and 5) was manipulated within-subjects to observe its effects on word fragment completion. It was predicted that we would observe an entrenchment effect, that is, fragment completion would be worse when more red herrings were primed. Experiment 3 also served as a manipulation check of the red herring stimuli that we generated for Experiment 3; observing an entrenchment effect can be interpreted as validation of these red herrings for blocking word fragment completion.

Method

Participants. A total of 138 undergraduate psychology students volunteering as participants to fulfill a course requirement were randomly divided into four counterbalancing groups, with 32, 36, 35 and 35 participants in the groups. Participants self-enrolled via a computerized database. Sessions were conducted with 1-15 participants at a time, depending upon the number of participants enrolled.

Design & Materials. A total of 12 word fragment problems were chosen from materials used in previous studies. Five red herrings were selected for each word fragment, words that were orthographically similar to solution words. All red herrings for a target word had the same initial letter as that target word. The 12 critical word fragments started with different letters of the alphabet to minimize unintended blocking among the 12 critical items. Except for a target word's corresponding red herring words, no other stimulus words began with the 12 initial letters of the 12 critical word fragments (i.e., the letters A, B, D, F, I, K, H, M, O, R, T, and V). Experimental design and stimuli can be found in Appendix I.

A 4 (blocking; 0, 1, 3, or 5 red herrings, a within-subjects measure) X 4 (counterbalancing, a between-subjects measure) mixed design was used, with proportion of correctly solved word fragments as the dependent measure. The 12 critical word fragments were randomly distributed to the four treatment conditions (control or zero red herrings, 1 red herring, 3 red herrings, 5 red herrings) for a given counterbalancing condition. The items in each condition were then counterbalanced between-subjects, so each problem appeared in each condition across our four counterbalancing groups. We also used seven non-critical word fragment problems, five of which were positively primed, and two of which were not primed. None of the non-critical word fragments began with the 12 initial letters of the 12 critical items.

Stimuli were projected in a PowerPoint slideshow using black letters on a plain white background. Participants recorded answers on paper. Instructions were visible on the slideshow and were also read aloud by the experimenters.

Procedure. The experiment consisted of two distinct tasks. First was an incidental priming task in which participants assigned pleasantness ratings to red herring words, one word at a time. Participants were instructed to first write down each word that appeared on the screen, and then to assign a pleasantness rating. Five positive primes were also presented along with the red herrings in this priming task. The order of presentation of the priming stimuli was randomized. When multiple red herring words were presented for a given target (in the 3 and 5 red herring conditions), red herrings for the same target had at least 2 intervening items. Participants had 8 seconds on each trial of the priming task to write down the word and assign it a rating.

Following the pleasantness rating task was the fragment completion test, in which participants saw word fragments, one at a time, with 8 seconds to write down a solution for each word fragment. Participants were encouraged to use words from the pleasantness rating task to solve the word fragments, and they were told some of the words that they had previously seen might help in solving word fragments. Five positively primed filler problems along with 2 neutral problems were also inserted in the stimulus sequence.

Results. To test the overall blocking effect we computed a planned orthogonal contrast, comparing fragment completion performance in the control (zero red herrings) condition with conditions in which any red herrings (i.e., 1, 3, and 5 combined) were primed. The blocking effect was significant, [$t(137) = 9.461$, $p < .001$, $d = .805$]; word fragment completion performance was worse for conditions in which any number of red herrings were primed ($M = .309$, $SD = .168$), as compared to the condition corresponding to unprimed words ($M = .575$, $SD = .279$, Figure 5).

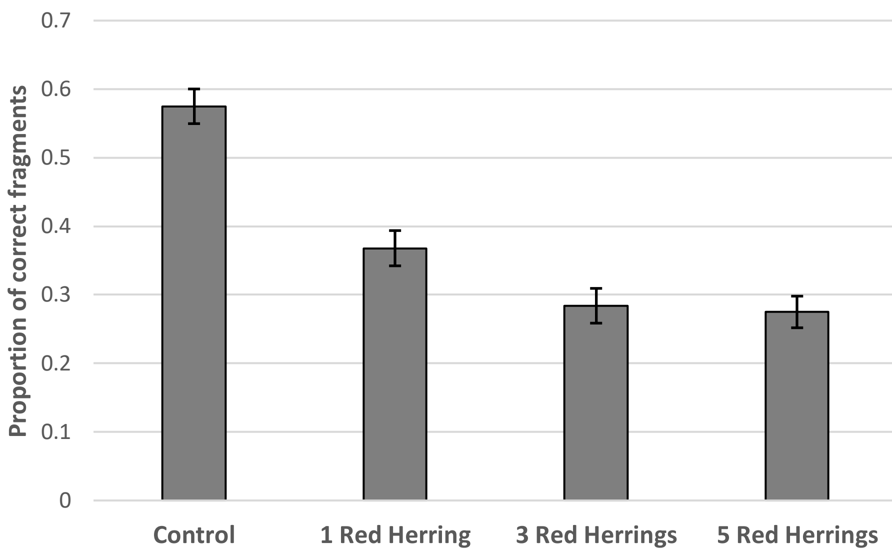

Figure 5 Mean proportion of word fragments completed as a function of the number of primed red herrings in Experiment 3. Error bars indicate the standard error of the mean. (Reprinted with permission from Memory)

To test the entrenchment effect, a repeated measures ANOVA was computed, using number of red herrings (1, 3, and 5) as a within-subjects factor. The entrenchment effect was significant, [$F(2, 274) = 4.31$, $p < .014$, $\eta_p^2 = .031$)]; priming more red herrings resulted in generally poorer performance. Three paired samples t-tests were computed as planned comparisons, comparing fragment completion among the three red herrings conditions. The difference between the 1- and 5-red herring conditions was significant [$t(137) = 2.65$, $p = .009$, $d = .226$]; performance was worse in the 5-red-herring condition ($M = .275$, $SD = .271$) than in the 1-red-herring condition ($M = .368$, $SD = .302$, Figure 5). The difference between the 1- and 3-red herring conditions was also significant [$t(137) = 2.34$, $p < .021$, $d = .199$]; performance was worse in the 3-red-herring condition ($M = .284$, $SD = .298$) than in the 1-red-herring condition ($M = .368$, $SD = .302$). The difference between the 3- and 5-red herring conditions was not significant [*t*(137) = 0.25, *p* = .803, *d* = .021], although it was numerically worse in the 5-red-herring condition (*M* = .275, *SD* = .271) than in the 3-red-herring condition (*M* = .284, *SD* = .298).

To better suit the analysis of categorical data (i.e., correct/incorrect answers, Jaeger, 2008), avoid violations to the assumptions of an ANOVA (Barr et al., 2013), and minimize the chance of committing Type I errors, a mixed-effects logistic regression was conducted to test both blocking and entrenchment effects. This analysis was done using the *glmer* function from the *lme4* package (Bates et al., 2015) in *R*. The model chosen for analysis used correct and incorrect fragment solutions (1 and 0, respectively) as the dependent variable. Because subjects and items (i.e., fragments) may account for different amounts of variance, they were both modeled as random intercepts. Number of red herrings (0, 1, 3, and 5), was included in the model as a fixed effect. This "full" model was compared against an "empty" model, which included only subjects and items as random intercepts, with a likelihood ratio test by using the *anova* function in *R.* The analysis showed the addition of the number-of-red-herrings condition to be warranted, $\chi^2(3) = 112.40$, $p < .001$. Furthermore, the full model (random effects: subject, *SD* = 0.545; item, *SD* = 1.606), shows the odds ratio of correctly solving a fragment in the 1- (*b* = -1.067,OR = 0.344), 3- (*b* = -1.512, OR = 0.220), and 5- (*b* = -1.715, OR = 0.180) red herrings condition to be significantly lower (*p's* < .001) than in the no red herrings condition, a blocking effect.

As a test of the entrenchment effect, the odds ratio of a correct fragment solution in the 3-red herrings condition (*b* = -0.445, *p* = .013, OR = 0.641) was significantly lower relative to the 1-red herring condition, but the 5-red herrings condition (*b* = -0.203, *p* = .280, OR = 0.816) was not significantly different from the 3-red herrings condition. The odds ratio was also significantly lower in the 5-red herrings condition (b = -0.648, p < .001, OR = 0.523) than in the 1-red herring condition.

Discussion.

In Experiment 3 a significant memory blocking effect was observed; performance was worse if *any* red herrings were studied, as compared to having no red herrings. This blocking effect, with a corresponding Cohen's d = .805, is considered a large effect size. Furthermore, a significant entrenchment effect was observed, with significant differences among the three red herring conditions. This entrenchment effect is consistent with the distractor set size principle.

Experiment 4: Fixation Strength with Multiple Red Herrings (Single Subject Study)

Experiment 4 used the same methods as described for Experiment 3, except that participants were run as single subjects, each seated at a computer in Experiment 4, as compared with the group sessions used in Experiment 3. In Experiment 4, we wanted to replicate our findings from Experiment 3, and to observe response times. We predicted poorer accuracy and slower completion times the more red herrings that were primed.

Method.

Participants. A total of 109 undergraduate students self-enrolled for participation in exchange for course credit. Each participant was randomly assigned to one of four counterbalancing conditions. Final counterbalancing group sizes for each condition were 30, 26, 26, and 27 participants.

Design & Materials. The design and materials were identical to Experiment 3, except that participants were run as single subjects, each seated at a computer in Experiment 4, as compared with the group sessions used in Experiment 3.

Procedure. Instructions for both experimental blocks were the same as in Experiment 3 with minor modifications to the procedures to accommodate a computerized adaptation. For the first part of the experiment, incidental priming of red herrings in a pleasantness rating task, each trial consisted of the presentation of one word placed in the center of a computer screen. Above each word was a text box in which participants could type their pleasantness rating. After each rating was made, participants pressed a key to proceed to the next trial. On the second part of the experiment, the word fragment completion test, each word fragment was presented for a maximum of 8 seconds. If participants knew the fragment solution they were to press a designated key. The fragment on the screen was then replaced with a text box in which participants typed their answer. After typing an answer, the participant pressed a key to move to the next fragment completion trial.

Results

Proportion Correct. To test the overall blocking effect we computed a planned orthogonal contrast, comparing fragment completion performance in the control (zero red herrings) condition with a combination of the conditions in which any red herrings (i.e., 1, 3, and 5 combined) were primed. The blocking effect was significant, [$t(108) = 7.49$, $p < .001$, $d = .72$]; word fragment completion performance was worse for conditions in which any number of red herrings were primed ($M = .26$, $SD = .15$), as compared to the condition corresponding to priming of no orthographically similar words ($M = .48$, $SD = .28$, see Figure 6).

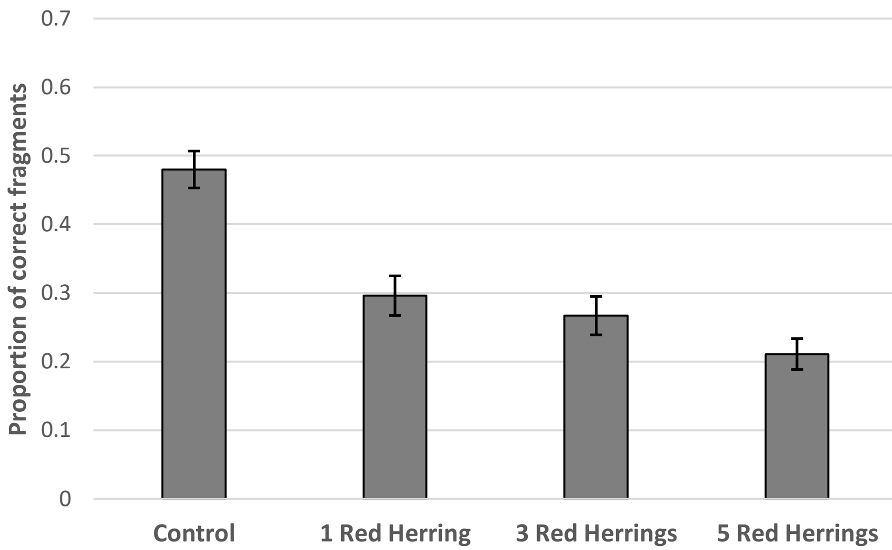

Figure 6 Mean proportion of word fragments completed as a function of the number of primed red herrings in Experiment 4. Error bars indicate the standard error of the mean. (Reprinted with permission from Memory)

To test the entrenchment effect, a repeated measures ANOVA was computed, using number of red herrings (1, 3, and 5) as a repeated factor. The entrenchment effect [$F(2, 216) = 2.47$, $p = .087$, $\eta_p^2 = .022$)] was not significant, but trended in the direction that more red herrings resulted in poorer performance. Three paired samples t-tests were computed as planned comparisons, comparing fragment completion among the three red herrings conditions. The difference between the 1- and 5-red herring conditions was significant [$t(108) = 2.07$, $p = .041$, $d = .318$]; performance was worse in the 5-red-herring condition ($M = .211$, $SD = .234$) than in the 1-red-herring condition ($M = .297$, $SD = .302$, Figure 6). The difference between the 1- and 3-red herring conditions was not significant [$t(108) = .71$, $p = .477$, $d = .097$], although performance was numerically worse in the 3-red-herring condition ($M = .268$, $SD = .294$) than in the 1-red-herring condition ($M = .297$, $SD = .302$). The difference between the 3- and 5-red herring conditions also was not significant [$t(108) = 1.61$, $p = .111$, $d = .213$]; performance was numerically worse in the 5-red-herring condition (M = .211, SD = .234) than in the 3-red-herring condition (M = .268, SD = .294).

A mixed-effects logistic regression was conducted using the same model as in Experiment 3 (i.e., with subjects and items as random intercepts and number-of-red-herrings condition as a fixed effect) with correct/incorrect answers (1 and 0, respectively) as the dependent variable. This model was compared to an "empty" model containing only the random effects of subject and items. A log likelihood test (using the *anova* function in *R*) showed the addition of the number-of-red-herrings condition was justified, $\chi^2(3) = 95.01$, $p < .001$. The estimates of the random intercepts (random effects: subject, SD = 0.614; item, SD = 1.730) and fixed effect model showed that all conditions (1-red-herring, b = -1.165, OR = 0.312; 3-red herrings, b = -1.510, OR = 0.221; 5-red herrings, b = -1.915, OR = 0.147) had significantly lower ($p < .001$) odds ratios than the 0-red herring condition for correct fragment completion. The 5-red herrings condition (b = -0.750, $p < .001$, OR = 0.472) also had lower log odds relative to the 1-red herring condition. The 3-red herrings condition (b = -0.345, p = .106, OR = 0.708) had lower log odds relative to the 1-red herring condition, and the 5-red herrings condition (b = -0.405, p = .068, OR = 0.667) had lower odds than the 3-red herring condition, although these differences were not significant.

Solution Latency. A meaningful one-way ANOVA analyzing fragment completion latency was not possible to report because of the great amount of missing data in such an analysis. With our repeated measures design, only correct solutions had response times, so any participant who missed all three of the fragments for any of the four treatment conditions would be deleted from the analysis (of our 106 participants, only 12 lacked missing data). Data from three participants were excluded from the analyses because their mean completion times were more than two standard deviations longer than the group mean. Mean completion times for the four treatment conditions (including all fragments completed by all participants) are shown in Table 1. Completion time was defined as the time from the appearance of a fragment on the screen until the bar press indicating that the participant knew the solution, and did not include typing time.

Number of Red Herrings	Mean Solution Time	SD
0	2862	1217
1	3401	1718
3	3387	1415
5	3383	1283

Table 1 Mean fragment completion times (milliseconds) as a function of number of red herrings for Experiment 4. (Reprinted with permission from Memory)

Discussion

Experiment 4 replicated the findings of Experiment 3, showing memory blocking and entrenchment effects. As in Experiment 3, participants in Experiment 4 solved nearly twice as many fragments in the zero-red-herring (control) condition as in the three conditions in which red herrings were primed. This memory blocking effect in Experiment 4 also could be observed in terms of solution times, which were considerably slower in the conditions corresponding to red herrings than in the control condition.

As in Experiment 3, an entrenchment effect was observed in Experiment 4, although the effect was relatively small. Fewer fragments were completed when five red herrings had been primed as compared with only one red herring. There was no evidence of an entrenchment effect in fragment completion latency scores.

Both experiments we report here found significant memory blocking effects. Word fragment completion was better in control conditions, in which no orthographically similar red herrings were primed, as compared to conditions in which one or more red herrings were primed, with a large effect size. This memory blocking effect is consistent with numerous reported results (e.g., Landau & Leynes, 2006; Logan & Balota, 2003; Lustig & Hasher, 2001a; Smith & Tindell, 1997).

Does priming several red herrings entrench fixation more than priming a single red herring? Both Experiments 3 and 4 provided evidence of entrenchment effects, with a greater memory blocking effect when five red herrings were primed, as compared to priming a single red herring. The observed effects were modest, but they were clearly present in both experiments when comparing the 1-red herring vs. 5-red herrings conditions. This entrenched memory blocking effect was caused not by pre-existing lexical neighborhoods of varying sizes, as in previous studies (e.g., Nelson et al., 1987), but rather by experimentally manipulated red herrings. This observed laboratory-induced entrenchment effect verifies that our red herring stimuli were effective for bringing about the intended entrenchment effect. Future research should examine blocking and entrenchment effects with a wider set of stimuli.

The present findings are consistent with the theory that both explicit and implicit memory are subject to the same influences, such as the number of competing responses that can potentially cause interference (Lustig & Hasher, 2001b). In this view, interference in the form of impairing performance when there are more competitors is a rule that governs both explicit and implicit memory. The present results support this view insofar as the blocking effects observed in both of our experiments. The entrenchment effects in Experiments 3 and 4 are consistent with the theory that distractor set size effects can be observed in both direct and indirect measures of memory. Our results do not necessarily show that distractor set size (e.g., fan size) effects occur in implicit memory, as stated by Lustig and Hasher (2001a), because performance on our word fragment completion test may well have been contaminated by deliberate recollection of red herrings. The present results show an entrenchment effect with an indirect memory measure. It remains to be seen whether or not entrenchment effects caused by laboratory manipulated distractors can be found when explicit recollection is controlled.

Experiments 1 – 4 showed that the number and relative memory strength of blocking items seem to have a strong influence on the fixation effect. What are the ways an incubation period might assist in the elimination of mental fixation? In the next section, effects of forgetting will be considered. To better understand how to eliminate fixation, some insight into memory processes is necessary.

CHAPTER 3

REMEMBERING AND FORGETTING FIXATION

Forgetting used to be regarded as an impediment to the memory process. However, since remembering is dependent on other memory items that might interfere with the recall process, forgetting of these interfering items might lead to better memory for the target items. This would make forgetting an adaptive memory process (M. C. Anderson & Neely, 1996; E. L. Bjork & Bjork, 1996; R. A. Bjork, 1970, 1989; Smith, 2011).

To start a search process in memory in order to retrieve a target item, a retrieval cue is necessary (M. C. Anderson & Neely, 1996). The same cue might be associated with multiple memory targets that compete for access (M. C. Anderson et al., 1994). Competition depends on the number and retrieval strength of these memory targets, the more and the stronger the targets, the lower the recall performance (the *cue-overload principle* by Watkins & Watkins, 1975).

There are three components of the memory retrieval process that these retrieval failures might be associated with: the association between cues and targets, the retrieval cues, and the activation level of the memory targets (M. C. Anderson & Neely, 1996).

Cue-target Association

The association between the retrieval cue and the target weakens when a memory item similar to the target intrudes in the recall (occlusion), or when a new association to the same retrieval cue eliminates a previously existing one completely (unlearning). In the case of word fragment completion, when participants are primed with orthographically similar, incorrect solutions, subsequent word fragment completion suffers because of occlusion of the primed red herrings.

Retrieval Cues

If the wrong retrieval cues are used, memory performance is also affected. Retrieval cues are specifically tied to memory targets, The *encoding specificity principle* (Tulving & Thomson, 1973) states that words are encoded and tied to their cues in their specific meaning at the time of the encoding. In the case of homographs, words with two distinct meanings, for example when the word *bank* was associated with its cue in the sense of *next to a river*, the same retrieval cue will be inappropriate to retrieve the word *bank* meaning *a financial institution*.

Target Memories

It is also possible that the target memories themselves are difficult to access. One of the reasons for the difficulty to access target memories can be suppression (Postman et al., 1968). The idea of suppression initially came as an explanation for *retroactive interference* but since gained ground and received more support in a sense different that it was originally intended by Postman.

Suppression[5] as a Forgetting Mechanism

Studies conducted in the 1970s on attention suggested that inhibition might play a part in cognitive processes, similar to lateral inhibition in visual, auditory, or tactile processing (Crowder, 1978; Walley & Weiden, 1973). Walley and Weiden, in their review paper, introduced the term *cognitive masking* to describe an inhibitory mechanism that assists attentional resources to increase cognitive contrast. In their theory the degree of this masking would be a function of the similarity of the inputs, and would also be related to levels of arousal.

[5] Suppression and inhibition are similar in meaning, with suppression signifying a top-down stopping mechanism and inhibition the neurophysiological control process that acts in the suppression.

Another evidence of inhibition in cognitive processes is *visual marking*. In a visual marking experiment a group of distractors is shown prior to a second group of items that also contains the target participants have to attend to. Experiments of visual marking found that when the group of distractors are presented before the target, as a separate group, visual search is as efficient as if the distracting group had not been shown. Visual marking is explained by a top-down attentional inhibition of the irrelevant visual targets (Watson & Humphreys, 1997).

Inhibition of a memory process should result in some sort of forgetting. The idea that the recall process itself may be the cause of forgetting has already appeared in the output interference and part-list or part-set cuing studies. Brown (1968) asked participants to free recall the 50 states in the US, some without help and some with the help of 25 of the states already listed. Performance on the critical remaining 25 states was worse for participants who received the first 25 states as cues, relative to those who did not receive cuing. Brown's experiment used a general knowledge question, and was designed to examine the organization of recall. In other studies participants had to study items to be recalled subsequently during the experiments. Rundus (1973) on his follow-up to the part list cuing study of Slamecka (1968) a few years earlier, made participants study lists of words that belonged to the same cue. Similarly to what the results of Brown (1968) were, he hypothesized a negative effect when cuing lists of previously studied items from the same list (thus the name part-list cuing).

