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BRIEF REPORT

Old Problems in New Contexts: The Context-Dependent Fixation Hypothesis

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Two experiments tested the context-dependent fixation hypothesis of incubation effects, that initially fixated problems can be resolved when problem-solvers are in new contexts not associated with fixated ideas. Both experiments associated misleading clues with initial problem-solving contexts, causing a fixation effect, and retested problems either in fixation contexts or in new contexts. Resolution of initially unsolved problems was greater after a delay (an incubation effect), and incubation was greater when retests of problems were in new contexts. The results are consistent with previous laboratory findings, and they help explain why many historic cases of sudden insight occurred outside of typical work contexts.

Keywords: creativity, fixation, incubation, context, Remote Associates Test

Many sudden insights occur outside of the customary workplace, as in the classic *Eureka* moments of Archimedes (in the bath), Sir Isaac Newton (in a garden), and Einstein (on a bus), examples of incubation effects. Our *context-dependent fixation hypothesis*, inspired by these historic examples, states that discovering solutions to unsolved problems can be enhanced when fixated problems are reconsidered in new contexts.

The *forgetting fixation* theory states that incubation effects occur when inappropriate solutions are put out of mind, freeing the problem solver to discover better ideas (Simon, 1966; Smith & Blankenship, 1989). *Fixation* is a block that impedes problem solving (e.g., Duncker, 1945; Luchins & Luchins, 1959; Maier, 1931; Scheerer, 1963), including finding puzzles difficult to solve (Smith & Blankenship, 1989, 1991), and overly constraining ideas in brainstorming (Kohn & Smith, 2011), creative idea generation (Smith, Ward, & Schumacher, 1993), or creative design (e.g., Jansson & Smith, 1991; Vasconcelos & Crilly, 2016). Types of fixation include functional fixity (inability to use tools for atypical functions (e.g., Maier, 1931), mental set (adherence to solutions when better solutions are available (e.g., Luchins & Luchins, 1959), structured imagination (inability to go beyond established concepts (e.g., Ward, 1994), conformity effects (implicit use of examples in creative production (e.g., Smith et al., 1993), design fixation (adherence to examples in creative design (e.g., Jansson & Smith, 1991), and blocking effects in problem solving (e.g., Smith & Blankenship, 1991). Forgetting fixation sets the stage for incubation effects.

The context-dependent fixation hypothesis states that fixated thoughts can become associated with the context of failed attempts at a problem, so reinstating the fixation context continues to block solutions. New contexts, not associated with fixating thoughts, might liberate problem solvers from fixated thoughts, thereby supporting incubation effects. Memory is better when event contexts are reinstated (e.g., Smith, 1979; Smith, Glenberg, & Bjork, 1978; Smith & Vela, 2001), and reinstatement effects are powerful with video and photo contexts (e.g., Smith, 2013; Smith & Manzano, 2010). Beda and Smith (2018) had participants study fixation words similar to those used by Smith and Blankenship (1991) in pictorial contexts, and found that reinstatement of context photos associated with fixation words strengthened fixation effects.

Even when environmental contexts do not change, our context-dependent fixation hypothesis explains incubation effects in terms of *temporal context*, a period of time encompassing a set of events (e.g., Glenberg, 1979; Glenberg & Swanson, 1986; Howard & Kahana, 2002; Mensink & Raaijmakers, 1989). Reinstating a temporal context by providing a word from a long sequence promotes recall of other words from the same time period, accounting for long-term recency (e.g., Glenberg et al., 1980) and lag recency effects (e.g., Howard & Kahana, 1999). If fixating words are associated with temporal contexts, then retesting in the same temporal context (i.e., retesting a short time later) is not likely to result in resolution of an unsolved problem. Retesting in a new temporal context (i.e., retesting after a delay), however, may enable the problem solver to avoid temporal context-dependent fixation. New environmental context cues may not provide a

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Some of the ideas and results were described on a poster at the 2018 annual meeting of the Association for Psychological Science. No inferential statistics were reported.

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release from fixation if they do not overcome temporal context cues. Therefore, immediate retests of fixated problems may not produce resolution because of the persistence of temporal context-dependent fixation.

