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Don’t wait to incubate: Immediate versus delayed incubation in divergent thinking

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Abstract Previous evidence for the effectiveness of immediate incubation in divergent creative tasks has been weak, because earlier studies exhibited a range of methodological problems. This issue is theoretically important, as a demonstration of the effects of immediate incubation would strengthen the case for the involvement of unconscious work in incubation effects. For the present experiment, we used a creative divergent-thinking task (alternative uses) in which separate experimental groups had incubation periods that were either delayed or immediate and that consisted of either spatial or verbal tasks. Control groups were tested without incubation periods, and we carried out checks for intermittent conscious work on the target task during the incubation periods. The results showed significant incubation effects that were stronger for immediate than for delayed incubation. Performance was not different between the verbal and spatial incubation conditions, and we found no evidence for intermittent conscious working during the incubation periods. These results support a role for unconscious work in creative divergent thinking, particularly in the case of immediate incubation.

Keywords Creativity · Problem solving

Creative problems are generally defined as problems that require the production of new approaches and solutions, where by “new” we mean novel to the solver (Boden, 2004). Explaining how such personally novel solutions are reached is still a major challenge for the psychology of thinking. In analyses of creative problem solving, it has often been claimed that setting creative problems aside for a while can lead to novel ideas about the solution, either spontaneously while attending to other matters or very rapidly when the previously intractable problem is revisited. Personal accounts by eminent creative thinkers in a range of domains have attested to this phenomenon (e.g., Csikszentmihalyi, 1996; Ghiselin, 1952; Poincaré, 1913). In his well-known four-stage analysis of creative problem solving, Wallas (1926, p. 80) labeled a stage at which the problem is set aside and not consciously addressed as “incubation,” and this stage is the focus of the present study.

Following Wallas (1926), a substantial body of experimental research on incubation effects has accumulated using both *insight* problems—to which there is a single solution, but the solver has to develop a new way of representing or structuring the task in order to reach that solution—and *divergent* problems—to which there is no single correct solution, but the solution process encourages seeking as many novel and useful ideas as possible. The prototypical divergent task, which was the one used in the present study, is the *alternative-uses task*, in which participants are asked to generate as many uses as possible that are different from the normal uses of one or more familiar objects, such as a brick (Guilford, 1971; Guilford, Christensen, Merrifield, & Wilson, 1978; Gilhooly, Fioratou, Anthony, & Wynn, 2007). In the classic laboratory paradigm for studying incubation effects, which we will label the *delayed-incubation paradigm*, participants in the incubation condition work on the target problem for an experimenter-determined amount of time (preparation time), are then given an *interpolated activity* away from the target task for a fixed time (incubation period), and finally return to the target problem for a postincubation work period. The performance of the incubation group is contrasted with that of a control group, who

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have worked continuously on the target task for a time equal to the sum of the preparation time and the postincubation conscious working time among the incubation group. A recently developed variant (the *immediate-incubation paradigm*) employs an interpolated task for a fixed period *immediately after* instructions on the target problem and *before* any conscious work has been undertaken, followed by uninterrupted work on the target problem (Dijksterhuis & Meurs, 2006).

Previous studies of delayed- and immediate-incubation effects

Considerable evidence has now emerged from laboratory studies for the efficacy of delayed incubation—that is, that setting a problem aside after a period of work is beneficial (see Dodds, Ward, & Smith, in press, for a qualitative review). A recent meta-analysis of 117 studies by Sio and Ormerod (2009) identified a positive effect of delayed incubation, in which the overall average effect size was in the low–medium band (mean d = 0.32) over a range of insight and divergent tasks. For divergent tasks considered separately, the mean d was larger, 0.65, which may be considered to be in the high–medium band of effect sizes. Overall, the existence of delayed-incubation effects can now be regarded as well established, particularly in the case of divergent problem solving.

Regarding the efficacy of immediate incubation, Dijksterhuis and Nordgren (2006) reported studies in which better decisions and more creative solutions were found when immediate incubation breaks were given after the decision problems or divergent tasks had been presented. In the realm of decision problems, Nordgren, Bos, and Dijksterhuis (2011) found that delayed incubation produced better decisions than did immediate incubation, and both were better than no incubation.

However, the beneficial effects of immediate incubation on decision making have proven difficult to reproduce, and a number of unsuccessful replication attempts have now been reported (e.g., Acker, 2008; Newell, Wong, Cheung, & Rakow, 2009; Rey, Goldstein, & Perruchet, 2009; Payne, Samper, Bettman, & Luce, 2008).