The review work of Roediger and Neely (1982) on retrieval blocks explicitly states that response competition should be conceived as *retrieval inhibition*. Retrieval inhibition is the temporary suppression of the retrieval strength of competing items to increase retrieval likelihood of the correct items, thus helping to sharpen *cognitive contrast* similarly to visual lateral inhibition. In their *New Theory of Disuse*, Bjork and Bjork (1992) distinguished between storage strength and retrieval strength of a memory item (stemming from the ideas of Tulving, 1974). Storage strength is a measure of how well-learned, whereas retrieval strength refers to how accessible a memory is at a given time. Storage strength typically increases with every exposure to the item, whereas retrieval strength is dependent upon contextual and other intervening information. Importantly, storage strength does not directly affect memory performance; rather, it determines memory potential. Retrieval inhibition acts exclusively on the retrieval strength of a given memory item and leaves the storage strength of a memory intact. Bjork (1989) described retrieval inhibition as an adaptive mechanism, a tool in memory management that might assist in the functions of memory updating, unitization, and serial order.

The idea of enhancing cognitive contrast returned in the studies of Neill and Westberry (1987), who examined time constraints of the distractor suppression effect (or negative priming) The observation came from an earlier finding by Dalrymple-Alford and Budayr (1966) that when participants are given Stroop (1935) color naming tasks, the naming of colors slows down when the current appropriate response is preceded by an identical inappropriate response that is activated by the previous trial. For example, when the word RED written in color *blue* is presented on a trial, reaction time on the following trial will slow down if the required response is “red,” compared to a neutral trial. The distractor suppression effect was hypothesized to occur because the inappropriateness of the response on the preceding trial (the misleading RED text) causes the word “red” to be temporarily suppressed. Neill and Westberry found that the effect persists for about a second, and then dissipates completely. More importantly, they interpreted their findings in a model, in which automatic spreading activation in memory is followed by a cognitive “narrowing down” to fit task demands.

In their work on semantic priming, Carr and colleagues (Carr & Dagenbach, 1990; Dagenbach et al., 1990) proposed a center-surround principle in the facilitation of “desirable” codes, information to be retained, and the inhibition of semantically related ones. Carr and Dagenbach used a lexical decision task paradigm (e.g., Meyer & Schvaneveldt, 1971) for their work. Participants had to decide whether letter strings that appeared on a screen were words or non-words. The critical trials were preceded by cues that were supposed to help participants in making their decisions. These preceding cues were either semantically related or unrelated to the stimuli in the critical trials. A standard finding of the lexical decision task is that priming with semantically related words facilitates recognition of stimuli as words (Meyer & Schvaneveldt, 1971). Carr and Dagenbach masked the priming words and found that when they set the prime-mask stimulus onset asynchrony (SOA) time below the threshold of semantic recognition, but above the detection threshold, the priming effect was reversed, and participants were slower in recognizing semantically related words as words, compared to baseline. Repetition priming, however, when the prime was not semantically related but the same as the lexical decision word in the critical trial, remained facilitatory at the same SOA level. The suggested explanation by Carr and Dagenbach was an attentional mechanism that, in order to boost weakly activated semantic codes, inhibits semantically related but not identical information during memory retrieval.

Forgetting can occur in different ways. These same ways of forgetting might be in play when fixating elements are being forgotten. Changing the problem solving environment can bring forth a new *context* not associated with fixation. A fresh start from a new *idea space* might lead to more fruitful directions during problem solving. Additional time in the incubation period might also help by either a change in the mental context or memory decay. It is also possible, that over repeated attempts to solve a problem, solutions that are recognized as misleading and incorrect are inhibited from subsequent retrievals. The following two experiments looked into the question of forgetting fixation due to changing context and the time elapsed during an incubation period.

Time and Context Dependent Forgetting of Fixation[6]

Experiments 5 and 6 tested the context-dependent fixation explanation of incubation effects. We induced initial context-dependent fixation with a method similar to Beda and Smith's (2018), and retested unsolved problems either in the fixation context or a new context. Because temporal context shifts do not occur on an immediate retest, in spite of a change in a background context photo, the benefit of retesting with a new pictorial context should occur after a delay, but not for an immediate retest.

Experiment 5: Forgetting Fixation Due to Time and Changed Context

Our method is diagrammed in Figure 7. The initial fixation induction involved learning and practicing recall of triads of fixation words, using photos of unrelated environments (context photos) as cues. Next, participants attempted each Remote Associates Test (RAT) problem twice, with the retest either a few seconds after the first attempt, or after a longer delay of approximately 2 (Experiment 5) to 3 min (Experiment 6). Each retest of a problem occurred either in the fixation context, or a new context, never before seen in the experiment. We measured resolution rates, the proportion of initially unsolved problems that were solved on the retest. We predicted that more unsolved problems would be resolved on delayed retests, relative

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to immediate retests (an incubation effect), and greater resolution when delayed retests were given in new contexts rather than fixation contexts (a context-dependent incubation effect).

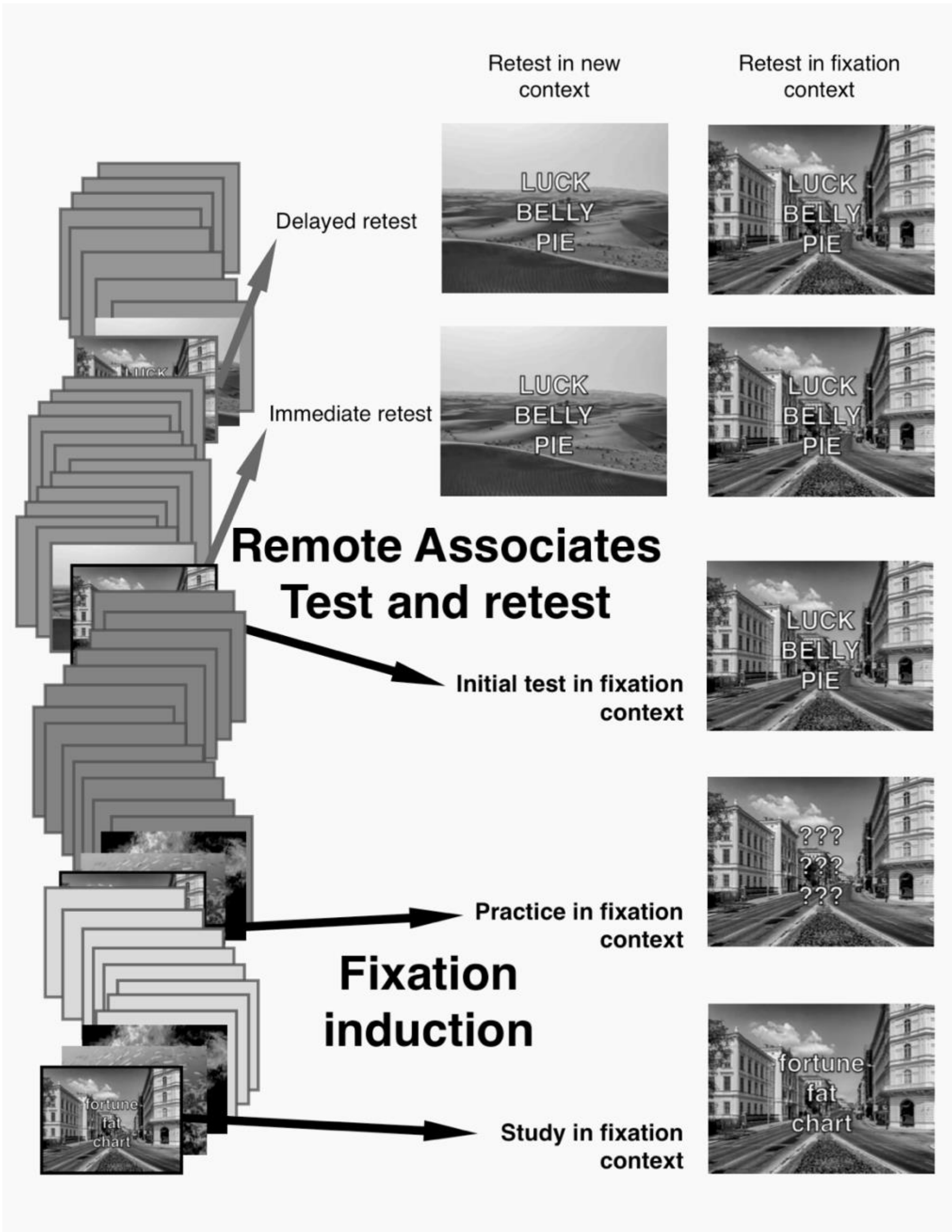

Figure 7 Fixation induction consisted of a study trial where participants memorized the 3 fixation words per context photo, followed by multiple practice trials recalling the 3 fixation words using the context photo as a cue, and an initial test of the associated RAT problem in the fixation context. Each problem was retested either immediately or after a delay, and with either the fixation context or a new context. (Reprinted with permission from JEP: General, Lic. No 5124920598089)

Method

Participants. Participants, undergraduates who volunteered to fulfill a course requirement, self-enrolled for time slots online. There were 146 students who participated in Experiment 5. Experiment sessions were conducted with 3–15 participants at a time.

Design. A 2 (context: reinstated or new contexts at retest, a within-subjects variable) x 2 (incubation: immediate or delayed retesting, a within-subjects variable) x 4 (counterbalancing: between-subjects) mixed design was used, using resolution, the proportion of unsolved RAT items at the first test that were successfully solved on the second test, as the dependent measure.

Materials. RAT problems were selected from the compendium by Bowden and Jung-Beeman (2003), using problems with high normed levels of solution rates. In Experiment 5, 24 RAT problems were used. Three RAT word-fixation word pairs corresponded to each problem (e.g., LUCK-fortune, BELLY-fat, PIE- chart). RAT words, solution words, and fixation words were unique within our materials; no RAT words or fixation words were repeated in any materials. RAT words were presented in uppercase and fixation words in lowercase letters. Stimuli were shown on a large screen for groups of participants.

A total of 48 photo contexts, photographs of places, were used in Experiment 5. The photos showed familiar types of places, such as an airport or a restaurant, but the specific places were likely not known to our participants. Each photo context was randomly assigned to a RAT problem, avoiding obvious associations of words and accompanying photos. Stimulus words, shown in red and outlined in yellow, were superimposed over photo contexts. On retrieval practice trials, photos accompanying fixation words were the same ones that had been seen at encoding. RAT problems were first tested with their fixation contexts, and then retested either with fixation contexts or with new photos, that is, photos of places not seen before in the experiment. The 24 RAT problems were counterbalanced so that each problem was used in each treatment condition.

Procedure. For the first task, fixation word encoding, participants tried to memorize 24 triads of fixation words. Each triad was superimposed over a photo context; participants were told to memorize the three words for each background for a later memory test. Each study trial of this fixation word encoding task was 5s.

Next was the fixation word retrieval practice task. On each trial participants saw an encoding context and they had 10s to recall and write down the three accompanying words (the fixation words) for that photo. Next, the correct responses were displayed for 10s; participants circled each response they got right, and wrote down any words they missed. There were three retrieval practice runs of all 24 items. Between each run participants counted how many of the 72 words they got correct, and wrote down the number.

The final task was the Remote Associates Test. For each problem, participants had 5s to think of the solution, and each problem was tested twice. For the first test, each problem was superimposed over the context photo corresponding to the associated fixation words. For the second test, each problem was superimposed over either the fixation context (fixation context condition) or a new context that had not been seen previously in the experiment (new context condition.) The second test followed the first test either immediately (immediate retest condition), or after some other problems were tested (delayed retest condition). The delay between the first test and the retest of problems in the delayed retest condition was approximately 26 intervening RAT problems, ranging between 22 and 29 RAT problems, an average delay of 130 seconds.

Results

A 2 (context: fixation or new context at retest, a within-subjects variable) x 2 (incubation: immediate or delayed retesting, a within-subjects variable) x 4 (counterbalancing: a between-subjects variable) mixed analysis of variance (ANOVA) was calculated, using resolution, the proportion of initially unsolved RAT problems that were solved at retest, as the dependent measure. A main effect of incubation was found ($F(1,142) = 22.86$, $p < .001$, $\eta^2_p = .139$); participants solved more of the initially unsolved problems after a delay compared to the immediate retest (Figure 8, left panel). A main effect of context [$F(1,142) = 6.18$, $p = .014$, $\eta^2_p = .042$] showed that when new contexts were provided on the retest, resolution was greater than when the retest was given with the fixation context (Figure 8, left panel). The incubation X context interaction was not significant [$F(1, 142) = 1.31$, $p = .255$, $\eta^2_p = .009$]. Planned comparisons showed that the simple main effect of context was not significant in the immediate retest condition [$t(145) = 1.04$, $p = .3$, $d = .09$], but it was significant in the delayed retest condition [$t(145) = 2.28$, $p = .024$, $d = .19$].

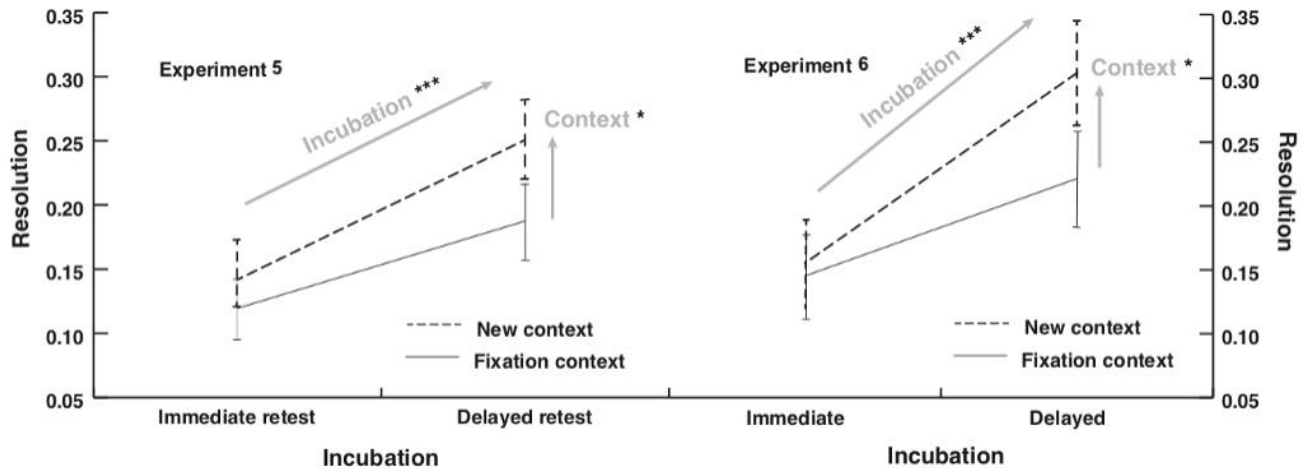

*Figure 8 Mean resolution, proportions of initially unsolved problems as a function of incubation and retest context. Greater incubation effects were found in new contexts relative to fixation contexts in both Experiments 5 (left panel) and 6 (right panel). Error bars represent 95% within-subjects confidence intervals. * p < .05, *** p < .001 (Reprinted with permission from JEP: General, Lic. No 5124920598089)*

The fixation induction effectively blocked performance on the initial test of RAT problems in Experiment 5. Normed solution rates for our 24 RAT problems (Bowden & Jung-Beeman, 2003) had a mean of 60%, as compared with 42%, the mean initial solution rate for those problems in Experiment 5.

Discussion

The results of Experiment 5 were consistent with predictions of the context-dependent fixation hypothesis. A greater proportion of initially fixated RAT problems was resolved when retests were given after a delay, an incubation effect, and when retests were given in new contexts, a context-dependent incubation effect. The effect size for the observed incubation effect in Experiment 5 was large, and the context effect size was in the moderate range, showing greater resolution when retests were given in new contexts.

Experiment 6: Forgetting Fixation Due to Time and Changed Context

Experiment 6 was conducted to replicate the results of Experiment 5, and to test the validity of our immediate retest condition. In Experiment 5, the immediate retest was given continuously with the initial test of a problem, which might have made the two tests seem like a single event. Therefore, in Experiment 6, the immediate retest was given with one intervening problem, so that participants could clearly see retested problems as new events. In all other ways, the methods of Experiment 5, including the experimental design, the materials, and the procedure, were the same as described for Experiment 5.

Method

Methods for Experiment 6 were identical to those described for Experiment 5, with the following exceptions.

Participants. In Experiment 6 there were 120 participants, none of whom participated in Experiment 5.

Procedure. In the final task, the RAT, one non-critical filler problem was inserted between the first test and the retest on RAT problems in the immediate retest condition. The 12 additional RAT problems used as fillers were never before seen, and they were presented on unique, never before seen contexts. Delayed retests occurred after an average delay of 34 items, ranging between 29 and 38 RAT problems, an average delay of 170 seconds.

Results

A 2 (context: fixation or new contexts at retest, within-subjects) x 2 (incubation: immediate or delayed retesting, within-subjects) x 4 (counterbalancing: between-subjects) mixed ANOVA was calculated, using resolution, the proportion of initially unsolved RAT problems that were successfully solved on the retest, as the dependent measure. A main effect of incubation was found, [$F(1,116) = 27.73$, $p < .001$, $\eta^2_p = .193$]; participants solved more of the initially unsolved problems after a delay compared to when they were retested immediately (Figure 8, right panel). A main effect of context [$F(1,116) = 5.56$, $p = .02$, $\eta^2_p = .046$] showed that resolution was greater when new contexts were given with retested problems, relative to retests given with fixation contexts reinstated (see Figure 8, right panel). The incubation X context interaction was not significant [$F(1, 116) = 2.89$, $p = .092$, $\eta^2_p = .024$]. Planned comparisons showed that the simple main effect of context was not significant in the immediate retest condition [$t(119) = .36$, $p = .72$, $d = .033$], but it was significant in the delayed retest condition [$t(119) = 2.43$, $p = .017$, $d = .222$].

We again found evidence that our fixation induction blocked performance on the initial test of RAT problems in Experiment 6. The initial solution rate for our RAT problems was 44% in Experiment 6, as compared to 60%, the normed solution rate for the same problems (Bowden & Jung-Beeman, 2003).

The incubation X context interaction predicted by our context-dependent fixation hypothesis was not significant in Experiment 6 [$F(1, 116) = 2.89$, $p = .092$, $\eta^2_p = .024$] nor was it significant in Experiment 5 [$F(1, 142) = 1.31$, $p = .255$, $\eta^2_p = .009$]. Because of the similarity in the methods and materials in Experiments 5 and 6, we computed an ANOVA with the data from both experiments combined to see if the increased power yielded a statistically reliable effect. The ANOVA with the combined results used a 2 (context: fixation or new context at retest, a within-subjects variable) X 2 (incubation: immediate or delayed retesting, a within-subjects variable) X 2 (experiment: Experiment 5 or 6, a between-subjects variable) mixed design, using resolution, the proportion of initially unsolved RAT problems that were solved at retest, as the dependent measure. That ANOVA found significant main effects of context [$F(1, 264) = 10.62$, $p < .001$, $\eta^2_p = .039$], with greater resolution in new contexts, incubation [$F(1, 264) = 52.32$, $p < .001$, $\eta^2_p = .165$], with greater resolution in the delayed retest condition, and experiment [$F(1, 264) = 4.28$, $p = .040$, $\eta^2_p = .016$], with greater resolution in Experiment 6 than in Experiment 5. This greater resolution rate likely occurred because the delayed retest in Experiment 6, about 170 seconds, was longer than the delay in Experiment 5, an average of 130 seconds, consistent with previous findings that longer incubation intervals can produce greater incubation effects (e.g., Goldman et al., 1992; Smith & Blankenship, 1989). Most importantly, however, this ANOVA found a significant incubation X context interaction [$F(1, 264) = 4.04$, $p = .045$, $\eta^2_p = .015$]; the benefit of retesting in a new context was significantly greater when retests were delayed, rather than immediate. No other effects were found in this analysis.

Discussion

The results of Experiment 6 replicated the finding in Experiment 5, showing that a higher proportion of problems were resolved when retests were given after a delay, and when retests were given in new contexts.

Experiments 5 and 6 provided clear support for the context-dependent fixation hypothesis of incubation effects, a corollary of the forgetting fixation theory. In both experiments, when fixated problems were retested in new contexts, resolution scores significantly increased. These findings are consistent with historic accounts of sudden insights that strike away from work settings where common approaches to typical problems are used. Although well-learned solutions are useful and efficient for most problems, there may be rare, but important problems that cannot be solved in the typical manner. In such cases, useful knowledge can be unknowingly fixating (Wiley, 1998), and the contexts associated with fixating knowledge can make fixation more entrenched. Our results are also consistent with findings that common anecdotal insights often occur away from work in places such as the shower, on the road, or while exercising (Ovington et al., 2018).

Both experiments found that a shift in context cues provided a means for escaping fixation when retests were delayed (i.e., after an incubation interval), but not when retests were given immediately after the initial failed attempt at a problem. These results suggest that the immediate retest condition saw no release from fixation because the temporal context at retest was unchanged from that of the initial test. The contextual stimuli used in Experiments 5 and 6, that is, pictures of places, may be weak in their influence over fixation words, making them unlikely to override the influence of temporal contexts.

Relation to Other Theories of Incubation

Other theories of incubation cannot explain how context change enhanced the resolution of fixated problems. The opportunistic assimilation explanation (Seifert et al., 1995) depends upon encounters with helpful stimuli, but none of our contextual stimuli provided any obvious hints. The unconscious work theory (e.g., Dijksterhuis & Nordgren, 2006) and the mind wandering theory of incubation (e.g., Baird et al., 2012b; Zedelius & Schooler, 2016a, 2017) both depend on time for progress to be made during the incubation interval, either for unconscious thinking or for mind wandering, to produce or discover solutions. Retests in our two context conditions, however, were given after identical delays. Although other theories cannot explain our results, our findings by no means invalidate those theories. Incubation effects may be multiply caused, that is, effects may be observed for a variety of reasons. Interestingly, most theories acknowledge that an initial impasse is a prerequisite for finding incubation effects, although the explanations give differing reasons for the role of initial impasses. Given this consensus, and the results of our experiments, initial fixation appears to be crucial for finding incubation effects in laboratory studies.