The present experiments 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 1

Our method is diagrammed in Figure 1. The initial fixation induction involved learning and practicing recall of triads of fixation words, using photos of unrelated environments (context

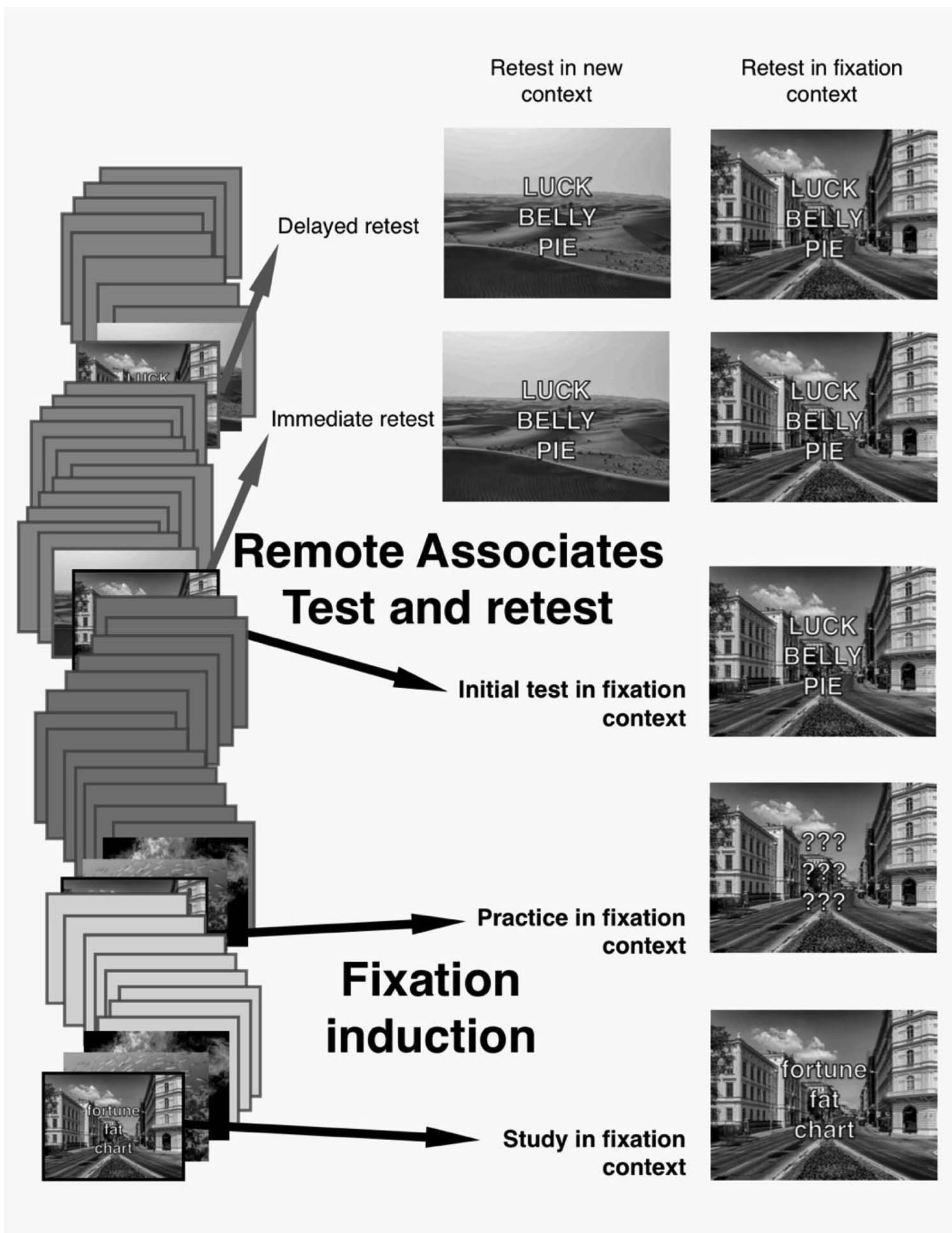

Figure 1. Methods used in Experiments 1 and 2. Fixation induction consisted of a study trial where participants memorized the three fixation words per context photo, followed by multiple practice trials recalling the three fixation words using the context photo as a cue, and an initial test of the associated 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.

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 1) to 3 min (Experiment 2). 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 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).

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 1. Experiment sessions were conducted with 3–15 participants at a time.

Design. A 2 (context: reinstated or new contexts at retest, within-subjects) × 2 (incubation: immediate or delayed retesting, within-subjects) ×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 1, 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 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. 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 5 s.

Next was the fixation word retrieval practice task. On each trial participants saw an encoding context and they had 10 s to recall and write down the three accompanying words (the fixation words) for that photo. Next, the correct responses were displayed for 10 s; 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 5 s 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, within-subjects) × 2 (incubation: immediate or delayed retesting, within-subjects) × 4 (counterbalancing: between-subjects) mixed analysis of variance (ANOVA) was calculated using resolution, the proportion of initially unsolved RAT problems solved at retest, as the dependent measure. A main effect of incubation was found ($F(1, 142) = 22.86$, $p < .001$, $\eta_p^2 = .139$); participants solved more initially unsolved problems after a delay compared to the immediate retest (see Figure 2). A main effect of context [$F(1, 142) = 6.18$, $p = .014$, $\eta_p^2 = .042$] showed that when new contexts were provided at retest, resolution was greater than when retests were given with fixation contexts (see Figure 2). The incubation × context interaction was not significant [$F(1, 142) = 1.31$, $p = .255$, $\eta_p^2 = .009$]. 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 [$t(145) = 2.28$, $p = .024$, $d = .19$].

The fixation induction effectively blocked performance on the initial test of RAT problems in Experiment 1. 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 1.

Discussion

The results of Experiment 1 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 1 was large, and the context effect size was in the moderate range, showing greater resolution when retests were given in new contexts.

Experiment 2

Experiment 2 was conducted to replicate the results of Experiment 1, and to test the validity of our immediate retest condition.

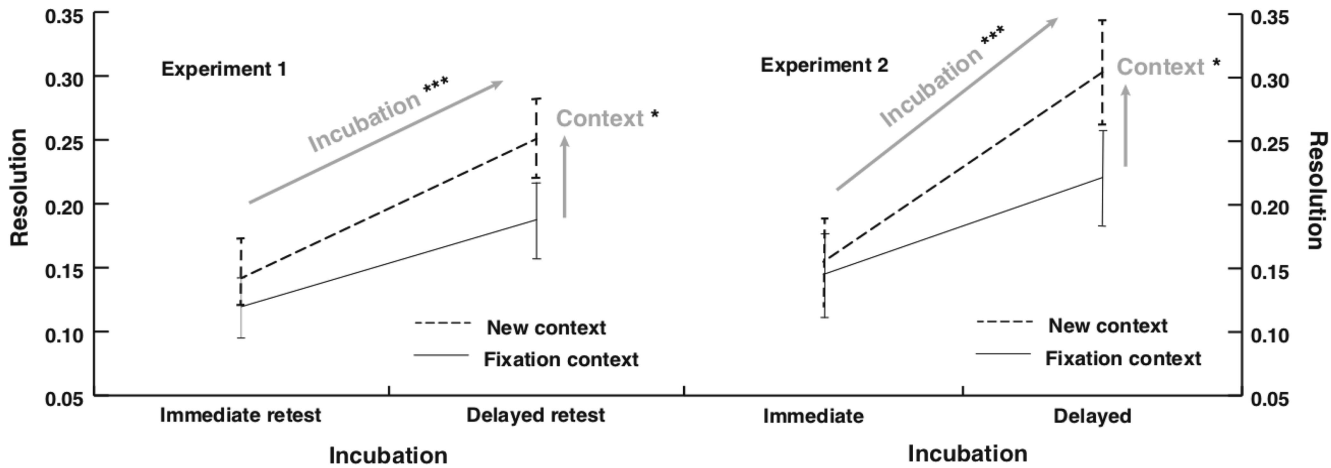

Figure 2. Mean resolution, proportions of initially unsolved problems as a function of incubation and retest context. Greater incubation effects were found in new contexts relative to fixation contexts in both Experiments 1 (left panel) and 2 (right panel). Error bars represent 95% within-subjects confidence intervals. * $p < .05$. *** $p < .001$.