The results of our Experiments 5 and 6 have implications for creative cognitive neuroscience, the neural underpinnings of creative cognition (e.g. Anderson et al., 2004; Anderson & Hanslmayr, 2014; Banich & Depue, 2015; Benedek et al., 2014; Depue, Curran, & Banich, 2007). Our findings suggest that selective retrieval is the critical process necessary for solving verbal insight problems. Selective retrieval can be accomplished either indirectly, in our case, by removing fixating contexts, or directly, via suppression of prepotent responses. In the remainder of present dissertation the contribution of retrieval inhibition of wrong answers to forgetting fixation will be examined, focusing on the neurocognitive mechanisms involved in the reduced accessibility of pre-potent blockers due to suppression of them, particularly, repeated suppression.

Forgetting Fixation with Retrieval Inhibition

Both *voluntary suppression* (Johnson, 1994) and *retrieval inhibition* (M. C. Anderson et al., 1994) are the result of an adaptive top-down control process to eliminate competing, or unwanted, memories, thus increasing cognitive contrast and making subsequent recall more fluent (e.g., M. C. Anderson & Hulbert, 2020). In *retrieval induced forgetting* (RIF) participants study category-exemplar pairs in different categories (e.g., Fruit-Orange, Fruit-Apple). Half the members of half the categories are further practiced. At a subsequent test, unpracticed members of practiced categories are remembered more poorly then exemplars from baseline categories (e.g., M. C. Anderson et al., 1994). Kuhl et al. (2007) found that as participants received more retrieval practices, brain areas responsible for top-down regulatory control of detection (anterior cingulate cortex, or ACC), and resolution (dorsolateral and ventrolateral prefrontal cortices (dlFPC and vlPFC respectively)) of mnemonic competition showed a gradual reduction of activation. Furthermore, the amount of reduction individuals showed between the beginning and the end of the retrieval practice predicted their performance at the final memory test; the larger the decline, the greater the forgetting.

Similar processes are in play in problem solving, in which, following fixation, mnemonic competition of incorrect ideas must be countered to solve a problem. Storm, Angello and Bjork (2011) showed this in their work, in which participants studied paired associates to each member of a remote associates test problem (RAT, Mednick, 1962). Studied response words were designed to derail problem solving. After study, participants solved RAT problems comprised of the encoded cue words. Storm et al. found that memory for studied associates was poorer when the cue word was in the problems to be solved, as compared to baseline responses that did not appear during problem solving. Furthermore, this memory deficit did not depend on whether the RAT was actually solved or not. If the brain processes producing these similar behavioral results in problem solving induced forgetting (PIF) and RIF are also similar, the same brain areas should be activated during subsequent attempts to solve problems on which participants are fixated.

Problem Solving Induced Forgetting to Eliminate Fixation

An imaging experiment using fMRI was designed to examine if PIF and RIF tap into the same neural networks for operation. The problem solving task used to find PIF was the word fragment completion task. Even though word fragment completion is not considered a test of creative abilities, it displays similar properties than the RAT in blocking (Smith & Tindell, 1997), and context dependence (e.g., Smith & Beda, 2020a), and has been widely used to study negative transfer effects (Lustig & Hasher, 2001a). Another advantage of the fragment completion task over the RAT is that it is easier to work with because it uses less stimuli and, based on my previous experience, participants exhibit less individual differences during solution attempts. Before the imaging study though, a preliminary experiment was conducted to ensure that the word fragment completion task can reliably exhibit PIF. This is important, because Angello et al. (2015) in their experiment could not find any evidence of suppression in implicit orthographic priming in a paradigm working with word fragments. Even though the proposed experiment was different than the one Angello et al. reported in that word fragments were not used to test the memory of inhibited items, but instead served as the problem to be solved during which inhibition of unwanted wrong solutions was expected, no experiment before had tested whether problem solving using word fragment completions would trigger a PIF effect.

The ability to suppress pre-potent but misleading targets is different for each individual. In their study Kuhl et al. (2007) performed a median split of participants based on the magnitude of their behavioral suppression score, that is the final performance deficit on the memory test compared to the baseline items, and designated participants as high suppressors or low suppressors. In the imaging part of the experiment high suppressors showed robust decreases in activation over the course of retrieval attempts in the areas thought to be responsible for conflict detection (left dorsal ACC) and retrieval inhibition (right anterior vlPFC), whereas this decrease was not significant in the case of low suppressors. The individual difference of suppression ability should also manifest during the problem solving stage, where behavioral suppression scores should indicate the decline of intrusions from the first until the last solution attempt and thus negatively correlate with difference on the proportion of correct solutions between the first and the last attempt to solve.

A novel paradigm, the *guess method* was used to elicit PIF in word fragment problems. In the guess method participants repeatedly guessed solutions to word fragment problems and were only allowed a limited amount of time to make their guesses, without the ability to spend more time to think about a problem. The rationale behind the procedure was that the initial quick exposure to the problem would activate the pre-potent red herring and the checking procedure that follows would assist in flagging this initial answer wrong. Subsequent exposures to the same problem should then activate retrieval inhibition for the inadequate pre-potent answer (the red herring). In the few published studies about PIF participants needed to work continuously on the solution for the problem (Becker et al., 2020; Storm et al., 2011). This might lead to persistent fixation due to the unchanged temporal context (Chapter 2, Experiments 3 and 4; also see Smith & Beda, 2020b), the elimination of which might tap into completely different neural processes than retrieval induced forgetting. Retrieval induced forgetting is thought of as automatic retrieval inhibition of targets that are incorrect, however, imaging evidence for this inhibitory process is very limited (Kuhl et al., 2007) and is not exclusive to automatic processes. There is, however, evidence about automatic retrieval inhibition from studies of voluntary suppression that points toward the role of the right inferior frontal gyrus (rIFG) as an important element in the process (e.g., Depue et al., 2007). Inhibition of retrieval though should be different than selection against the already retrieved wrong target, where evidence suggest the left inferior frontal gyrus (lIFG) to be a key player (Schnur et al., 2005; Thompson-Schill et al., 1998). Becker et al (2020) in their imaging study about PIF fall short of differentiating between automatic processes of inhibition and voluntary suppression because the behavioral paradigm they used does not allow dissociation between these two processes due to the continuous thinking participants are allowed. In the guess method quick guesses had to be made following a short exposure to the problem (500 ms). The time allowed to make a guess was not long enough to consciously think about the problem (3 sec), in addition, participants were instructed to say the first word that comes to mind. Consequently, the guesses reported are expected to be automatic, so whenever a studied distractor was reported as a guess participants had to select against it to be able to continue thinking, and whenever there was no guess, or an unstudied distractor was reported, automatic retrieval inhibition of the studied distractor could be assumed.

Following the behavioral validation of this novel paradigm, an imaging experiment was conducted to examine neural correlates of efforts aimed at elimination of mnemonic competition of orthographically similar, and therefore incorrect, solutions to word fragments.

Experiment 7: Problem Solving Induced Forgetting Using Word Fragment Problems and the Guess Method

The method used in both the behavioral and the imaging experiments was similar and consisted of three stages. In the memory encoding stage participants had to memorize and practice misleading *red herring* words that were orthographically similar to solutions of word fragment completion problems (e.g., ANALOGY for the fragment A _ L _ _ GY, *solution: allergy*) together with faces of different people. In the following problem solving stage participants had multiple attempts to solve the words fragments, to half of the red herrings memorized during encoding, using the *guess method*. Finally, in the memory test phase, participants were tested again on their memories about the face-red herring pairs encoded in phase 1. A visual depiction of the method for both Experiments 7 and 8 is displayed on Figure 9. In Experiment 7 the following predictions were made: During the memory encoding and practice phase, memory of the pairing of red herring words and faces would gradually increase. During the multiple attempts to solve the word fragment problems solution rates would gradually increase and, in the meantime, the number of intrusions, that is the number of times participants used the red herring word as a solution, would gradually decrease. The change in the number of intrusions between the first and last solution attempts should also predict the change in the number of correct solutions. During the final memory test memory of the red herrings that were also involved in the problem solving phase would be inferior to those that were not (the baseline items.) Finally, this memory deficit predicted the overall reduction of red herring intrusions during the problem solving stage in the individual level with high suppressors, that is, those with their suppression scores above the group mean.

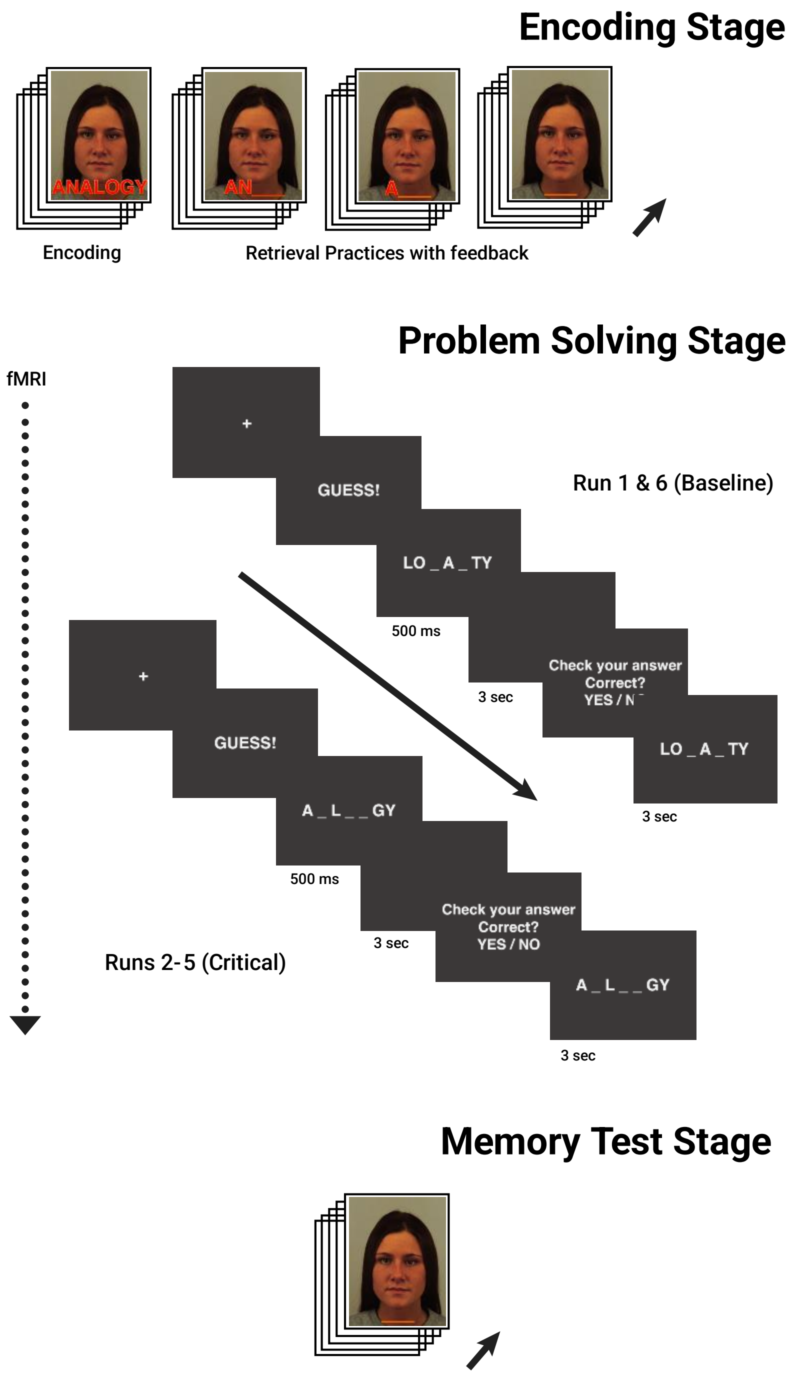

Figure 9 The guess method paradigm. Following the encoding and retrieval practices of red herrings is the problem solving stage, where participants had to guess the correct solution for word fragments that are orthographically similar to half of the red herring words that were practiced before, and then had to evaluate their guesses for correctness. The last stage was a final memory test for all red herring words that were practiced in the encoding stage.

Method

Participants. Based on earlier reports of RIF Murayama et al. (2014) in their meta-analysis suggested a fail-safe *N* of at least 56 based on a moderate to weak effect size of g = .35. Storm et al. in their report of PIF (2011) reported effect sizes between d = .26 and d = .54. Based on a power analysis assuming an effect size of d = .4 and an alpha level of .05, a total sample size of N = 80 was used for the experiment. Participants were undergraduate students who volunteered to fulfill a course requirement.

Design. A 2 (suppression: suppressed vs non-suppressed, baseline red herrings, within-subjects) X 2 (counterbalancing: between-subjects) mixed design was used, using *memory*, the proportion of total items that were remembered at the final memory test as the dependent measure. Experimental design of Experiment 7 and 8 can be found in Appendices J1 and J2.

Materials. The experiment was run entirely on the Qualtrics online platform (Qualtrics, Provo, UT). Participants were using their own computers or tablets to see the stimuli and type in the answers, cellphones were not be permitted to be used to complete the experiment.
Word fragment problems were be selected based on earlier reports (Chapter 3, Experiments 5 and 6, also see Smith & Beda, 2020a), and 3 preliminary pilot experiments to proof the stimuli. For a total of 22 critical word fragment problems, 22 orthographically similar red herring words were assigned. In addition, 5 words fragment problems to be positively primed and 16 neutral, non-critical word fragment problems were also included in the experiment. Word fragment words, red herring words, and neutral items were all unique within the materials. Furthermore, neutral baseline, and positively primed non-critical items started with a different letter than critical word fragment problems and red herring words.

A total of 27 background pictures of human faces with neutral facial expression (14 female and 13 male) were be selected from the Karolinska Directed Emotional Faces (KDEF) database (Lundqvist et al., 1998). Each picture was randomly assigned to a priming word, making sure that an equal number of male and female faces appear in each counterbalancing. Stimulus words were be typed on the bottom of the pictures shown in red and outlined in yellow. The 22 critical word fragment problems and their red herrings were counterbalanced so that each problem was used in each treatment condition.

Procedure. Participants used the online platform Qualtrics[7] (Qualtrics, Provo, UT) to participate on the experiment. Following the consent procedure and some control questions about their environment, participants had to complete the experiment without an interruption. Participants who logged out of the platform before completing all of the tasks were excluded. For the encoding stage participants tried to memorize 27 faces together with 27 words (11 baseline + 11 suppressed + 5 positively primed). They saw a slideshow of the faces with the words to be memorized on the bottom of the picture. They had 5 seconds to see each stimulus. The encoding stage was followed by 3 retrieval practices (RP). In a RP, participants saw the picture and had 10 seconds to type the word that was associated with it into an answer box. After the 10 seconds elapsed, the correct word was displayed along with the picture for an additional 10 seconds. To help with the retrieval, the first RP also displayed the first two letters of the to-be-remembered word. This was be reduced to the first letter only for the second RP and no additional help was be given for the third RP.

[7] The Qualtrics platform is primarily designed for online surveys and questionnaires. Even though it has a timer function, it shows variability in the actual timing of the display of stimuli. The effect of this variability and the additional noise introduced by the nature of the online study could only be reduced by the greater statistical power resulted by adding participants to the study.

The problem solving stage consisted of three different sections. In the sections at the beginning and the end of the problem solving stage, participants had to solve 8-8 never before seen word fragment problems (*the solve method*). These problems were be the baseline items for the scanning experiments and were used to norm solution rates in Experiment 7. After the word fragment problem appeared participants had 10 seconds to type an answer into their answer box. In the middle section of the problem solving stage participants had to solve 11 of the 22 critical word fragment problems. Participants saw each problem 6 different times in blocks of 11. In the initial block 5 positively primed word fragment problems were also be displayed to lure participants into thinking that words studied during the encoding stage would assist them during problem solving. In this section the *guess method* was be used to receive answers from participants. In the guess method, participants only saw the word fragment problems for 500ms and then had 5 seconds to make a guess and type their guess into the answer box. Following the guess, the word fragment problem returned to the screen and participants had 3 seconds to check their initial guess and report whether their guess was correct or not using clickable YES and NO boxes.

During the memory test stage, memory for the initially encoded red herring-face pairs was tested. In a test 22 of the original 27 pictures were shown to the participants (all of the critical items) and they had 5 seconds to type in what words were associated with the picture displayed. The whole procedure took approximately 1 hour. A visual depiction of the method is displayed on Figure 9.

Results

4 of the 80 participants did not complete the experiment in one sitting and were excluded from the analysis (N = 76) As a manipulation check for the retrieval practice in the Encoding

phase, a repeated measures analysis of variance (ANOVA) indicated a significant difference between the three stages of retrieval practice (*M1* = 0.31, *SD1* = 0.19; *M2* = 0.51, *SD2* = 0.22; *M3* = 0.54, *SD3* = 0.25). The data failed the assumption of sphericity ($W = .722$, $p < .001$), so calculations were made using the Huynh-Feldt correction; [$F(1.59, 119.43) = 80.4$; $p < .001$; $\eta^2_p = .517$]. Post-hoc pairwise comparisons with a Bonferroni correction revealed differences between the first and the second [$t(75) = 11.94$; $p < .001$] and the first and the third [$t(75) = 9.37$; $p < .001$] retrieval practices. Participants gradually got better at retrieving red herring words with more practice. There was no significant difference between the second and the third practices [$t(75) = 1.53$; $p = .393$].

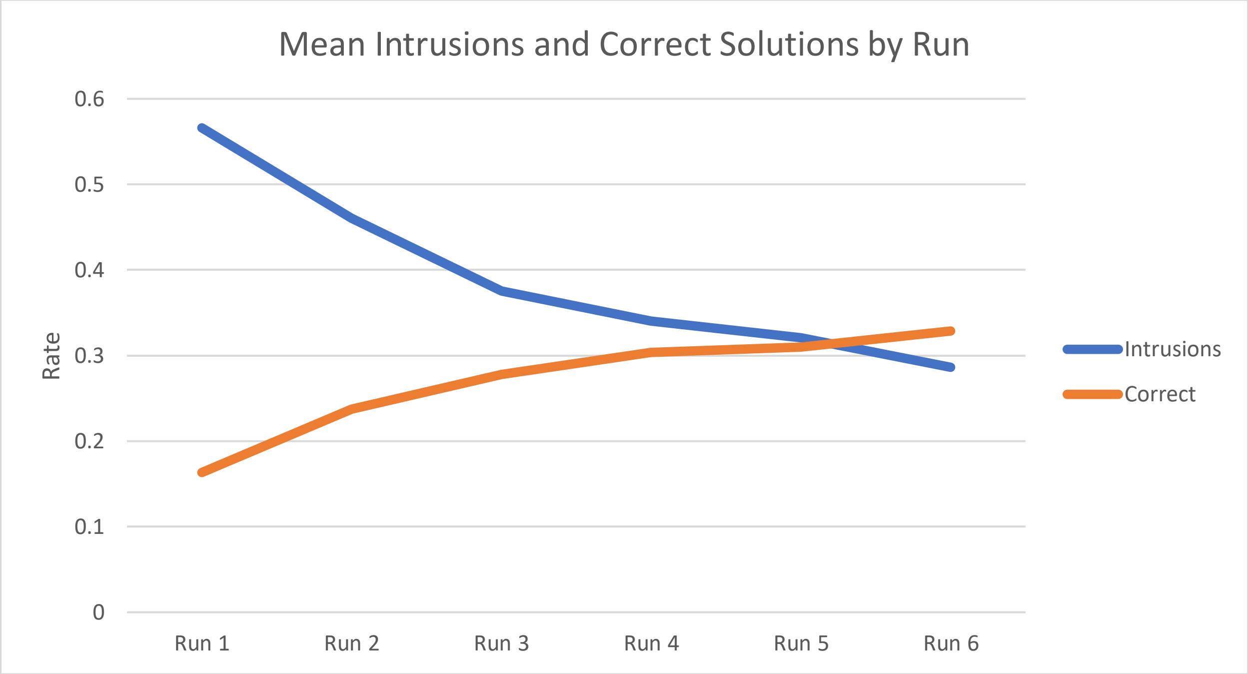

Figure 10 Mean proportion of intrusions and correct solutions as a function of number of solution attempts

To explore how solution rates changed during problem solving, a within-subjects analysis of variance (ANOVA) showed a significant difference among solution rates over the 6 solution trials (Figure 10). The data failed the assumption of sphericity ($W = .343$, $p < .001$), so calculations were made using the Huynh-Feldt correction [$F(3.84, 287.85) = 25.5$; $p < .001$; $\eta^2_p = .254$]. The results of post-hoc pairwise comparisons are shown on Table 2. Number of correct solutions gradually increased with the solution attempts.

Post Hoc Comparisons - Solution Attempts

Comparison							
Solution Attempts		Solution Attempts	Mean Difference	SE	df	t	$p_{bonferroni}$
1st	-	2nd	-0.07416	0.0175	75.0	-4.236	< .001
	-	3rd	-0.10646	0.0151	75.0	-7.061	< .001
	-	4th	-0.13158	0.0181	75.0	-7.256	< .001
	-	5th	-0.13876	0.0196	75.0	-7.079	< .001
	-	6th	-0.15789	0.0208	75.0	-7.587	< .001
2nd	-	3rd	-0.03230	0.0144	75.0	-2.240	0.421
	-	4th	-0.05742	0.0152	75.0	-3.773	0.005
	-	5th	-0.06459	0.0158	75.0	-4.095	0.002
	-	6th	-0.08373	0.0201	75.0	-4.174	0.001
3rd	-	4th	-0.02512	0.0102	75.0	-2.472	0.235
	-	5th	-0.03230	0.0142	75.0	-2.272	0.390
	-	6th	-0.05144	0.0164	75.0	-3.143	0.036
4th	-	5th	-0.00718	0.0109	75.0	-0.660	1.000
	-	6th	-0.02632	0.0151	75.0	-1.741	1.000
5th	-	6th	-0.01914	0.0142	75.0	-1.350	1.000

Table 2 Post-hoc comparisons of correct solution rates over the 6 solution attempts

The same exploratory analysis of intrusion rates during problem solving, another within-subjects analysis of variance (ANOVA) showed a significant difference among intrusion rates over the 6 solution trials (Figure 10). The data failed the assumption of sphericity ($W = .287$, $p < .001$), so calculations were made using the Huynh-Feldt correction [$F(3.54, 265.49) = 37.2$; $p < .001$; $\eta^2_p = .332$]. The results of post-hoc pairwise comparisons are shown on Table 3. Number of intrusions gradually decreased with the solution attempts.

Post Hoc Comparisons - Solution Attempts

Comparison							
Solution Attempts		Solution Attempts	Mean Difference	SE	df	t	$p_{bonferroni}$
1st	-	2nd	0.1053	0.0232	75.0	4.53	< .001
	-	3rd	0.1914	0.0256	75.0	7.48	< .001
	-	4th	0.2237	0.0308	75.0	7.27	< .001
	-	5th	0.2548	0.0313	75.0	8.15	< .001
	-	6th	0.2799	0.0316	75.0	8.87	< .001
2nd	-	3rd	0.0861	0.0191	75.0	4.51	< .001
	-	4th	0.1184	0.0197	75.0	6.01	< .001
	-	5th	0.1495	0.0229	75.0	6.53	< .001
	-	6th	0.1746	0.0294	75.0	5.94	< .001
3rd	-	4th	0.0323	0.0165	75.0	1.96	0.807
	-	5th	0.0634	0.0199	75.0	3.18	0.032
	-	6th	0.0885	0.0245	75.0	3.61	0.008
4th	-	5th	0.0311	0.0203	75.0	1.54	1.000
	-	6th	0.0562	0.0241	75.0	2.33	0.338
5th	-	6th	0.0251	0.0207	75.0	1.21	1.000

Table 3 Post-hoc comparisons of intrusion rates over the 6 solution attempts

To test whether the reduction of intrusions (*M* = 0.28, *SD* = 0.275) reliably predicted the improvement of solutions (*M* = 0.158, *SD* = 0.181), a simple linear regression was calculated. The omnibus test found a significant relationship [$F(1, 74) = 24.4$, $p < .001$] with $R^2 = .248$ Predicted improvement of solutions was 0.066 + 0.328(decrease in intrusions). During the 6 solution attempts solution rates improved by about 33% for a 100% reduction of intrusions.

To find the Problem Solving Induced Forgetting effect, a paired-samples t-test was to be used to find a difference between recall of baseline (*M* = 0.477, *SD* = 0.282, *Mdn* = 0.5) and suppressed (*M* = 0.426, *SD* = 0.259, *Mdn* = 0.364) items in the final memory test. The data violated the assumption of normal distribution (*W* = 0.959, *p* = .015), therefore a Wilcoxon signed-rank test was used instead. Significant evidence was found that recall scores for suppressed items were lower compared to recall of baseline items [Wilcoxon *W* = 1411, *p* = .027].

To determine whether the individual ability to suppress wrong answers, operationalized as a difference between memory performance of suppressed and baseline items in the final memory test (*M* = 0.051, *SD* = 0.187) predicted decrease in the proportion of intrusions over the 6 solution attempts (*M* = 0.28, *SD* = 0.275), a simple linear regression was calculated. The omnibus test found no significant relationship [$F(1, 74) = 0.32$, $p = .573$]. This same relationship between suppression scores (*M* = 0.22, *SD* = 0.103) and decrease of intrusions (*M* = 0.298, *SD* = 0.274), remained non-significant even after a median split to eliminate low-suppressors [$F(1, 34) = 0.32$, $p = .43$].

Discussion

Experiment 7 tested whether reliable problem solving induced forgetting effects could be found using word fragment completion and the novel guess method. As predicted, memory of words was inferior at a final memory test when these words were used as red herrings in a problem solving task compared to words that were not misleading wrong solutions to word fragment problems. This result supports the presence of problem solving induced forgetting. The result is especially interesting in light of the fact that during initial attempts for problem solving the same red herring words, to which memory was shown to be inferior in the final memory test, came up as intrusions. This means that participants were actually exposed to them more than to the baseline items, in fact, they were generating these red herring words as replies during problem solving which, according to the generation effect (Slamecka & Graf, 1978), should have increased memory further.

Another prediction for Experiment 7 was a manipulation check, that during the memory encoding and practice phase memory of the pairing of red herring words and faces would gradually increase. This prediction was also supported by the data, indicating a successful encoding manipulation. Proportion of correct answers for the third retrieval practice was still fairly low at 54%, this was probably due to not providing participants with a letter stem for the third retrieval attempt. A third feedback after the retrieval attempt was added to Experiment 8 to improve memory scores.

During the multiple attempts to solve the word fragment problems solution rates gradually increased and, in the meantime, the number of intrusions, that is the number of times participants used the red herring word as a solution, gradually decreased as predicted. Furthermore, the change in the number of intrusions between the first and last solution attempts reliably predicted the change in the number of correct solutions. The more the proportion of intrusions was reduced, the more correct solutions participants had, an indication that forgetting fixation during the incubation period does give way to correct solutions.

The final prediction that the suppression score, memory deficit due to suppression of red herrings, would predict the overall reduction of red herring intrusions during the problem solving stage in the individual level was not supported by the data. This prediction was not supported either in the full sample, nor looking into high suppressors only following a median split. This no result could have been caused by the lack of statistical power, especially because using a fully online paradigm might have introduced several additional variables that were difficult to control. A fully online experiment should have probably used a much larger sample to reach statistical significance.

Experiment 8: Neural Correlates of Problem Solving Induced Forgetting in a Word Fragment Paradigm

Following the probing of the behavioral paradigm, an imaging experiment was conducted to find neural correlates of retrieval inhibition and voluntary suppression of the intruding red herrings during the problem solving stage. The experimental paradigm was identical to the one used in Experiment 7 with some modifications for imaging. To be able to better compare baseline and suppression conditions for imaging purposes, *guess* trials were used for all problem solving items so the only difference between baseline and suppression conditions for imaging purposes was the stimuli used. Another change in the paradigm was the introduction of a 1-3 second random jitter before each problem solving trial to better separate hemodynamic response functions belonging to each trial. In the imaging experiment, instead of typing, all answers were given verbally and were recorded during the experiments. This also enabled the shortening of time participants were allowed to work on the problems, since no typing was involved. The encoding and the final test stages took place in an isolated preparation room in the imaging center and the problem solving stage took place in the fMRI scanner. This change of procedure also carried a concern for context effects to outshine the effect of problem solving induced forgetting. The outshining effect is when the presence of a stronger effect obscures one of a lower effect size (e.g., McDaniel et al., 1989; Smith & Vela, 1986, 2001). In our case, effects of context reinstatement between the encoding and the final test (both procedures used the same room and the same equipment, while the problem solving trials were taking place in a noisy fMRI scanner in a different room and a different body position) might outshine effects of problem solving induced forgetting due to retrieval inhibition of intruding red herring words. To counter the outshining effect and to make forgetting stronger, two additional attempts at problem solving were added to Experiment 8 for a total of 8 attempts. The predictions regarding behavioral results were the same as for Experiment 7. For the imaging results, heightened activation for the brain areas thought to be responsible to control mnemonic competition, namely the anterior cingulate cortex (ACC), and the dorsolateral and ventrolateral pre-frontal cortices (dlPFC, vlPFC) was predicted. Furthermore, this heightened activation was expected to gradually decrease during subsequent problem solving attempts. The magnitude of the total decrease of activation during problem solving trials was also expected to be predicted by the number of intrusions during problem solving and results of the final memory test on an individual level; the greater the decrease of intrusions and the greater the forgetting, the greater the decrease of activation in the ACC and vlPFC.

Method

Participants. The number of participants was determined based on the results and effect size in Experiment 7. Some participants were recruited using internal emails of the university and were paid $20 for participation, others participated for an exchange of experimental credits as part of their compulsory class assessment for introductory psychology classes. 30 Right-handed English speaking students between the ages 18 and 30 were planned to be recruited from the university for the scanning experiment. Exclusion criteria for the participants was the presence of contraindications for the fMRI environment. Participants were consented and the procedure approved by the Texas A&M University Institutional Review Board. The results reported here are based on the data collected from those 15 participants. Prior to the experiment, a pilot version was also conducted with almost the same protocol that also collected data from 14 participants, protocol differences are described in the procedures subsection. For the behavioral calculations data is also reported pooling the participants of the pilot experiment and Experiment 8 together.

Design. A 2 (suppression: suppressed vs non-suppressed, baseline red herrings, within-subjects) X 2 (counterbalancing: between-subjects) mixed design was used, using *memory*, the proportion of total items that were remembered at the final memory test as the dependent measure.

Materials. For the behavioral part of the study, the same materials were used as in Experiment 7 with the following exceptions. Computer monitors in a separated room or in the scanning suite were used to present the data. Microphones were used to collect verbal answers from the participants.

fMRI Data Acquisition, Preprocessing and General Linear Analysis. fMRI data was collected using 3T Siemens Magnetom Verio (software version syngo_MR_B17) equipment, using multi-band pulse sequences with a 32-channel head coil. Structural images were acquired using a sagittal T1-weighted interleaved sequence (repetition time (TR) = 1900 ms, echo-time (TE) = 2.52 ms, flip angle = 9o, voxel resolution = 1 mm) and a sagittal T2-weighted interleaved sequence (repetition time (TR) = 3200 ms, echo-time (TE) = 561 ms, flip angle = 120o, voxel resolution = 0.8 mm). Six runs of multiband Echo Planar Images (EPI) were be acquired in the posterior to anterior direction with the following parameters (multiband acceleration factor = 4, bandwidth = 2000 Hz/Px, TR = 1000 ms, TE = 24.2 ms, echo-spacing = 0.62 ms, flip angle = 52o, voxel resolution = 2.5 mm). The length of the six runs varied between 2:00 min and 6:00 min depending on the tasks (baseline or critical trials). The 6 runs of functional data were acquired while participants were performing the word fragment completion tasks. In addition, a pair of spin-echo images with identical parameters to the functional runs except with opposing phase encoding (AP and PA) were collected to allow for distortion correction {topup}. Preprocessing tasks of motion correction, realignment, co-registration, segmentation into gray matter, white matter, and cerebrospinal fluid, normalization, and parcellation was performed using the minimal preprocessing, and functional pipelines from the Human Connectome Project (Glasser et al., 2013).

For the analysis of the preprocessed fMRI data, suppression was modeled with a duration of 3 s (the time allowed for the guess from the onset of stimulus) and was convolved with the double-gamma canonical hemodynamic response function (HRF). Second-level fixed effects analyses modeled the following between-run contrasts: Early Suppression Trials > Baseline Trials, Early Attempts > Late Attempts.

Group level analyses were be performed using Permutation Analysis of Linear Models (PALM, Winkler et al., 2014); Cohen's D effect sizes were calculated due to low sample size.

Procedure. The three stages of the experiment were similar to those in Experiment 7 with the following differences. The encoding stage took place in a separated room in the imaging center. After the explanation of the task participants had to give their answers verbally, using a microphone in front of the screen.

After an explanation and practice of the word fragment completion task in the same room, participants were taken to the imaging suite to perform the problem solving task. The problem solving stage consisted of 6 scanning runs. The first and last runs were the baseline, never before seen word fragment problems, using the *guess method*. For the pilot experiment the *solve method* described in Experiment 7 was used for the baseline problems in runs 1 and 6. The 4 middle runs each consisted of 2 blocks of critical, blocked word fragment problems, using the same *guess method*. The first attempt at the critical trains contained 5 positively primed work fragment problems to make participants think of the red herring words that were part of the encoding stage as potential solutions. Between problems, a random jitter of 1-3 seconds was added to better separate hemodynamic responses for individual problems. For the pilot data no random jitter was added. Structural data was collected after the completion of all the problem solving tasks.

Following the problem solving stage, participants had to return to the preparation room and complete the final memory test using the same computer screen and microphone as during the encoding stage. The entire procedure took no more than 90 minutes.

Results

Behavioral Data. As a manipulation check for the retrieval practice in the Encoding phase, a repeated measures analysis of variance (ANOVA) indicated a significant difference between the three stages of retrieval practice ($M1 = 0.27$, $SD1 = 0.09$; $M2 = 0.39$, $SD2 = 0.2$; $M3 = 0.43$, $SD3 = 0.23$); [$F(2, 28) = 6.62$; $p = .004$; $\eta^2_p = .321$]. Post-hoc pairwise comparisons with a Bonferroni correction revealed differences between the first and the second [$t(14) = 3.1$; $p = .024$] and the first and the third [$t(14) = 3$; $p = .03$] retrieval practices. Participants gradually got better at retrieving red herring words with more practice. There was no significant difference between the second and the third practices [$t(14) = 1$; $p = 1$].

The same manipulation check for retrieval practice in the encoding phase using the combined data for the pilot experiment and Experiment 8, the repeated measures ANOVA also indicated a significant difference between the three stages ($M1 = 0.29$, $SD1 = 0.09$; $M2 = 0.46$, $SD2 = 0.21$; $M3 = 0.49$, $SD3 = 0.25$); [$F(2, 56) = 20$; $p < .001$; $\eta^2_p = .416$]. Likewise, post-hoc pairwise comparisons with a Bonferroni correction revealed differences between the first and the second [$t(28) = 5.17$; $p < .001$] and the first and the third [$t(28) = 4.92$; $p < .001$] retrieval practices. Participants gradually got better at retrieving red herring words with more practice. There was no significant difference between the second and the third practices [$t(28) = 1.16$; $p = .762$].

To explore how intrusion rates changed during problem solving, a within-subjects analysis of variance (ANOVA) was computed and showed a significant difference among intrusion rates over the 8 solution trials. The data failed the assumption of sphericity (W = .0019, p = .004), so calculations were made using the Huynh-Feldt correction [$F(3.89, 42.75) = 16.3$; $p < .001$; $\eta^2_p = .597$]. The results of post-hoc pairwise comparisons are shown on Table 4. Number of intrusions gradually decreased with the solution attempts.

Post Hoc Comparisons - Attempt

Comparison							
Attempt		Attempt	Mean Difference	SE	df	t	$p_{bonferroni}$
1st	-	2nd	0.1288	0.0597	11.0	2.157	1.000
	-	3rd	0.1818	0.0690	11.0	2.636	0.649
	-	4th	0.2576	0.0732	11.0	3.517	0.135
	-	5th	0.3333	0.0825	11.0	4.041	0.054
	-	6th	0.3712	0.0721	11.0	5.152	0.009
	-	7th	0.3712	0.0694	11.0	5.349	0.007
	-	8th	0.3864	0.0735	11.0	5.258	0.008
2nd	-	3rd	0.0530	0.0306	11.0	1.735	1.000
	-	4th	0.1288	0.0284	11.0	4.529	0.024
	-	5th	0.2045	0.0476	11.0	4.294	0.036
	-	6th	0.2424	0.0492	11.0	4.927	0.013
	-	7th	0.2424	0.0492	11.0	4.927	0.013
	-	8th	0.2576	0.0385	11.0	6.691	< .001
3rd	-	4th	0.0758	0.0293	11.0	2.590	0.704
	-	5th	0.1515	0.0438	11.0	3.458	0.150
	-	6th	0.1894	0.0454	11.0	4.172	0.044
	-	7th	0.1894	0.0425	11.0	4.451	0.027
	-	8th	0.2045	0.0435	11.0	4.700	0.018
4th	-	5th	0.0758	0.0401	11.0	1.890	1.000
	-	6th	0.1136	0.0373	11.0	3.045	0.312
	-	7th	0.1136	0.0421	11.0	2.702	0.576
	-	8th	0.1288	0.0284	11.0	4.529	0.024
5th	-	6th	0.0379	0.0284	11.0	1.332	1.000
	-	7th	0.0379	0.0284	11.0	1.332	1.000
	-	8th	0.0530	0.0440	11.0	1.205	1.000
6th	-	7th	0.0000	0.0158	11.0	0.000	1.000
	-	8th	0.0152	0.0351	11.0	0.432	1.000
7th	-	8th	0.0152	0.0401	11.0	0.378	1.000

Table 4 Post-hoc comparisons of intrusion rates over the 8 solution attempts

Using the combined data for the pilot and Experiment 8 for the exploratory analysis of intrusion rates, another within-subjects analysis of variance (ANOVA) showed a significant difference among intrusion rates over the 8 solution trials (Figure 11). The data failed the assumption of sphericity (*W* = .036, $p < .001$), so calculations were made using the Huynh-Feldt correction [$F(3.92, 94.11) = 31.2$; $p < .001$; $\eta^2_p = .565$]. The results of post-hoc pairwise comparisons are shown on Table 5. Number of intrusions gradually decreased with the solution attempts.

Post Hoc Comparisons - Attempt

Comparison							
Attempt		**Attempt**	**Mean Difference**	**SE**	**df**	**t**	**$p_{bonferroni}$**
1st	-	2nd	0.16364	0.0360	24.0	4.548	0.004
	-	3rd	0.24000	0.0472	24.0	5.084	< .001
	-	4th	0.30182	0.0466	24.0	6.481	< .001
	-	5th	0.33455	0.0483	24.0	6.925	< .001
	-	6th	0.36000	0.0474	24.0	7.599	< .001
	-	7th	0.35636	0.0478	24.0	7.456	< .001
	-	8th	0.38909	0.0465	24.0	8.366	< .001
2nd	-	3rd	0.07636	0.0305	24.0	2.507	0.542
	-	4th	0.13818	0.0283	24.0	4.879	0.002
	-	5th	0.17091	0.0337	24.0	5.066	< .001
	-	6th	0.19636	0.0347	24.0	5.661	< .001
	-	7th	0.19273	0.0390	24.0	4.937	0.001
	-	8th	0.22545	0.0332	24.0	6.782	< .001
3rd	-	4th	0.06182	0.0194	24.0	3.180	0.113
	-	5th	0.09455	0.0285	24.0	3.318	0.081
	-	6th	0.12000	0.0300	24.0	3.997	0.015
	-	7th	0.11636	0.0299	24.0	3.888	0.020
	-	8th	0.14909	0.0301	24.0	4.954	0.001
4th	-	5th	0.03273	0.0251	24.0	1.304	1.000
	-	6th	0.05818	0.0234	24.0	2.486	0.567
	-	7th	0.05455	0.0278	24.0	1.964	1.000
	-	8th	0.08727	0.0226	24.0	3.868	0.021
5th	-	6th	0.02545	0.0207	24.0	1.231	1.000
	-	7th	0.02182	0.0218	24.0	1.000	1.000
	-	8th	0.05455	0.0268	24.0	2.038	1.000
6th	-	7th	-0.00364	0.0185	24.0	-0.196	1.000
	-	8th	0.02909	0.0227	24.0	1.281	1.000
7th	-	8th	0.03273	0.0222	24.0	1.475	1.000

Table 5 Post-hoc comparisons of intrusion rates over the 8 solution attempts

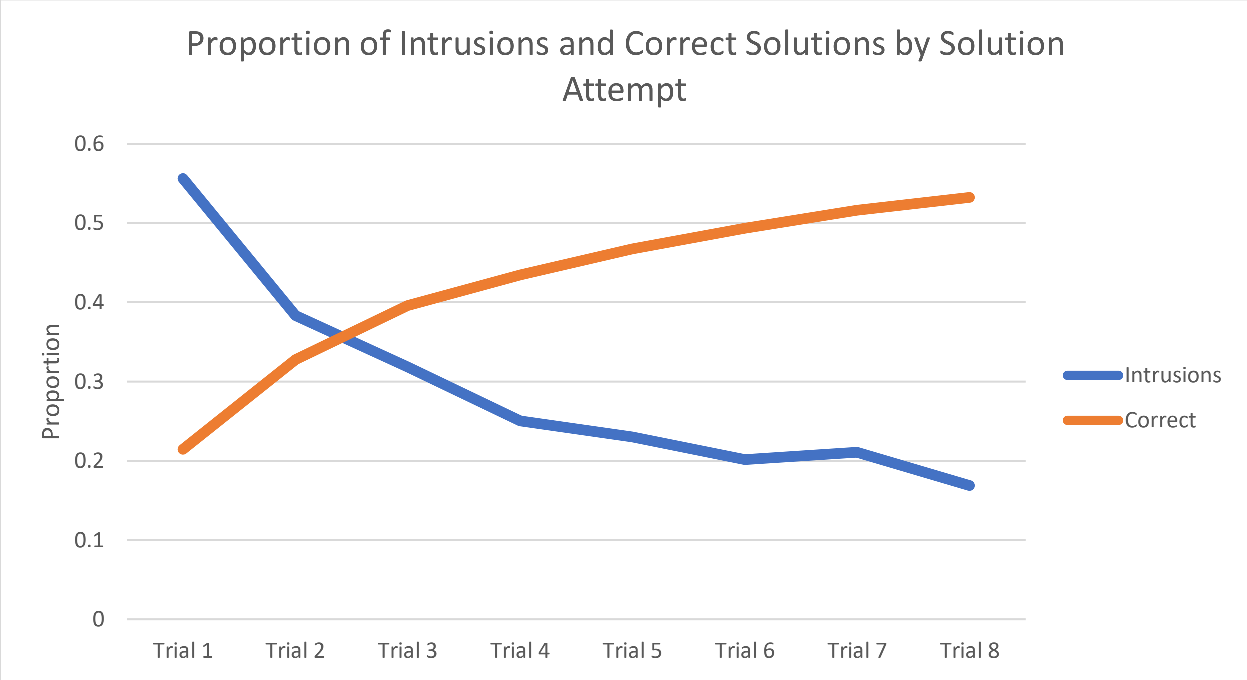

Figure 11 Mean proportion of intrusions and correct solutions as a function of solution attempts

Continuing the exploratory analysis of the problem solving stage with the correct solution rates, a within-subjects analysis of variance (ANOVA) showed a significant difference among correct solution rates over the 8 solution trials. The data failed the assumption of sphericity (W = .0024, p = .006), so calculations were made using the Huynh-Feldt correction [$F(3.39, 37.25) = 14.2$; $p < .001$; $\eta^2_p = .563$]. The results of post-hoc pairwise comparisons are shown on Table 6. Number of correct solutions gradually increased with the solution attempts.