In Experiment 1, 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 2, 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 2, including the experimental design, the materials, and the procedure, were the same as described for Experiment 1.

Method

Methods for Experiment 2 were identical to those described for Experiment 1, with the following exceptions.

Participants. In Experiment 2 there were 120 participants, none of whom participated in Experiment 1.

Procedure. In the final task, the RAT, one noncritical filler problem was inserted between the first test and the retest of 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) × 2 (incubation: immediate or delayed retesting, within-subjects) × 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, [$F(1, 116) = 27.73$, $p < .001$, $\eta_p^2 = .193$]; participants solved more initially unsolved problems after a delay compared to when they were retested immediately (see Figure 2). A main effect of context [$F(1, 116) = 5.56$, $p = .02$, $\eta_p^2 = .046$] showed that resolution was greater when new contexts were given with retested problems, relative to retests given with fixation contexts reinstated (see Figure 2). The incubation × context interaction was not significant [$F = (1, 116) = 2.89$, $p = .092$, $\eta_p^2 = .024$]. 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 2. The initial solution rate for our RAT problems was 44% in Experiment 2, as compared to 60%, the normed solution rate for the same problems (Bowden & Jung-Beeman, 2003).

The incubation × context interaction predicted by our context-dependent fixation hypothesis was not significant in Experiment 2 [$F = (1, 116) = 2.89$, $p = .092$, $\eta_p^2 = .024$], nor was it significant in Experiment 1 [$F(1, 142) = 1.31$, $p = .255$, $\eta_p^2 = .009$]. Because of the similarity in the methods and materials in Experiments 1 and 2, 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) × 2 (incubation: immediate or delayed retesting, a within-subjects variable) × 2 (experiment: Experiment 1 or 2, 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 [$F(1, 264) = 10.62$, $p = .001$, $\eta_p^2 = .039$], with greater resolution in new contexts, incubation [$F(1, 264) = 52.32$, $p < .001$, $\eta_p^2 = .165$], with greater resolution in the delayed retest condition, and experiment [$F(1, 264) = 4.28$, $p = .040$, $\eta_p^2 = .016$], with greater resolution in Experiment 2 than in Experiment 1. This greater resolution rate likely occurred because the delayed retest in Experiment 2, about 170 seconds, was longer than the delay in Experiment 1, an average of 130 seconds, consistent with previous findings that longer incubation intervals can produce greater incubation effects (e.g., Goldman, Wolters, & Winograd, 1992; Smith & Blankenship, 1989). Most importantly, however, this ANOVA found a significant incubation × context interaction [$F(1, 264) = 4.04$, $p = .045$, $\eta_p^2 = .015$]; 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 2 replicated the findings of Experiment 1, showing that a higher proportion of problems were resolved when retests were given after a delay, and when retests were given in new contexts.

General Discussion

Two experiments 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, Saliba, Moran, Goldring, & MacDonald, 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 the present experiments, 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, Meyer, Davidson, Patalano, & Yaniv, 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., 2012; Zedelius & Schooler, 2016, 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.

Context

Two experiments tested our hypothesis that stumped problem solvers get ideas away from places associated with unprofitable ideas. Our participants first learned to associate misleading clues with pictures of places. Next, they saw puzzle problems with those pictures in the background; the problems were especially difficult because the background pictures made participants think of the misleading clues. Participants then had a second chance to solve the problems, either a few seconds later, or a few minutes later. Retests of the problems occurred either with the same pictures that made participants fail initially, or with pictures of new places participants had never seen before. When retests of problems occurred immediately, participants solved few of the problems, but after a delay they were much better at solving the problems that initially had them stumped. This improvement after a delay, an incubation effect, was better when new pictures were shown with the problems, as compared with retesting problems with the original pictures. The results explain why special problems that baffle people at work might be easier to solve when people are away from their workplace.

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