Post Hoc Comparisons - Attempts

Comparison							
Attempts		Attempts	Mean Difference	SE	df	t	$p_{bonferroni}$
1st	-	2nd	-0.0682	0.0463	11.0	-1.472	1.000
	-	3rd	-0.1667	0.0621	11.0	-2.682	0.597
	-	4th	-0.2121	0.0552	11.0	-3.843	0.077
	-	5th	-0.2424	0.0665	11.0	-3.645	0.108
	-	6th	-0.2652	0.0628	11.0	-4.225	0.040
	-	7th	-0.2879	0.0631	11.0	-4.560	0.023
	-	8th	-0.3106	0.0647	11.0	-4.799	0.016
2nd	-	3rd	-0.0985	0.0306	11.0	-3.223	0.227
	-	4th	-0.1439	0.0284	11.0	-5.062	0.010
	-	5th	-0.1742	0.0325	11.0	-5.354	0.007
	-	6th	-0.1970	0.0431	11.0	-4.570	0.022
	-	7th	-0.2197	0.0468	11.0	-4.699	0.018
	-	8th	-0.2424	0.0438	11.0	-5.533	0.005
3rd	-	4th	-0.0455	0.0262	11.0	-1.732	1.000
	-	5th	-0.0758	0.0246	11.0	-3.079	0.294
	-	6th	-0.0985	0.0440	11.0	-2.238	1.000
	-	7th	-0.1212	0.0424	11.0	-2.861	0.434
	-	8th	-0.1439	0.0344	11.0	-4.183	0.043
4th	-	5th	-0.0303	0.0233	11.0	-1.301	1.000
	-	6th	-0.0530	0.0284	11.0	-1.865	1.000
	-	7th	-0.0758	0.0293	11.0	-2.590	0.704
	-	8th	-0.0985	0.0236	11.0	-4.168	0.044
5th	-	6th	-0.0227	0.0299	11.0	-0.761	1.000
	-	7th	-0.0455	0.0326	11.0	-1.393	1.000
	-	8th	-0.0682	0.0277	11.0	-2.462	0.884
6th	-	7th	-0.0227	0.0198	11.0	-1.149	1.000
	-	8th	-0.0455	0.0262	11.0	-1.732	1.000
7th	-	8th	-0.0227	0.0198	11.0	-1.149	1.000

Table 6 Post-hoc comparisons of correct solution rates over the 8 solution attempts

The same exploratory within-subjects analysis of variance (ANOVA), this time for the combined data for the pilot and Experiment 8, showed a significant difference among correct solution rates over the 8 solution trials (Figure 11). The data failed the assumption of sphericity ($W = .019$, $p < .001$), so calculations were made using the Huynh-Feldt correction [$F(3.72, 89.24) = 37.6$; $p < .001$; $\eta^2_p = .611$]. The results of post-hoc pairwise comparisons are shown on Table 6. Number of correct solutions gradually increased with the solution attempts.

Post Hoc Comparisons - Attempts

Comparison							
Attempts		Attempts	Mean Difference	SE	df	t	$p_{bonferroni}$
1st	-	2nd	-0.0982	0.0277	24.0	-3.54	0.047
	-	3rd	-0.1855	0.0342	24.0	-5.42	< .001
	-	4th	-0.2291	0.0288	24.0	-7.95	< .001
	-	5th	-0.2655	0.0352	24.0	-7.55	< .001
	-	6th	-0.2836	0.0345	24.0	-8.21	< .001
	-	7th	-0.3055	0.0352	24.0	-8.69	< .001
	-	8th	-0.3273	0.0375	24.0	-8.73	< .001
2nd	-	3rd	-0.0873	0.0219	24.0	-3.98	0.016
	-	4th	-0.1309	0.0217	24.0	-6.04	< .001
	-	5th	-0.1673	0.0261	24.0	-6.42	< .001
	-	6th	-0.1855	0.0290	24.0	-6.40	< .001
	-	7th	-0.2073	0.0317	24.0	-6.53	< .001
	-	8th	-0.2291	0.0337	24.0	-6.81	< .001
3rd	-	4th	-0.0436	0.0175	24.0	-2.49	0.559
	-	5th	-0.0800	0.0225	24.0	-3.56	0.044
	-	6th	-0.0982	0.0272	24.0	-3.61	0.040
	-	7th	-0.1200	0.0291	24.0	-4.12	0.011
	-	8th	-0.1418	0.0311	24.0	-4.56	0.004
4th	-	5th	-0.0364	0.0157	24.0	-2.31	0.836
	-	6th	-0.0545	0.0166	24.0	-3.29	0.087
	-	7th	-0.0764	0.0187	24.0	-4.09	0.012
	-	8th	-0.0982	0.0209	24.0	-4.69	0.003
5th	-	6th	-0.0182	0.0174	24.0	-1.04	1.000
	-	7th	-0.0400	0.0197	24.0	-2.03	1.000
	-	8th	-0.0618	0.0215	24.0	-2.88	0.230
6th	-	7th	-0.0218	0.0121	24.0	-1.81	1.000
	-	8th	-0.0436	0.0175	24.0	-2.49	0.559
7th	-	8th	-0.0218	0.0132	24.0	-1.66	1.000

Table 7 Post-hoc comparisons of correct solution rates over the 8 solution attempts

To test whether the reduction of intrusions (*M* = 0.39, *SD* = 0.255) reliably predicted the improvement of solutions (*M* = 0.311, *SD* = 0.224), a simple linear regression was calculated. The omnibus test did not find a significant relationship [$F(1, 10) = 3.52$, $p = .09$], most probably because of the lack of power.

For the combined data for the pilot and Experiment 8, the same linear regression testing whether the reduction of intrusions (*M* = 0.39, *SD* = 0.233) reliably predicted the improvement of solutions (*M* = 0.327, *SD* = 0.187) was calculated. This time omnibus test did find a significant relationship [$F(1, 23) = 17.2$, $p < .001$] with $R^2 = .428$. Predicted improvement of solutions was 0.122 + 0.527(decrease in intrusions). During the 8 solution attempts solution rates improved by about 53% for a 100% reduction of intrusions.

To find a problem solving induced forgetting effect, at the final memory test, a paired-samples t-test was used to find a difference between recall of baseline (*M* = 0.455, *SD* = 0.247) and suppressed (*M* = 0.364, *SD* = 0.22) items. Significant evidence was found that recall scores for suppressed items were lower compared to recall of baseline items [$t(13) = 2.55$, $p = .024$, $d = .681$].

The same paired-samples t-test that included participants from the pilot study [baseline (*M* = 0.566, *SD* = 0.278) and suppressed (*M* = 0.488, *SD* = 0.262)] has also found a significant difference between the two groups [$t(26) = 2.44$, $p = .022$, $d = .470$]

To determine whether the individual ability to suppress wrong answers, operationalized as a difference between memory performance of suppressed and baseline items in the final memory test (*M* = 0.083, *SD* = 0.131) predicted decrease in the proportion of intrusions over the 8 solution attempts (*M* = 0.386, *SD* = 0.255), a simple linear regression was calculated. The omnibus test found no significant relationship [$F(1, 10) = 2.62$, $p = .137$]. The median split to eliminate low suppressors was not calculated because of the lack of statistical power.

After adding the data from participants in the pilot study, the simple linear regression between suppression scores (*M* = 0.072, *SD* = 0.166) and decrease of intrusions (*M* = 0.389, *SD* = 0.233) remained non-significant [$F(1, 23) = 0.397$, $p = .535$], even after a median split to eliminate low-suppressors [suppression scores (*M* = 0.195, *SD* = 0.1); decrease of intrusions (*M* = 0.383, *SD* = 0.234); $F(1, 12) = 2.55$, $p = .136$].

Imaging Data. For the imaging results, heightened activation for the brain areas thought to be responsible to control mnemonic competition, namely the anterior cingulate cortex (ACC), and the dorsolateral and ventrolateral pre-frontal cortices (dlPFC, vlPFC) was predicted during critical problem solving trials whenever suppression of a red herring was involved as compared to baseline trials that had no associated red herrings. For the analysis of the preprocessed fMRI data, suppression was modeled with a duration of 3 s (the time allowed for the guess from the onset of stimulus) and was convolved with the double-gamma canonical hemodynamic response function (HRF). The initial second-level fixed effects analysis modeled the between-run contrast: Early Attempts > Baseline Attempts. As seen in Figures 12 and 13, imaging results show exactly the opposite of what was predicted. For the early attempts heightened activity was detected in the left hippocampus and bilateral ventromedial pre-frontal cortices (vmPFC), in the meantime, activity in the frontal areas, especially the middle frontal gyrus was lower compared to the baseline trials.

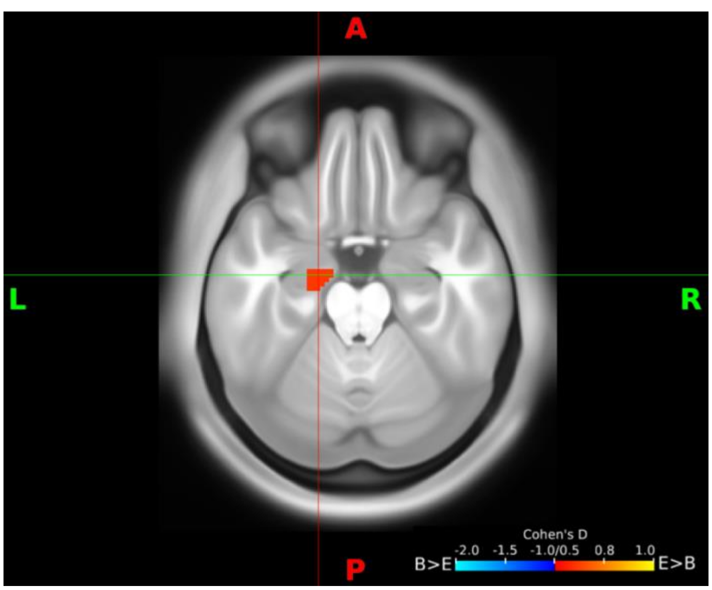

Figure 12 *In the Early Attempts > Baseline contrast heightened activity can be observed in the left hippocampus.*

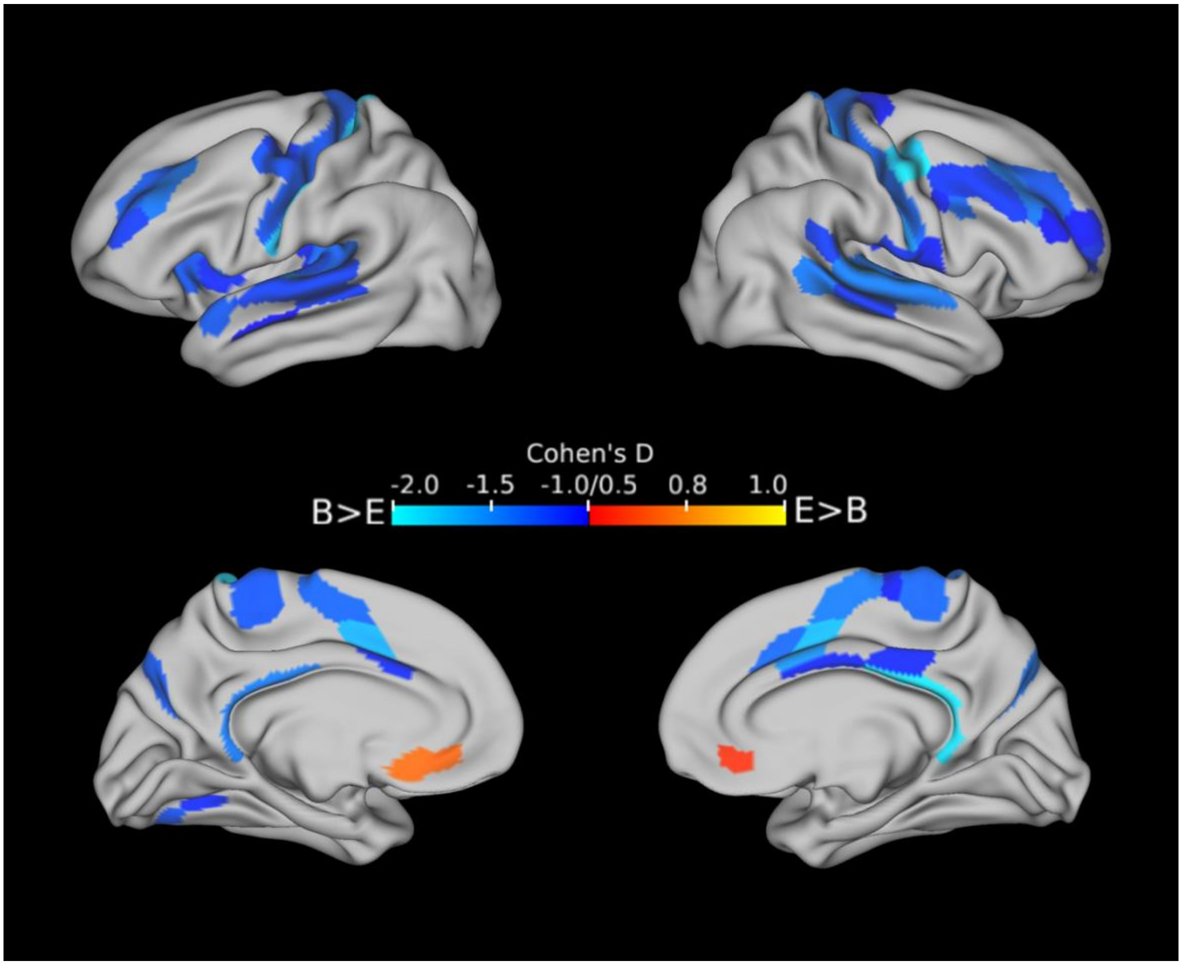

Figure 13 In the Early Attempts > Baseline contrast lower activation is detected in the frontal areas, especially the middle frontal gyrus, during early solution attempts. The vmPFC shows higher activation during early solution attempts than baseline.

The second prediction was that this heightened activation for the critical problems would gradually decrease during subsequent problem solving attempts. The second fixed-effects analysis modeled the between-run contrast: Early Attempts > Late Attempts. Figure 14 shows lower activation in bilateral hippocampi, ventral striata and the right entorhinal cortex during early attempts compared to late attempts. This is consistent with the hippocampal downregulation described by Anderson & Hanslmayr (2014) for retrieval inhibition. In the cortical areas the early attempts show heightened activation in bilateral dlPFC and vlPFC, an indication of the control effort necessary for inhibiting retrieval of the misleading red herrings.(Figure 13)

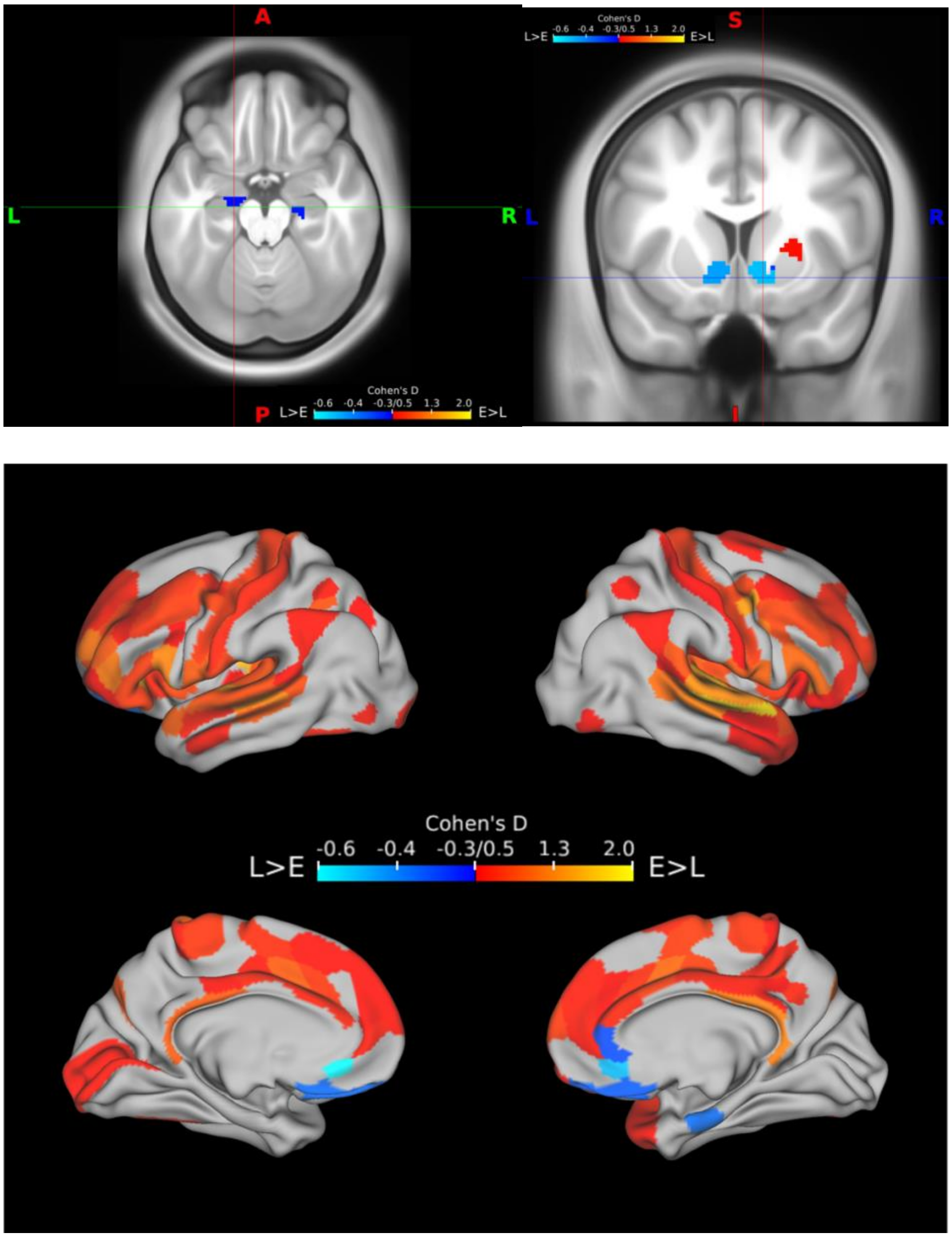

Figure 14 In the Early Attempts > Late Attempts contrast, deactivation of bilateral hippocampus (top left) and ventral striatum (nucleus accumbens, top right) is shown in the early solution attempts. In the meantime, heightened activation was detected in the prefrontal cortices in the early trials and lowered activation is shown in the right entorhinal cortex (bottom).

Discussion

Over continuous attempts to solve problems on which participants are blocked, intrusions by red herrings gradually diminished, and, in the same time, correct solution rates gradually increased. Diminishing intrusion rates reliably predicted the increase in correct solutions thus providing support for the forgetting fixation hypothesis. At the final test, memory of red herrings was inferior to the control words that were not used in the problem solving phase. This finding was counter-intuitive, as red herring words appeared as intrusions during the problem solving phase, therefore, without the additional hypothesized active inhibition, memory of these words should have been be better than those that did not appear during problem solving as red herrings. Decrease of intrusions during the course of problem solving attempts did not predict performance on the final memory test, probably due to the lack of statistical power. This prediction on both the individual and item levels, could have highlighted an individual difference in the ability to suppress unwanted memories (as described in Levy & Anderson, 2008).

If intruding red herrings are indeed inhibited from further retrieval during the multiple attempts of problem solving and this results in higher resolution rates, the process describes a *suppression account of incubation effects*.

Further evidence to the suppression account of incubation effects and neural correlates were presented in Experiment 8. Brain areas, namely bilateral dlPFC, and vlPFC, thought to be responsible to resolve mnemonic competition (Becker et al., 2020; Kuhl et al., 2007) in general, and suppression of motor (Aron et al., 2014) and memory (Depue et al., 2015; Guo et al., 2018) processes in particular, showed higher activation levels in early solution attempts than in later attempts. This is consistent with the findings of Kuhl et al (2007), who found gradually diminishing pre-frontal activation as participants went through retrieval practices in the retrieval induced forgetting paradigm. In the meantime, early solution attempts showed diminished activation levels for bilateral hippocampi and ventral striata, described by Anderson & Hanslmayr (2014) as a deregulation triggered by frontal control areas to inhibit retrieval of incorrect memories.

Imaging results contrasting the baseline problems, problems that were never primed with a misleading red herring, and early solution attempts showed the opposite of what was predicted. Hippocampal activation level was higher and prefrontal activation level lower in early solution attempts as compared to baseline levels. It is possible that hippocampal activation was higher in the critical trials because the problems looked familiar to the already studied red herrings and participants were trying to effortfully retrieve them. Prefrontal activation levels especially in the middle frontal gyrus might have been higher in the baseline attempts because participants were not primed for these problems, and with no automatic, fluent answer executive processes had to make a selection from more potential replies. Also, in the early attempts, participants might have just accepted automatic answers as correct and thus no effort to suppress these was made. It is also possible that the small sample size might have caused this result, however, the brain areas implicated are consistent with the hypothesis, only in the opposite direction. More research is needed to unveil the nature of this finding.

Results also validated the novel *guess method* used to elicit repeated suppression of the red herrings by first making a guess about the correct solution and later checking it for correctness. Other than a novel method to study retrieval inhibition, the guess method could also serve as an experimental model for analytical problem solving. The experiment was a step into disentangling the various cognitive processes and their neural correlates that are in play during creative problem solving, including memory retrieval, conflict detection, suppression, and retrieval inhibition.

More analyses are suggested with the current data. During the repeated attempts to solve the work fragment problems participants were sometimes not aware that their answer might be incorrect. This was shown when participants incorrectly assessed their own solution as correct during the second exposure to the problem. An analysis based on the correctness of the participants' self-assessment is suggested, comparing the first solution attempt after they realize that their answer is wrong to their last solution attempt. Other planned analyses should be run with parameter estimates extracted from a priori regions of interest (ROI) in the brain. The prefrontal areas, in particular the inferior frontal gyrus, the anterior cingulate and the hippocampus are all implicated as ROI in previous studies (e.g., M. C. Anderson & Hanslmayr, 2014; Kuhl et al., 2007). A generalized linear model is suggested to see how behavioral suppression success in the final memory test is predicted by the change of activation in the pre frontal areas. fMRI denoising was not performed during the processing of the brain data, multirun ICA-FIX, an automated denoising method is suggested to further process the imaging data once data collection with a larger sample size is completed.

CHAPTER 4

SUMMARY

8 experiments examined fixation, and the ways forgetting might alleviate mental blocks during incubation. Pursuing causes for fixation strength, Experiments 1 and 2 found that repetition and context reinstatement of fixating red herrings impair problem solving. Experiments 3 and 4 examined the effects of multiple red herrings and concluded that more red herrings might lead into entrenchment and cause a larger fixation effect. Looking into forgetting, Experiments 5 and 6 provided support that longer incubation times and an environmental context different from that of the initial attempt might bring release from fixation; Experiments 7 and 8 circled around automatic retrieval inhibition or suppression as the cause of incubation effects and its neural footprint, introducing a new paradigm, the guess method, into the research of problem solving induced forgetting.

The strength of fixation is an important factor when it comes to creative problem solving. The stronger the fixation, the harder it will be to eliminate in order to continue thinking into more fruitful directions. Strong fixation will more likely lead to an impasse faster, as output interference will cause the retrieval set to become biased (Raaijmakers & Shiffrin, 1981). Experiments 1 and 2 successfully demonstrated that factors positively affecting memory strength, namely repetition and context reinstatement, will increase effects of fixation. The task used in Experiments 1 and 2, the Remote Associates Task, has been used to assess creativity (e.g., Benedek & Neubauer, 2013). Repetition is thought to improve storage strength, and context reinstatement is thought to improve retrieval strength of memory items (R. A. Bjork & Bjork, 1992). Even though Experiment 1 did not show effects of context reinstatement, most probably due to the strong semantic cues present between the red herrings and the RAT words that might have outshined effects of context, in Experiment 2 a clear context-dependent fixation effect was found after simultaneous exposure to the red herrings and the RAT words was eliminated. Inappropriate use of prior knowledge has been linked to fixation and constraints by a considerable size of literature starting from the Gestalt psychologists and the already discussed functional fixedness (Adamson & Taylor, 1954; Maier, 1931). If retrieval of memories that cause fixation might be triggered by problems and contexts alike, this shows that fixation might stem from multiple sources, and efforts to eliminate it might concentrate on either memory cues or contexts that are associated with the problems.

Studies of memory about output interference (e.g., Brown, 1968; Rundus, 1973) and how a memory search is performed (e.g., Estes, 1955; Raaijmakers & Shiffrin, 1981; Slamecka, 1968) also stress the importance of the number of potential red herrings that might be associated to the same cue. The more targets, the bigger the competition for cognitive resources and the lower the performance (the *cue-overload effect* by Watkins & Watkins, 1975). Experiments 3 and 4 demonstrated that effects of too many targets connected to the same retrieval cue might also affect performance of problem solving and provided further links between studies of memory and problem solving. Entrenchment in problem solving is when multiple distractors render the problem solver even more fixated and unable to continue with the thinking process, and is consistent with findings referred to as the *list-length effect* (Strong, 1912), the already mentioned *cue-overload effect* (Watkins & Watkins, 1975), the *fan-effect* (J. R. Anderson, 1974), or the *target set size effect* (Lustig & Hasher, 2001a; Nelson et al., 1989) in studies of memory. Both Experiments 3 and 4 found considerable blocking effects when more red herrings were associated with the same cue. An interesting question is whether these multiple red herrings would also cause a heightened blocking effect when the effect is mediated by a common context. The question of blocking potential of a particular context based on distractor load could be a subject of further studies.

Chapter 2 of present dissertation examined how three variables usually determining retrievability of memories, storage strength (repetition), retrieval strength (context reinstatement), and number of competitors might affect retrieval of blockers and thus solution rates in a problem solving context. Chapter 3 looked into how already existing blockers might be forgotten to improve problem solving performance. If in problem solving this forgetting takes place during an incubation period, a time when following an impasse no active thinking is going on towards the desired target, forgotten fixation might give way to the correct solution to come to mind. Occlusion and unlearning, in which the association between the cue and the target is changed, both require additional learning that, in the case of problem solving, would only generate more misleading targets (unless we stumble into the correct solution). Forgetting due to changed retrieval cues might happen with a change of either temporal or physical context, possibilities that Experiments 5 and 6 examined. After getting participants fixated and had an unsuccessful solution attempt, length of incubation and context of second solution attempt were manipulated to find effects of temporal and physical context changes on the incubation process. A clear effect of time and context change indicated that the change of either temporal or physical context might be beneficial in forgetting fixating solutions during an incubation period in problem solving. Even though the interaction between effects of temporal and physical context did not rise to significance in the individual experiments, probably due to the lack of statistical power, a calculation combining results of Experiments 5 and 6 did find a significant interaction effect, resolution of initially unsolved problems was greater in the case of delayed second attempts whenever the original fixating context was changed. Furthermore, Experiments 5 and 6 provided a clear example where alternative explanations of incubation effects would not be suitable. The difference found in resolution rates in favor of the changed context compared to the reinstated context after the same amount of incubation cannot be explained with unconscious work, mind wandering or opportunistic assimilation. Theories of unconscious work (Dijksterhuis & Nordgren, 2006) and mind wandering (Baird et al., 2012a; Zedelius & Schooler, 2016b, 2017) both rely on additional time between two solution attempts, and opportunistic assimilation (Seifert et al., 1995) requires accidental encounters to solutions that reactivate the problem. The only difference between the two conditions in Experiments 5 and 6 is the background context displayed behind the problem that was unrelated to the solution or any part of the problem.

Finally, forgetting might happen by changes in the memory targets. If we discount temporal decay, a phenomenon the existence of which is widely debated (Neath & Brown, 2012), and organic amnesia due to trauma or aging, retrieval inhibition and voluntary suppression are two possible explanations that remain to account for forgetting. Experiments 7 and 8 examined behavioral and neural characteristics of problem solving induced forgetting (Storm et al., 2011), the problem solving version of retrieval induced forgetting as described in the memory literature (e.g., M. C. Anderson et al., 1994). A new paradigm, the guess method, was also introduced to add to the tools used to study problem solving induced forgetting. In the guess method, participants were only exposed to the problem to be solved for a short period of time (500 ms) and had to guess the answer. Following the guess, the problem was shown again and participants had to evaluate whether their guess was correct or not. This enabled participants to label their original solution as correct or incorrect and, when exposed to the same problem again, initiate the inhibition effort on the retrieval of the incorrect solution.

Behavioral results found a clear problem solving induced forgetting effect, in which memory for red herring words that were misleading solutions to word fragment completion problems in the problem solving stage of the study was inferior to memory for baseline words that were not acting as red herrings to the word fragment problems. In spite of concerns about outshining effects due to reinstatement of encoding context at the final test, forgetting was more pronounced in the case of Experiment 8 compared to Experiment 7.

Imaging results also supported the hypothesis that problem solving induced forgetting is based on cognitive and neural processes similar to retrieval induced forgetting and provided further evidence of a memory effect playing an important integral part in problem solving.

Validation of the guess method should continue in other problem solving paradigms that tap more into creative problem solving abilities, like the remote associates test or rebus problems. In Experiments 7 and 8 the word fragment completion task was used to investigate problem solving induced forgetting. The reasons for choosing the word fragment completion task was because of its relative simplicity compared to the remote associates test (only one semantic element instead of three) and the better control and more reliable effects this relative simplicity means. The word fragment completion task also exhibits similar characteristics as the remote associates test when it comes to fixation (e.g., Logan & Balota, 2003; Smith & Tindell, 1997), and incubation effects (Chapter 2, Experiments 3 and 4, also see Smith & Beda, 2020a). The word fragment completion task, however, is not universally recognized as a test of creative abilities so validation of the guess method in tests of creative abilities is necessary to be able to utilize this new method in later research.

The difference between effect sizes in Experiments 7 and Experiment 8 also suggest that, as far as suppression is concerned, *number of attempts* an individual makes to solve a problem is an important element. In Experiment 7 participants had 6 attempts to solve the word fragment problems, while in Experiment 8 participants had 8 attempts. Experiment 8 found a much more pronounced forgetting effect in spite of the potential outshining effect of context reinstatement in the paradigm. Examined whether *duration* of the solution attempt is a contributing factor in the suppression of red herrings compared to the times a participant might attempt to solve the problem should be a subject of further studies. There is already evidence that longer suppression periods, in which sustained control over intrusive memories has to be maintained, might lead to diminished control over these intrusions (van Schie & Anderson, 2017), however, it has never been tested whether repeated, short suppression attempts might be more beneficial than less, longer attempts to suppress.

Another line of research should further investigate *individual differences* in the ability to inhibit retrieval of unwanted memories and the way these individual differences are manifested in creative abilities. A growing literature already suggests that individual differences in the ability of suppression might be a contributing factor to many behavioral phenomena in both healthy and clinical cases. Memory control abilities, potentially stemming from deficits in executive control, might have modulatory effects in the purging of unwanted memories in healthy individuals, or treatment of post-traumatic stress disorder (Levy & Anderson, 2008; Streb et al., 2016). The ability to better suppress memories has also been shown to benefit creative problem solving. Participants with better forgetting scores in retrieval induced forgetting also performed better in the remote associates test (Storm & Angello, 2010). This difference in creative problem solving diminished after an incubation period indicating that whenever fixation levels are lower, differences in abilities to suppress intrusive thoughts do not make much of a difference in creative problem solving abilities (Koppel & Storm, 2014). Further investigation of populations with assumed inhibitory deficits (frontal lobe traumas, children and youth, Alzheimer's patients, older adults) might be necessary to link deficits in suppression ability and creative problem solving performance (for the costs and benefits of inhibition, see M. C. Anderson & Levy, 2007; Schilling et al., 2014; also see Storm & Levy, 2012).

Imaging experiments so far have concentrated on creative tasks of convergent thinking. The role of memory suppression in tests of divergent thinking, like the alternative uses task, or the category generation task using ad-hoc categories should also be investigated. Individual differences in the ability to automatically inhibit retrieval of pre-potent but incorrect responses should manifest in the ability to generate more novel responses to tests of creative divergent thinking. Imaging studies would be necessary to link known inhibitory processes to abilities of divergent creative thinking.

One thing that was assumed during Experiments 7 and 8 is that feedback of correctness after a solution attempt is crucial to label the solution as one "to-be-suppressed" or "to-be-reinforced". This assumption should also be tested, because it has far reaching consequences about how dynamics of memory updating operate. With no feedback about correctness wrong guesses, or wrong automatic solutions, might be regarded as correct and thus be reinforced in memory. The feeling of correctness has consequences in subsequent attempts for solution as following reinforcement the wrong solution will become more fluent and therefore more potent in blocking the correct answer. An investigation of the role of post-solution correctness feedback on retrieval inhibition and memory is necessary. This has further implications about creating and adjusting beliefs, impacts of fake news, and might also provide explanations for memory phenomena like the hypercorrection effect (Butterfield & Metcalfe, 2001; Metcalfe & Kornell, 2007).

REFERENCES

Adamson, R. E., & Taylor, D. W. (1954). Functional fixedness as related to elapsed time and to set. *Journal of Experimental Psychology*, *47*(2), 122–126. https://doi.org/10.1037/h0057297

Anderson, J. R. (1974). Retrieval of propositional information from long-term memory. *Cognitive Psychology*, *6*(4), 451–474. https://doi.org/10.1016/0010-0285(74)90021-8

Anderson, M. C., Bjork, R. A., & Bjork, E. L. (1994). Remembering can cause forgetting: Retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(5), 1063–1087. https://doi.org/10.1037//0278-7393.20.5.1063

Anderson, M. C., & Hanslmayr, S. (2014). Neural mechanisms of motivated forgetting. *Trends in Cognitive Sciences*, *18*(6), 279–282. https://doi.org/10.1016/j.tics.2014.03.002

Anderson, M. C., & Hulbert, J. C. (2020). Active Forgetting: Adaptation of Memory by Prefrontal Control. *Annual Review of Psychology*, *72*(1), annurev-psych-072720-094140. https://doi.org/10.1146/annurev-psych-072720-094140

Anderson, M. C., & Levy, B. J. (2007). Theoretical issues in inhibition: Insights from research on human memory. In *Inhibition in cognition.* (pp. 81–102). American Psychological Association. https://doi.org/10.1037/11587-005

Anderson, M. C., & Neely, J. H. (1996). Interference and Inhibition in Memory Retrieval. In E. L. Bjork & R. A. Bjork (Eds.), *Memory* (pp. 237–313). Elsevier. https://doi.org/10.1016/B978-012102570-0/50010-0

Anderson, M. C., Ochsner, K. N., Kuhl, B. A., Cooper, J., Robertson, E., Gabrieli, S. W., Glover, G. H., & Gabrieli, J. D. E. (2004). Neural Systems Underlying the Suppression of Unwanted Memories. *Science*, *303*(5655), 232–235. https://doi.org/10.1126/science.1089504

Angello, G. M., Storm, B. C., & Smith, S. M. (2015). Overcoming fixation with repeated memory suppression. *Memory*, *23*(3), 381–389. https://doi.org/10.1080/09658211.2014.889167

Aron, A. R., Robbins, T. W., & Poldrack, R. A. (2014). Inhibition and the right inferior frontal cortex: one decade on. *Trends in Cognitive Sciences*, *18*(4), 177–185. https://doi.org/10.1016/j.tics.2013.12.003

Baird, B., Smallwood, J., Mrazek, M. D., Kam, J. W. Y., Franklin, M. S., & Schooler, J. W. (2012a). Inspired by Distraction. *Psychological Science*, *23*(10), 1117–1122. https://doi.org/10.1177/0956797612446024

Baird, B., Smallwood, J., Mrazek, M. D., Kam, J. W. Y., Franklin, M. S., & Schooler, J. W. (2012b). Inspired by Distraction. *Psychological Science*, *23*(10), 1117–1122. https://doi.org/10.1177/0956797612446024

Banich, M. T., & Depue, B. E. (2015). Recent advances in understanding neural systems that support inhibitory control. *Current Opinion in Behavioral Sciences*, *1*, 17–22. https://doi.org/10.1016/j.cobeha.2014.07.006

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, *67*(1). https://doi.org/10.18637/jss.v067.i01

Beaman, C. P., & Williams, T. I. (2010). Earworms (stuck song syndrome): Towards a natural history of intrusive thoughts. *British Journal of Psychology*, *101*(4), 637–653. https://doi.org/10.1348/000712609X479636

Becker, M., Sommer, T., & Kühn, S. (2020). Inferior frontal gyrus involvement during search and solution in verbal creative problem solving: A parametric fMRI study. *NeuroImage*, *206*(January 2019), 116294. https://doi.org/10.1016/j.neuroimage.2019.116294

Beda, Z., & Smith, S. M. (2018). Chasing red herrings: Memory of distractors causes fixation in creative problem solving. *Memory & Cognition*, *46*(5), 671–684. https://doi.org/10.3758/s13421-018-0799-3

Benedek, M., Jauk, E., Fink, A., Koschutnig, K., Reishofer, G., Ebner, F., & Neubauer, A. C. (2014). To create or to recall? Neural mechanisms underlying the generation of creative new ideas. *Neuroimage*, *88*, 125–133. https://doi.org/10.1016/j.neuroimage.2013.11.021

Benedek, M., & Neubauer, A. C. (2013). Revisiting Mednick's Model on Creativity-Related Differences in Associative Hierarchies. Evidence for a Common Path to Uncommon Thought. *J Creat Behav*, *47*(4), 273–289. https://doi.org/10.1002/jocb.35

Bilalić, M., McLeod, P., & Gobet, F. (2008a). Why good thoughts block better ones: The mechanism of the pernicious Einstellung (set) effect. *Cognition*, *108*(3), 652–661. https://doi.org/10.1016/j.cognition.2008.05.005

Bilalić, M., McLeod, P., & Gobet, F. (2008b). Expert and "novice" problem solving strategies in chess: Sixty years of citing de Groot (1946). *Thinking & Reasoning*, *14*(4), 395–408. https://doi.org/10.1080/13546780802265547

Binder, J. R., Frost, J. A., Hammeke, T. A., Bellgowan, P. S. F., Rao, S. M., & Cox, R. W. (1999). Conceptual Processing during the Conscious Resting State: A Functional MRI Study. *Journal of Cognitive Neuroscience*, *11*(1), 80–93. https://doi.org/10.1162/089892999563265

Bjork, E. L., & Bjork, R. A. (1996). Continuing Influences of To-Be-Forgotten Information.

Consciousness and Cognition, *5*(1–2), 176–196. https://doi.org/10.1006/ccog.1996.0011

Bjork, R. A. (1970). Positive forgetting: The noninterference of Items intentionally forgotten. *Journal of Verbal Learning and Verbal Behavior*, *9*(3), 255–268. https://doi.org/10.1016/S0022-5371(70)80059-7

Bjork, R. A. (1989). Retrieval inhibition as an adaptive mechanism in human memory. In H. L. I. I. I. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving.* (pp. 309–330). Lawrence Erlbaum Associates, Inc. http://ezproxy.library.tamu.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=1989-97876-016&site=ehost-live

Bjork, R. A., & Bjork, E. L. (1992). A new theory of disuse and an old theory of stimulus fluctuation. In A. F. Healy, S. M. Kosslyn, & R. M. Shiffrin (Eds.), *Essays in honor of {William K. Estes}, {Vol. 1}: From learning theory to connectionist theory; {Vol. 2}: From learning processes to cognitive processes.* Lawrence Erlbaum Associates Inc.

Bowden, E. M., & Jung-Beeman, M. (2003). Normative data for 144 compound remote associate problems. *Behavior Research Methods Instruments & Computers*, *35*(4), 634–639. https://doi.org/Doi 10.3758/Bf03195543

Brown, J. (1968). Reciprocal facilitation and impairment of free recall. *Psychonomic Science*, *10*(2), 41–42. https://doi.org/10.3758/BF03331397

Butterfield, B., & Metcalfe, J. (2001). Errors committed with high confidence are hypercorrected. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*(6), 1491–1494. https://doi.org/10.1037/0278-7393.27.6.1491

Carr, T. H., & Dagenbach, D. (1990). Semantic priming and repetition priming from masked words: Evidence for a center-surround attentional mechanism in perceptual recognition.

Journal of Experimental Psychology: Learning, Memory, and Cognition, *16*(2), 341–350. https://doi.org/10.1037/0278-7393.16.2.341

Crowder, R. G. (1978). Mechanisms of auditory backward masking in the stimulus suffix effect. *Psychological Review*, *85*(6), 502–524. https://doi.org/10.1037/0033-295X.85.6.502

Dagenbach, D., Carr, T. H., & Barnhardt, T. M. (1990). Inhibitory semantic priming of lexical decisions due to failure to retrieve weakly activated codes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *16*(2), 328–340. https://doi.org/10.1037/0278-7393.16.2.328

Dalrymple-Alford, E. C., & Budayr, B. (1966). Examination of Some Aspects of the Stroop Color-Word Test. *Perceptual and Motor Skills*, *23*(3_suppl), 1211–1214. https://doi.org/10.2466/pms.1966.23.3f.1211

Depue, B. E., Curran, T., & Banich, M. T. (2007). Prefrontal Regions Orchestrate Suppression of Emotional Memories via a Two-Phase Process. *Science*, *317*(5835), 215–219. https://doi.org/10.1126/science.1139560

Depue, B. E., Orr, J. M., Smolker, H. R., Naaz, F., & Banich, M. T. (2015). The Organization of Right Prefrontal Networks Reveals Common Mechanisms of Inhibitory Regulation Across Cognitive, Emotional, and Motor Processes. *Cerebral Cortex*, *26*(4), 1634–1646. https://doi.org/10.1093/cercor/bhu324

Dijksterhuis, A., & Meurs, T. (2006). Where creativity resides: the generative power of unconscious thought. *Conscious Cogn*, *15*(1), 135–146. https://doi.org/10.1016/j.concog.2005.04.007

Dijksterhuis, A., & Nordgren, L. F. (2006). A Theory of unconscious thought. *Perspect Psychol Sci*, *1*(2), 95–109. https://doi.org/10.1111/j.1745-6916.2006.00007.x

Duncker, K. (1945). *On problem-solving*. The American psychological association.

Estes, W. K. (1955). Statistical theory of spontaneous recovery and regression. *Psychological Review*, *62*(3), 145–154. https://doi.org/10.1037/h0048509

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications*. The MIT Press.

Gilhooly, K. J. (2016). Incubation and Intuition in Creative Problem Solving. *Frontiers in Psychology*, *7*(JUL), 1–9. https://doi.org/10.3389/fpsyg.2016.01076

Gilhooly, K. J., Fioratou, E., Anthony, S. H., & Wynn, V. (2007). Divergent thinking: Strategies and executive involvement in generating novel uses for familiar objects. *British Journal of Psychology*, *98*(4), 611–625. https://doi.org/10.1111/j.2044-8295.2007.tb00467.x

Glasser, M. F., Sotiropoulos, S. N., Wilson, J. A., Coalson, T. S., Fischl, B., Andersson, J. L., Xu, J., Jbabdi, S., Webster, M., Polimeni, J. R., Van Essen, D. C., & Jenkinson, M. (2013). The minimal preprocessing pipelines for the Human Connectome Project. *NeuroImage*, *80*, 105–124. https://doi.org/10.1016/j.neuroimage.2013.04.127

Goldman, W., Wolters, N. C. W., & Winograd, E. (1992). A demonstration of incubation in anagram problem solving. *Bulletin of the Psychonomic Society*, *30*(1), 36–38.

Goschke, T., & Kuhl, J. (1993). Representation of intentions: Persisting activation in memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*(5), 1211–1226. https://doi.org/10.1037/0278-7393.19.5.1211

Greene, R. L. (1990). Spacing effects on implicit memory tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *16*(6), 1004–1011. https://doi.org/10.1037/0278-7393.16.6.1004

Guo, Y., Schmitz, T. W., Mur, M., Ferreira, C. S., & Anderson, M. C. (2018). A supramodal role of the basal ganglia in memory and motor inhibition: Meta-analytic evidence. *Neuropsychologia*, *108*(December 2017), 117–134. https://doi.org/10.1016/j.neuropsychologia.2017.11.033

Hayes-Roth, B., & Hayes-Roth, F. (1979). A Cognitive Model of Planning*. *Cognitive Science*, *3*(4), 275–310. https://doi.org/10.1207/s15516709cog0304_1

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, *110*(3), 306–340. https://doi.org/10.1037//0096-3445.110.3.306

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language*, *59*(4), 434–446. https://doi.org/10.1016/j.jml.2007.11.007

Johnson, H. M. (1994). Processes of successful intentional forgetting. *Psychological Bulletin*, *116*(2), 274–292. https://doi.org/10.1037/0033-2909.116.2.274

Kinoshita, S., & Towgood, K. (2001). Effects of dividing attention on the memory-block effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*(3), 889–895. https://doi.org/10.1037//0278-7393.27.3.889

Klinger, E. C. (1999). Thought flow: Properties and mechanisms underlying shifts in content. In J. A. Singer & P. Salovey (Eds.), *At play in the fields of consciousness: Essays in the honour of Jerome L. Singer* (pp. 29–50). Erlbaum.

Koppel, R. H., & Storm, B. C. (2014). Escaping mental fixation: Incubation and inhibition in creative problem solving. *Memory*, *22*(4), 340–348. https://doi.org/10.1080/09658211.2013.789914

Kounios, J., Fleck, J. I., Green, D. L., Payne, L., Stevenson, J. L., Bowden, E. M., & Jung-

Beeman, M. (2008). The origins of insight in resting-state brain activity. *Neuropsychologia*, *46*(1), 281–291. https://doi.org/10.1016/j.neuropsychologia.2007.07.013

Kuhl, B. A., Dudukovic, N. M., Kahn, I., & Wagner, A. D. (2007). Decreased demands on cognitive control reveal the neural processing benefits of forgetting. *Nature Neuroscience*, *10*(7), 908–914. https://doi.org/10.1038/nn1918

Landau, J. D., & Leynes, P. A. (2006). Do Explicit Memory Manipulations Affect the Memory Blocking Effect? *The American Journal of Psychology*, *119*(3), 463. https://doi.org/10.2307/20445353

Levy, B. J., & Anderson, M. C. (2008). Individual differences in the suppression of unwanted memories: The executive deficit hypothesis. *Acta Psychologica*, *127*(3), 623–635. https://doi.org/10.1016/j.actpsy.2007.12.004

Logan, J. M., & Balota, D. A. (2003). Conscious and unconscious lexical retrieval blocking in younger and older adults. *Psychol Aging*, *18*(3), 537–550. https://doi.org/10.1037/0882-7974.18.3.537

Lord, C. G., Ross, L., & Lepper, M. R. (1979). Biased assimilation and attitude polarization: The effects of prior theories on subsequently considered evidence. *Journal of Personality and Social Psychology*, *37*(11), 2098–2109. https://doi.org/10.1037/0022-3514.37.11.2098

Luchins, A. S., & Luchins, E. H. (1959). Rigidity of behavior, a variational approach to the effect of Einstellung. In *University of Oregon monographs, studies in psychology*, (Issue no 3). Univ. of Oregon Books.

Lundqvist, D., Flykt, A., & Ohman, A. (1998). *The Karolinska Directed Emotional Faces - KDEF*. Department of Clinical Neuroscience, Psychology section, Karolinska Institutet.

Lustig, C., & Hasher, L. (2001a). Implicit memory is not immune to interference. *Psychological*

Bulletin, *127*(5), 618–628. https://doi.org/10.1037/0033-2909.127.5.618

Lustig, C., & Hasher, L. (2001b). Implicit memory is vulnerable to proactive interference. *Psychol Sci*, *12*(5), 408–412. https://doi.org/10.1111/1467-9280.00375

Maier, N. R. F. (1931). Reasoning in humans. II. The solution of a problem and its appearance in consciousness. *Journal of Comparative Psychology*, *12*(2), 181–194. https://doi.org/10.1037/h0071361

Mäntyla, T. (1993). Priming effects in prospective memory. *Memory*, *1*(3), 203–218. https://doi.org/10.1080/09658219308258233

McDaniel, M. A., Anderson, D. C., Einstein, G. O., & O'Halloran, C. M. (1989). Modulation of Environmental Reinstatement Effects through Encoding Strategies. *The American Journal of Psychology*, *102*(4), 523. https://doi.org/10.2307/1423306

Mednick, S. (1962). The associative basis of the creative process. *Psychological Review*, *69*, 220–232. https://doi.org/10.1037/h0048850

Metcalfe, J., & Kornell, N. (2007). Principles of cognitive science in education: The effects of generation, errors, and feedback. *Psychonomic Bulletin & Review*, *14*(2), 225–229. https://doi.org/10.3758/BF03194056

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology*, *90*(2), 227–234. https://doi.org/10.1037/h0031564

Mooneyham, B. W., & Schooler, J. W. (2013). The costs and benefits of mind-wandering: A review. *Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale*, *67*(1), 11–18. https://doi.org/10.1037/a0031569

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior*, *16*(5), 519–533. https://doi.org/10.1016/S0022-5371(77)80016-9

Mrazek, M. D., Smallwood, J., & Schooler, J. W. (2012). Mindfulness and mind-wandering: Finding convergence through opposing constructs. *Emotion*, *12*(3), 442–448. https://doi.org/10.1037/a0026678

Mulligan, N. W. (2011). Conceptual implicit memory and environmental context. *Consciousness and Cognition*, *20*(3), 737–744. https://doi.org/10.1016/j.concog.2010.11.008

Murayama, K., Miyatsu, T., Buchli, D., & Storm, B. C. (2014). Forgetting as a consequence of retrieval: A meta-analytic review of retrieval-induced forgetting. *Psychological Bulletin*, *140*(5), 1383–1409. https://doi.org/10.1037/a0037505

Neath, I., & Brown, G. D. A. (2012). Arguments Against Memory Trace Decay: A SIMPLE Account of Baddeley and Scott. *Frontiers in Psychology*, *3*(FEB), 2–4. https://doi.org/10.3389/fpsyg.2012.00035

Neill, W. T., & Westberry, R. L. (1987). Selective attention and the suppression of cognitive noise. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *13*(2), 327–334. https://doi.org/10.1037/0278-7393.13.2.327

Nelson, D. L., Canas, J. J., Bajo, M. T., & Keelean, P. D. (1987). Comparing word fragment completion and cued recall with letter cues. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *13*(4), 542–552. https://doi.org/10.1037/0278-7393.13.4.542

Nelson, D. L., Keelean, P. D., & Negrao, M. (1989). Word-fragment cuing: The lexical search hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*(3), 388–397. https://doi.org/10.1037/0278-7393.15.3.388

Nelson, D. L., McKinney, V. M., Gee, N. R., & Janczura, G. A. (1998). Interpreting the influence of implicitly activated memories on recall and recognition. *Psychological Review*, *105*(2), 299–324. https://doi.org/10.1037/0033-295X.105.2.299

Ovington, L. A., Saliba, A. J., Moran, C. C., Goldring, J., & MacDonald, J. B. (2018). Do People Really Have Insights in the Shower? The When, Where and Who of the Aha! Moment. *The Journal of Creative Behavior*, *52*(1), 21–34. https://doi.org/10.1002/jocb.126

Parker, A., Gellatly, A., & Waterman, M. (1999). The effect of environmental context manipulation on memory: Dissociation between perceptual and conceptual implicit tests. *European Journal of Cognitive Psychology*, *11*(4), 555–570. https://doi.org/10.1080/095414499382291

Patalano, A. L., & Seifert, C. M. (1997). Opportunistic Planning: Being Reminded of Pending Goals. *Cognitive Psychology*, *34*(1), 1–36. https://doi.org/10.1006/cogp.1997.0655

Pavlov, I. (1927). *Conditioned Reflexes*. Oxford University Press.

Postman, L., Stark, K., & Fraser, J. (1968). Temporal changes in interference. *Journal of Verbal Learning and Verbal Behavior*, *7*(3), 672–694. https://doi.org/10.1016/S0022-5371(68)80124-0

Raaijmakers, J. G. W., & Shiffrin, R. M. (1981). Search of associative memory. *Psychological Review*, *88*(2), 93–134. https://doi.org/10.1037/0033-295X.88.2.93

Rass, O., & Leynes, P. A. (2007). When do primes go bad? A corpus of orthographically related primes that inhibit fragment completion. *Behavior Research Methods*, *39*(4), 870–875. https://doi.org/10.3758/BF03192981

Roediger, H. L., & Blaxton, T. A. (1987). Effects of varying modality, surface features, and retention interval on priming in word-fragment completion. *Memory & Cognition*, *15*(5), 379–388. https://doi.org/10.3758/BF03197728

Roediger, H. L., & Challis, B. H. (1992). Effects of exact repetition and conceptual repetition on free recall and primed word-fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *18*(1), 3–14. https://doi.org/10.1037/0278-7393.18.1.3

Roediger, H. L., & Neely, J. H. (1982). Retrieval blocks in episodic and semantic memory. *Canadian Journal of Psychology/Revue Canadienne de Psychologie*, *36*(2), 213–242. https://doi.org/10.1037/h0080640

Rundus, D. (1973). Negative effects of using list items as recall cues. *Journal of Verbal Learning and Verbal Behavior*, *12*(1), 43–50. https://doi.org/10.1016/S0022-5371(73)80059-3

Schilling, C. J., Storm, B. C., & Anderson, M. C. (2014). Examining the costs and benefits of inhibition in memory retrieval. *Cognition*, *133*(2), 358–370. https://doi.org/10.1016/j.cognition.2014.07.003

Schnur, T. T., Lee, E., Coslett, H. B., Schwartz, M. F., & Thompson-Schill, S. L. (2005). When lexical selection gets tough, the LIFG gets going: A lesion analysis study of interference during word production. *Brain and Language*, *95*(1), 12–13. https://doi.org/10.1016/j.bandl.2005.07.008

Schooler, J. W., Smallwood, J., Christoff, K., Handy, T. C., Reichle, E. D., & Sayette, M. A. (2011). Meta-awareness, perceptual decoupling and the wandering mind. *Trends in Cognitive Sciences*, *15*(7), 319–326. https://doi.org/10.1016/j.tics.2011.05.006

Seifert, C. M., Meyer, D. E., Davidson, N., Patalano, A. L., & Yaniv, I. (1995). Demystification of Cognitive Insight: Opportunistic Assimilation and the Prepared-Mind Perspective. In R. J. Sternberg (Ed.), *The Nature of Insight* (pp. 65–124). MIT Press.

Seifert, C. M., & Patalano, A. L. (2001). Opportunism in Memory: Preparing for Chance Encounters. *Current Directions in Psychological Science*, *10*(6), 198–201.

https://doi.org/10.1111/1467-8721.00148

Shahabuddin, S. S., & Smith, S. M. (2016). Asymmetric Reinstatement Effects in Recognition. *The Journal of General Psychology*, *143*(4), 267–280. https://doi.org/10.1080/00221309.2016.1214100

Sio, U. N., & Ormerod, T. C. (2009). Does incubation enhance problem solving? A meta-analytic review. *Psychol Bull*, *135*(1), 94–120. https://doi.org/10.1037/a0014212

Slamecka, N. J. (1968). An examination of trace storage in free recall. *Journal of Experimental Psychology*, *76*(4), 504–513.

Slamecka, N. J., & Graf, P. (1978). The generation effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning & Memory*, *4*(6), 592–604. https://doi.org/10.1037/0278-7393.4.6.592

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, *132*(6), 946–958. https://doi.org/10.1037/0033-2909.132.6.946

Smith, S. M. (1979). Remembering in and out of context. *Journal of Experimental Psychology: Human Learning & Memory*, *5*(5), 460–471. https://doi.org/10.1037//0278-7393.5.5.460

Smith, S. M. (1988). *Environmental context-dependent memory.* (D. M. Thomson & G. M. Davies (eds.); pp. 13–34). New York: Wiley.

Smith, S. M. (2011). Blocking out Blocks: Adaptive Forgetting of Fixation in Memory, Problem Solving, and Creative Ideation. In *Successful remembering and successful forgetting: A Festschrift in honor of Robert A Bjork.* (pp. 153–174). Psychology Press. https://doi.org/10.4324/9780203842539

Smith, S. M. (2013). Effects of environmental context on human memory. In T. J. Perfect & D. S. Lindsay (Eds.), *Sage handbook of applied memory* (pp. 162–182). Sage Publications.

Smith, S. M., & Beda, Z. (2020a). Blocked and recovered memories. In A. M. Cleary & B. L. Schwartz (Eds.), *Memory quirks: The study of odd phenomena in memory*. Routledge.

Smith, S. M., & Beda, Z. (2020b). Forgetting Fixation with Context Change. *Journal of Applied Research in Memory and Cognition*, *9*(1), 19–23. https://doi.org/10.1016/j.jarmac.2019.12.002

Smith, S. M., Beda, Z., & Hernandez, A. (2020). Entrenchment: effects of multiple red herrings on memory blocks in word fragment completion. *Memory*, *28*(6), 830–836. https://doi.org/10.1080/09658211.2020.1769137

Smith, S. M., & Blankenship, S. E. (1989). Incubation effects. *Bulletin of the Psychonomic Society*, *27*(4), 311–314. https://doi.org/10.3758/bf03334612

Smith, S. M., & Handy, J. D. (2014). Effects of varied and constant environmental contexts on acquisition and retention. *J Exp Psychol Learn Mem Cogn*, *40*(6), 1582–1593. https://doi.org/10.1037/xlm0000019

Smith, S. M., & Handy, J. D. (2016). The crutch of context-dependency: Effects of contextual support and constancy on acquisition and retention. *Memory*, *24*(8), 1134–1141. https://doi.org/10.1080/09658211.2015.1071852

Smith, S. M., Handy, J. D., Angello, G. M., & Manzano, I. (2014). Effects of similarity on environmental context cueing. *Memory*, *22*(5), 493–508. https://doi.org/10.1080/09658211.2013.800553

Smith, S. M., Handy, J. D., Hernandez, A., & Jacoby, L. L. (2018). Context Specificity of Automatic Influences of Memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, No Pagination Specified-No Pagination Specified. https://doi.org/10.1037/xlm0000523

Smith, S. M., Heath, F. R., & Vela, E. (1990). Environmental context-dependent homophone spelling. *The American Journal of Psychology*, *103*(2), 229–242. http://www.ncbi.nlm.nih.gov/pubmed/2349977

Smith, S. M., & Manzano, I. (2010). Video context-dependent recall. *Behavior Research Methods*, *42*(1), 292–301. https://doi.org/10.3758/brm.42.1.292

Smith, S. M., & Tindell, D. R. (1997). Memory blocks in word fragment completion caused by involuntary retrieval of orthographically related primes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*(2), 355–370. https://doi.org/10.1037//0278-7393.23.2.355

Smith, S. M., & Vela, E. (1986). Outshining-the relative effectiveness of cues. *Bulletin of the Psychonomic Society*, *24*(5), 350.

Smith, S. M., & Vela, E. (2001). Environmental context-dependent memory: a review and meta-analysis. *Psychon Bull Rev*, *8*(2), 203–220. https://doi.org/10.3758/bf03196157

Storm, B. C., & Angello, G. M. (2010). Overcoming Fixation. *Psychological Science*, *21*(9), 1263–1265. https://doi.org/10.1177/0956797610379864

Storm, B. C., Angello, G. M., & Bjork, E. L. (2011). Thinking can cause forgetting: memory dynamics in creative problem solving. *J Exp Psychol Learn Mem Cogn*, *37*(5), 1287–1293. https://doi.org/10.1037/a0023921

Storm, B. C., & Levy, B. J. (2012). A progress report on the inhibitory account of retrieval-induced forgetting. *Memory & Cognition*, *40*(6), 827–843. https://doi.org/10.3758/s13421-012-0211-7

Streb, M., Mecklinger, A., Anderson, M. C., Lass-Hennemann, J., & Michael, T. (2016). Memory control ability modulates intrusive memories after analogue trauma. *Journal of*

Affective Disorders, *192*, 134–142. https://doi.org/10.1016/j.jad.2015.12.032

Strong, E. K. J. (1912). The effect of length of series upon recognition memory. *Psychological Review*, *19*(6), 447–462. https://doi.org/10.1037/h0069812

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*(6), 643–662. https://doi.org/10.1037/h0054651

Thompson-Schill, S. L., Swick, D., Farah, M. J., D'Esposito, M., Kan, I. P., & Knight, R. T. (1998). Verb generation in patients with focal frontal lesions: A neuropsychological test of neuroimaging findings. *Proceedings of the National Academy of Sciences*, *95*(26), 15855–15860. https://doi.org/10.1073/pnas.95.26.15855

Tulving, E. (1974). Cue-dependent forgetting. *American Scientist*, *62*(1), 74–82. http://www.jstor.org/stable/27844717%5Cnhttp://about.jstor.org/terms

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, *80*(5), 352–373. https://doi.org/10.1037/h0020071

van Schie, K., & Anderson, M. C. (2017). Successfully controlling intrusive memories is harder when control must be sustained. *Memory*, *25*(9), 1201–1216. https://doi.org/10.1080/09658211.2017.1282518

Walley, R. E., & Weiden, T. D. (1973). Lateral inhibition and cognitive masking: A neuropsychological theory of attention. *Psychological Review*, *80*(4), 284–302. https://doi.org/10.1037/h0035007

Watkins, O. C., & Watkins, M. J. (1975). Buildup of proactive inhibition as a cue-overload effect. *Journal of Experimental Psychology: Human Learning & Memory*, *1*(4), 442–452. https://doi.org/10.1037/0278-7393.1.4.442

Watson, D. G., & Humphreys, G. W. (1997). Visual marking: Prioritizing selection for new objects by top-down attentional inhibition of old objects. *Psychological Review*, *104*(1), 90–122. https://doi.org/10.1037/0033-295X.104.1.90

Wegner, D. M. (1994). Ironic processes of mental control. *Psychol Rev*, *101*(1), 34–52. https://www.ncbi.nlm.nih.gov/pubmed/8121959

Wiley, J. (1998). Expertise as mental set: The effects of domain knowledge in creative problem solving. *Memory & Cognition*, *26*(4), 716–730. https://doi.org/10.3758/bf03211392

Winkler, A. M., Ridgway, G. R., Webster, M. A., Smith, S. M., & Nichols, T. E. (2014). Permutation inference for the general linear model. *NeuroImage*, *92*, 381–397. https://doi.org/10.1016/j.neuroimage.2014.01.060

Woodworth, R. S., & Schlosberg, H. (1954). *Experimental psychology* (Rev.). Holt.

Zedelius, C. M., & Schooler, J. W. (2015). Mind wandering "Ahas" versus mindful reasoning: alternative routes to creative solutions. *Frontiers in Psychology*, *6*, 834. https://doi.org/10.3389/fpsyg.2015.00834

Zedelius, C. M., & Schooler, J. W. (2016a). The Richness of Inner Experience: Relating Styles of Daydreaming to Creative Processes. *Frontiers in Psychology*, *6*(February). https://doi.org/10.3389/fpsyg.2015.02063

Zedelius, C. M., & Schooler, J. W. (2016b). The Richness of Inner Experience: Relating Styles of Daydreaming to Creative Processes. *Frontiers in Psychology*, *6*, 2063. https://doi.org/10.3389/fpsyg.2015.02063

Zedelius, C. M., & Schooler, J. W. (2017). What Are People's Lay Theories About Mind Wandering and How Do Those Beliefs Affect Them? In *The Science of Lay Theories* (pp. 71–93). Springer International Publishing. https://doi.org/10.1007/978-3-319-57306-9_4

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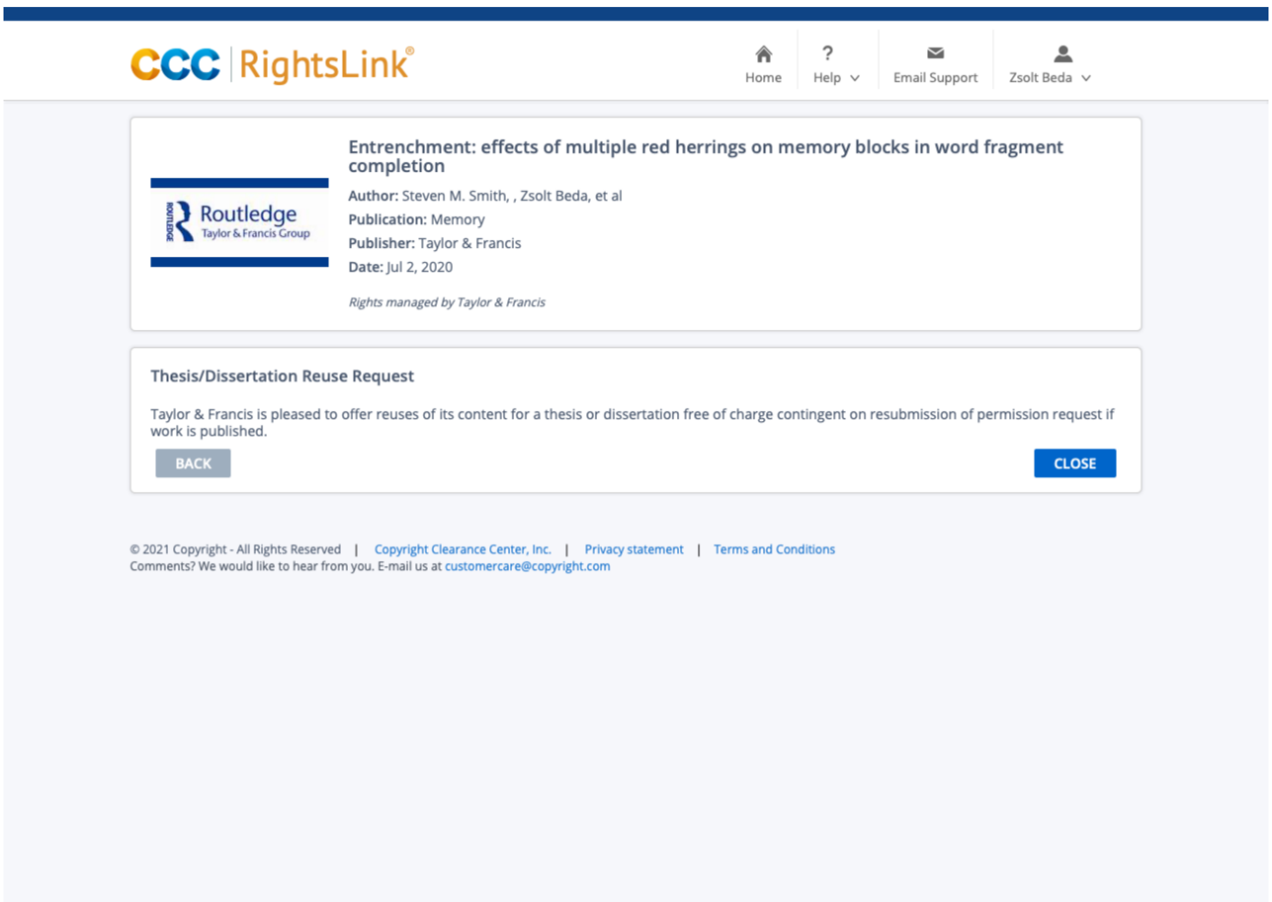

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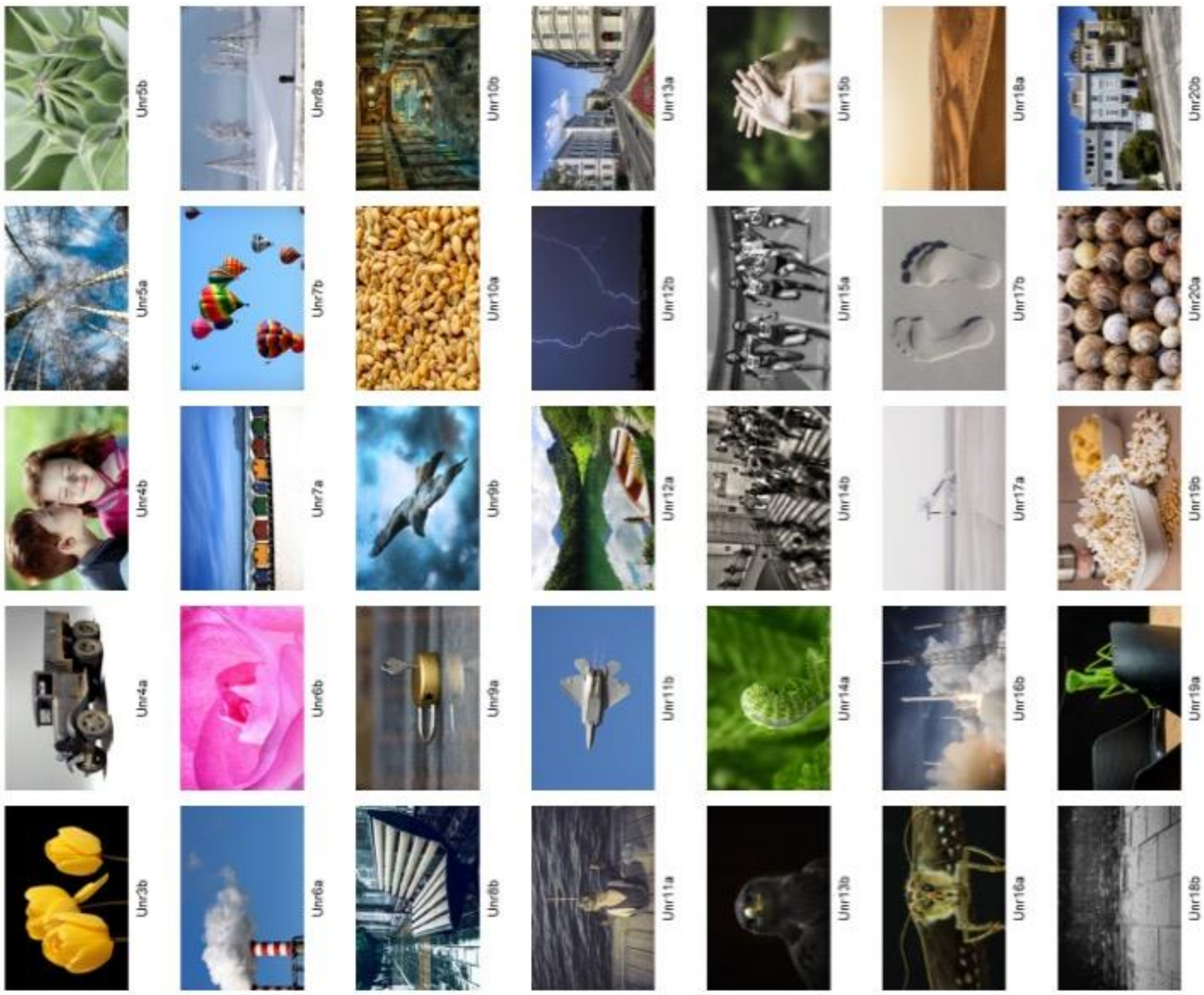
Appendix F

Remote Associates Test Stimuli

Solution	RAT test words	Associates						
1 cheese	COTTAGE	hut	13 fire	CRACKER	nut	25 pot	PIE	chart
	SWISS	chocolate		FLY	kite		LUCK	fortune
	CAKE	icing		FIGHTER	soldier		BELLY	fat
2 ice	CREAM	butter	14 pin	SAFETY	belt	26 soap	OPERA	soprano
	SKATE	board		CUSHION	couch		HAND	fingers
	WATER	hose		POINT	score		DISH	satellite
3 sore	LOSER	winner	15 sugar	CANE	crutch	27 space	CADET	corps
	THROAT	swallow		DADDY	mommy		CAPSULE	pill
	SPOT	notice		PLUM	purple		SHIP	cruise
4 boat	SHOW	movie	16 blind	DATE	time	28 sick	HOME	plate
	LIFE	death		ALLEY	path		SEA	turtle
	ROW	dispute		FOLD	center		BED	sheet
5 watch	NIGHT	crawler	17 gold	FISH	hook	29 coat	FUR	otter
	WRIST	flick		MINE	yours		RACK	torture
	STOP	signal		RUSH	hurry		TAIL	spin
6 camp	BOOT	cowboy	18 party	POLITICAL	office	30 blood	HOUND	canine
	SUMMER	season		SURPRISE	attack		PRESSURE	cooker
	GROUND	coffee		LINE	up		SHOT	gun
7 chair	ROCKING	rolling	19 common	SENSE	vision	31 hole	FOX	hunt
	WHEEL	axle		COURTESY	manners		MAN	primate
	HIGH	priest		PLACE	mat		PEEP	chicken
8 honey	DEW	morning	20 book	WORM	earth	32 family	NUCLEAR	bomb
	COMB	hair		SHELF	storage		FEUD	argument
	BEE	spelling		END	deadline		ALBUM	music
9 soda	FOUNTAIN	youth	21 copy	RIGHT	left	33 bag	SLEEPING	pillow
	BAKING	oven		CAT	mouse		BEAN	kidney
	POP	star		CARBON	oxygen		TRASH	garbage
10 forest	PRESERVE	jelly	22 girl	FLOWER	daisy	34 fast	FOOD	hungry
	RANGER	Texas		FRIEND	enemy		FORWARD	backward
	TROPICAL	heat		SCOUT	ahead		BREAK	shatter
11 band	AID	cool	23 bank	RIVER	canoe	35 moon	SHINE	armor
	RUBBER	tire		NOTE	worthy		BEAM	laser
	WAGON	station		ACCOUNT	receipt		STRUCK	hit
12 snow	FLAKE	weirdo	24 blue	PRINT	press	36 pit	PEACH	fuzz
	MOBILE	phone		BERRY	bush		ARM	mechanical
	CONE	traffic		BIRD	nest		TAR	heel

Appendix G

Background Context Stimuli



Appendix H

Experiments 1-2 Design

24 items

Conditions	PR	PN	U
CB1			
CB2			
CB3			

Group A	Group B	Group C
2	3	5
7	4	11
14	6	13
18	10	19
23	15	22
29	20	25
31	24	26
35	34	33

PR= Primed, Reinstated
PN= Primed, New
U= Unprimed

Length: approx. 28 minutes

		Ctx encoding	CB1	CB2	CB3
	1	R	31	26	24
	2	N	24	31	26
4	3	R	35	33	34
	4	N	34	35	33
	5	N	6	14	13
	6	R	14	13	6
2	7	R	18	19	10
	8	N	10	18	19
	9	R	23	22	15
	10	R	29	25	20
3	11	N	15	23	22
	12	N	20	29	25
	13	R	2	5	3
	14	N	3	2	5
1	15	N	4	7	11
	16	R	7	11	4

	PA encoding	CB1	CB2	CB3
	N	15	23	22
	R	23	22	15
3	R	29	25	20
	N	20	29	25
	N	3	2	5
	R	2	5	3
1	N	4	7	11
	R	7	11	4
	R	31	26	24
	N	24	31	26
4	N	34	35	33
	R	35	33	34
	N	6	14	13
	N	10	18	19
2	R	14	13	6
	R	18	19	10

	PA Test1	CB1	CB2	CB3
	N	3	2	5
	R	2	5	3
1	R	7	11	4
	N	4	7	11
	N	15	23	22
	R	23	22	15
3	N	20	29	25
	R	29	25	20
	R	14	13	6
	N	6	14	13
2	N	10	18	19
	R	18	19	10
	N	24	31	26
	N	34	35	33
4	R	31	26	24
	R	35	33	34

	PA Test2	CB1	CB2	CB3
	N	6	14	13
	R	14	13	6
2	R	18	19	10
	N	10	18	19
	N	24	31	26
	R	31	26	24
4	N	34	35	33
	R	35	33	34
	R	2	5	3
	N	3	2	5
1	N	4	7	11
	R	7	11	4
	N	15	23	22
	N	20	29	25
3	R	23	22	15
	R	29	25	20

	RAT	CB1	CB2	CB3
	1	5	3	2
	2	2	5	3
	3	7	11	4
1	4	3	2	5
	5	11	4	7
	6	4	7	11
	7	6	14	13
	8	13	6	14
	9	19	10	18
2	10	14	13	6
	11	10	18	19
	12	18	19	10
	13	23	22	15
	14	22	15	23
	15	15	23	22
3	16	25	20	29
	17	29	25	20
	18	20	29	25
	19	24	31	26
	20	31	26	24
	21	26	24	31
4	22	33	34	35
	23	34	35	33
	24	35	33	34

Appendix I

Experiments 3-4 Design and Word Fragments Stimuli

Context	Same	Same	Different
Priming	Positive	Negative	Negative
CB1			
CB2			
CB3			

3, 4, 5, 11, 13, 18, 19, 24
1, 7, 9, 10, 15, 17, 20, 23
2, 6, 8, 12, 14, 16, 21, 22

				RP1				RP2				RP3				Test 1				
Seq	CB1	CB2	CB3	Seq	CB1	CB2	CB3	Seq	CB1	CB2	CB3	Seq	CB1	CB2	CB3	Seq	CB1	CB2	CB3	Context
1	9	8	5	1	4	7	6	1	12	11	10	1	11	10	12	1	3	1	2	
2	8	5	9	2	2	3	1	2	9	8	5	2	9	8	5	2	1	2	3	
3	11	10	12	3	7	6	4	3	5	9	8	3	8	5	9	3	4	7	6	
4	10	12	11	4	6	4	7	4	10	12	11	4	5	9	8	4	2	3	1	NEW1
5	5	9	8	5	3	1	2	5	11	10	12	5	10	12	11	5	7	6	4	
6	12	11	10	6	1	2	3	6	8	5	9	6	12	11	10	6	6	4	7	NEW2
7	18	17	16	7	14	13	15	7	19	20	21	7	7	6	4	7	5	9	8	
8	14	13	15	8	17	16	18	8	20	21	19	8	2	3	1	8	8	5	9	NEW3
9	15	14	13	9	13	15	14	9	22	24	23	9	3	1	2	9	9	8	5	
10	13	15	14	10	16	18	17	10	23	22	24	10	6	4	7	10	12	11	10	NEW4
11	16	18	17	11	18	17	16	11	24	23	22	11	4	7	6	11	11	10	12	
12	17	16	18	12	15	14	13	12	21	19	20	12	1	2	3	12	10	12	11	
13	3	1	2	13	24	23	22	13	17	16	18	13	23	22	24	13	14	13	15	NEW5
14	2	3	1	14	20	21	19	14	16	18	17	14	19	20	21	14	13	15	14	
15	1	2	3	15	21	19	20	15	18	17	16	15	22	24	23	15	15	14	13	
16	6	4	7	16	23	22	24	16	14	13	15	16	20	21	19	16	16	18	17	NEW6
17	4	7	6	17	19	20	21	17	15	14	13	17	24	23	22	17	18	17	16	
18	7	6	4	18	22	24	23	18	13	15	14	18	21	19	20	18	17	16	18	
19	22	24	23	19	5	9	8	19	6	4	7	19	18	17	16	19	19	20	21	
20	20	21	19	20	12	11	10	20	7	6	4	20	15	14	13	20	20	21	19	
21	19	20	21	21	9	8	5	21	4	7	6	21	14	13	15	21	21	19	20	NEW7
22	21	19	20	22	11	10	12	22	1	2	3	22	17	16	18	22	24	23	22	
23	24	23	22	23	10	12	11	23	2	3	1	23	13	15	14	23	23	22	24	
24	23	22	24	24	8	5	9	24	3	1	2	24	16	18	17	24	22	24	23	NEW8

Test 2			
25	4	7	6
26	6	4	7
27	7	6	4
28	2	3	1
29	3	1	2
30	1	2	3
31	11	10	12
32	12	11	10
33	10	12	11
34	8	5	9
35	5	9	8
36	9	8	5
37	16	18	17
38	17	16	18
39	18	17	16
40	14	13	15
41	15	14	13
42	13	15	14
43	22	24	23
44	24	23	22
45	23	22	24
46	19	20	21
47	21	19	20
48	20	21	19

	Fragments				
	Problems	Solutions	Blockers		
1	A_L__GY	ALLERGY	ANALOGY	ANGRY	ANTHOLOGY
2	B_G_A_E	BAGGAGE	BRIGADE	BEGRIME	BELGIAN
3	D__NITY	DIGNITY	DENSITY	DYNASTY	DESTINY
4	F_I_URE	FAILURE	FIXTURE	FIGURE	FURIOUS
5	I_T_R_ST	INTEREST	ITERATES	IMPERIALIST	ITSELF
6	K_N_D_M	KINGDOM	KNOWING	KNOTTED	KNIGHTED
7	H_ST_R_	HISTORY	HOLSTER	HOSTILE	HARVEST
8	MAG__IN_	MAGAZINE	MAGICIAN	MERGING	MAPPING
9	OR__NA__	ORDINARY	ORNAMENT	ORIGINAL	ORIGINATE
10	RE_A__VE	RELATIVE	RETROACTIVE	REPAVE	RECEIVE
11	TR_G__Y	TRAGEDY	TRILOGY	TRIBUNE	TRINITY
12	VO__AGE	VOLTAGE	VOYAGE	VOGUE	VOMITING
13	H___ITA_	HOSPITAL	HERITAGE	HERMITAGE	HUNGARIAN
14	OPPO__T_	OPPOSITE	OPPONENT	OPPORTUNITY	OPPORTUNIST
15	SYMP__HY	SYMPATHY	SYMPHONY	SYMPTOM	SIMPLICITY
16	DEF_U_T	DEFAULT	DEFUNCT	DEFINITE	DEFECT
17	B_RM__D	BARMAID	BERMUDA	BROMIDE	BREMOND
18	EL_S_I_	ELASTIC	ELUSIVE	ELYSIUM	ELIXIR
19	B_O_KA_E	BLOCKADE	BOOKCASE	BAROCCO	BROCCOLI
20	C_TA__G	CATALOG	COTTAGE	CONTAGION	COTANGENT
21	H_RP__N	HARPOON	HAIRPIN	HERPES	HURTING
22	EX_ERI__	EXTERIOR	EXERCISE	EXCELSIOR	EXPERIENCE
23	GU__D_AN	GUARDIAN	GUIDANCE	GUIDELINE	GUILDSMAN
24	M_IST_RE	MOISTURE	MISTRESS	MISFIRE	MISTREAT

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Experiments 7-8 Design (Page 1)

Encoding		RP		Test Seq		MEMORY TEST Seq		Fragments	Problems	Solutions	Blockers
1	ORIGINATE	1	DEFUNCT	1	LO_A_TY	1	MAGICIAN				
2	UNIVERSE	2	HAIRPIN	2	NA_R_W	2	DENSITY	1	A_L__GY	ALLERGY	ANALOGY
3	ITERATES	3	DENSITY	3	PI_N_ST	3	ORIGINATE	2	B_G_A_E	BAGGAGE	BRIGADE
4	BERMUDA	4	LUSTFUL	4	ZI_LO_K	4	ITERATES	3	D__NITY	DIGNITY	DENSITY
5	DEFUNCT	5	ELYSIUM	5	PE__OCK	5	RETRIEVE	4	F_I_URE	FAILURE	FIXTURE
6	MISTRESS	6	ORIGINATE	6	QU_C_LY	6	EXERCISE	5	I_T_R_ST	INTEREST	ITERATES
7	OPPORTUNITY	7	HERITAGE	7	NAT_O_AL	7	VOYAGE	6	H_ST_R_	HISTORY	HOLSTER
8	PATIENCE	8	LEGROOM	8	WE_G_T	8	ANALOGY	7	MAG__IN_	MAGAZINE	MAGICIAN
9	ELYSIUM	9	HOLSTER	1	P_TI__CE	9	HAIRPIN	8	OR__NA__	ORDINARY	ORIGINATE
10	BRIGADE	10	COTTAGE	2	UNI_E_SE	10	SYMPHONY	9	RE_A__VE	RELATIVE	RETRIEVE
11	FIGURE	11	BERMUDA	3	H___ITA_	11	COTTAGE	10	VO__AGE	VOLTAGE	VOYAGE
12	LUSTFUL	12	ANALOGY	4	LU_T_UL	12	BRIGADE	11	H___ITA_	HOSPITAL	HERITAGE
13	ANALOGY	13	EXERCISE	5	B_RM__D	13	BERMUDA	12	OPPO__T_	OPPOSITE	OPPORTUNITY
14	SYMPHONY	14	PRAIRIE	6	D__NITY	14	GUIDANCE	13	SYMP__HY	SYMPATHY	SYMPHONY
15	GUIDANCE	15	VOYAGE	7	SYMP__HY	15	HOLSTER	14	DEF_U_T	DEFAULT	DEFUNCT
16	DENSITY	16	GUIDANCE	8	PRA_R__	16	HERITAGE	15	B_RM__D	BARMAID	BERMUDA
17	HOLSTER	17	PATIENCE	9	F_I_URE	17	ELYSIUM	16	EL_S_I_	ELASTIC	ELYSIUM
18	MAGICIAN	18	RETRIEVE	10	MAG__IN_	18	DEFUNCT	17	B_O_KA_E	BLOCKADE	BOOKCASE
19	BOOKCASE	19	BRIGADE	11	RE_A__VE	19	OPPORTUNITY	18	C_TA__G	CATALOG	COTTAGE
20	VOYAGE	20	OPPORTUNITY	12	LE_RO_M	20	BOOKCASE	19	H_RP__N	HARPOON	HAIRPIN
21	LEGROOM	21	UNIVERSE	13	EL_S_I_	21	MISTRESS	20	EX_ERI__	EXTERIOR	EXERCISE
22	HAIRPIN	22	ITERATES	14	C_TA__G	22	FIGURE	21	GU__D_AN	GUARDIAN	GUIDANCE
23	COTTAGE	23	BOOKCASE	15	VO__AGE			22	M_IST_RE	MOISTURE	MISTRESS
24	HERITAGE	24	FIGURE	16	OPPO__T_						
25	EXERCISE	25	MISTRESS		F_I_URE						
26	RETRIEVE	26	MAGICIAN		SYMP__HY						
27	PRAIRIE	27	SYMPHONY		MAG__IN_						
		28	ORIGINATE		VO__AGE						
		29	PATIENCE		D__NITY						
		30	EXERCISE	2	B_RM__D						
		31	ITERATES		H___ITA_						
		32	OPPORTUNITY		C_TA__G						
		33	UNIVERSE		EL_S_I_						
		34	GUIDANCE		OPPO__T_						
		35	BERMUDA		RE_A__VE						
		36	BOOKCASE		SYMP__HY						
		37	DENSITY		F_I_URE						
		38	PRAIRIE		MAG__IN_						
		39	MISTRESS		B_RM__D						
		40	BRIGADE		RE_A__VE						
		41	ELYSIUM	3	C_TA__G						
		42	COTTAGE		D__NITY						
		43	DEFUNCT		OPPO__T_						
		44	MAGICIAN		H___ITA_						
		45	VOYAGE		EL_S_I_						
		46	ANALOGY		VO__AGE						
		47	LUSTFUL		C_TA__G						
		48	HERITAGE		MAG__IN_						
		49	HOLSTER		EL_S_I_						
		50	LEGROOM		SYMP__HY						
		51	FIGURE		OPPO__T_						
		52	SYMPHONY	4	B_RM__D						
		53	RETRIEVE		VO__AGE						
		54	HAIRPIN		F_I_URE						
		55	UNIVERSE		D__NITY						
		56	PRAIRIE		RE_A__VE						
		57	MAGICIAN		H___ITA_						
		58	BOOKCASE		B_RM__D						

NEUTRAL
POSITIVE FILLERS
CRITICAL SUPPRESSED
CRITICAL BASELINE

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Experiments 7-8 Design (Page 2)

59	COTTAGE		SYMP _ _ HY
60	ORIGINATE		OPPO _ _ T _
61	HAIRPIN		F _ I _ URE
62	PATIENCE		RE _ A _ _ VE
63	FIGURE	5	MAG _ _ IN _
64	GUIDANCE		H _ _ _ ITA _
65	EXERCISE		EL _ S _ I _
66	DENSITY		VO _ _ AGE
67	LUSTFUL		C _ TA _ _ G
68	MISTRESS		D _ _ NITY
69	ANALOGY		MAG _ _ IN _
70	SYMPHONY		F _ I _ URE
71	BERMUDA		B _ RM _ _ D
72	ITERATES		EL _ S _ I _
73	DEFUNCT		C _ TA _ _ G
74	OPPORTUNITY	6	SYMP _ _ HY
75	HOLSTER		OPPO _ _ T _
76	VOYAGE		H _ _ _ ITA _
77	HERITAGE		RE _ A _ _ VE
78	BRIGADE		D _ _ NITY
79	ELYSIUM		VO _ _ AGE
80	LEGROOM		H _ _ _ ITA _
81	RETRIEVE		D _ _ NITY
			C _ TA _ _ G
			F _ I _ URE
			OPPO _ _ T _
		7	B _ RM _ _ D
			VO _ _ AGE
			EL _ S _ I _
			SYMP _ _ HY
			MAG _ _ IN _
			RE _ A _ _ VE
			OPPO _ _ T _
			B _ RM _ _ D
			EL _ S _ I _
			C _ TA _ _ G
			RE _ A _ _ VE
		8	MAG _ _ IN _
			H _ _ _ ITA _
			F _ I _ URE
			D _ _ NITY
			VO _ _ AGE
			SYMP _ _ HY
			POT _ U _ K
			WE _ _ ERN
			NA _ U _ AL
			PAC _ F _ C
			US _ F _ L
			ZE _ L _ US
			NO _ H _ NG
			PH _ _ AOH