The present study concerns creative thinking using a divergent task, and Dijksterhuis and Meurs (2006) did report that, in their Experiment 3, participants produced responses of higher rated average creativity when the instructions to list things one can do with a brick were followed immediately by a 3-min distractor task (immediate incubation) before generating uses, relative to participants who began generating uses right away. It may be noted that the instructions did not ask for unusual uses, which is the norm in divergent-thinking tasks, and so it is not clear whether participants had a goal of being creative. They may have been reporting infrequent uses that they happened to know rather than generating uses novel to them. Raters tend to score infrequent responses as creative, although such uses may have been preknown, and therefore could reflect memory retrieval rather than the generation of subjectively novel responses (Quellmalz, 1985). Gilhooly et al. (2007) developed a self-report method for assessing subjective novelty that addresses the issue of individually creative responses as against rare responses, and this method was used in the present experiment. In this method, participants indicate which of their responses were first thought of while doing the task, and so were subjectively novel. Gilhooly et al. found converging evidence for the validity of this method of assessing responses as personally old or new. Self-judged new responses were rated as significantly more creative by independent judges and were more frequently produced by participants with higher executive-functioning test scores. Self-judged novel responses occurred later in the sequences of responses, which is consistent with a reliance on memory for the retrieval of early responses, followed by executively demanding processes for generation of novel ideas when the pool of already known uses is exhausted.

Zhong, Dijksterhuis, and Galinsky (2008), using the immediate-incubation paradigm with the remote associates task (RAT)—in which participants have to retrieve an associate common to three given words (e.g., *cottage, blue, mouse*? Answer: *cheese*)—found that, although immediate incubation did not facilitate actual solution, it appeared to activate solution words on unsolved trials, as indicated by lexical decision measures, as compared to unsolved trials without immediate incubation. However, it may be noted that some theorists (e.g., Weisberg, 2006, p. 468) have disputed whether the RAT is a creative task, as the solutions are already-known associations rather than novel responses. A normal criterion for a creative task is that it requires the participant to generate a response that is novel for the participant rather than one already known.

Overall, the evidence in favor of a beneficial effect of immediate incubation in creative tasks is rather weak, as it is based on one study of a divergent task that did not require novel responses (Dijksterhuis & Meurs, 2006) and another study (Zhong et al., 2008) using a convergent task (the RAT) in which the responses are not themselves creative. The question of whether immediate incubation is effective in creative tasks is important for its bearing on theories of incubation, and the present study aimed to provide more solid evidence regarding the efficacy, or otherwise, of immediate incubation than has been available hitherto. We now outline the main theories regarding incubation effects.

Theories of incubation effects

Intermittent conscious work This theory suggests that although incubation is intended to be a period without conscious work on the target task, nevertheless participants may carry out intermittent conscious work (Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995, p. 82; Weisberg, 2006, pp. 443–445). Any conscious work during the supposed incubation period would reduce the time required when the target problem was readdressed—but would be expected to impair performance on the interpolated task. As a check against the possibility of intermittent conscious work, performance on the interpolated task during the incubation period should be compared with the performance of a control group working on the same interpolated task without being in an incubation condition. A deficit in the interpolated task on the part of the incubation group would be consistent with the hypothesis of some conscious work on the target task occurring during incubation. Although this seems a rather basic methodological check, surprisingly, it does not appear to have been carried out in previous research (Dodds et al., in press; Sio & Ormerod, 2009). The study reported here, on the other hand, did incorporate suitable checks for intermittent conscious work on the target task during the incubation period.

"Fresh look" This view (e.g., Segal, 2004; Simon, 1966; see also Dijksterhuis & Meurs, 2006) proposes an important role for automatic passive reduction in idea strength or activation during the incubation period. The proposal is that misleading strategies, mistaken assumptions, and related "mental sets" weaken through forgetting during the incubation period, and thus a fresh start or "set shifting" is facilitated when the problem is resumed. On this view, incubation works by allowing the weakening of misleading approaches to the task during a break after a period of work (delayed incubation), thus allowing a fresh start. This approach would not predict a beneficial effect of immediate incubation, because with immediate incubation there is no time for sets or fixations to develop, so that forgetting of misleading approaches cannot occur.

Unconscious work This approach proposes that incubation effects occur through active but unconscious processing of the problem materials (as against the passive forgetting processes envisaged in the fresh-look approach.) The term "unconscious work" seems to have first been used in the context of problem solving by Poincaré (1913, p. 393). Other phrases referring to the same notion include "nonconscious idea generation" (Snyder, Mitchell, Ellwood, Yates, & Pallier, 2004) and "unconscious thought" (Dijksterhuis & Nordgren, 2006), but we will generally use the term "unconscious work" in this article. The question naturally arises of what form unconscious work might take. Is it possible that unconscious work could be just like conscious work, but carried out without conscious awareness? Or is it better thought of as automatic spreading activation along associative links, as against a rule- or strategy-governed activity? We will consider the question of what form unconscious work might take more fully in the Discussion section.

The possible mechanisms outlined above are not mutually exclusive. A delayed-incubation condition could conceivably evoke all three mechanisms, with the person engaging in some intermittent conscious work when attention wanders from the interpolated incubation task, and with some beneficial forgetting and unconscious work taking place when the person is attending to the interpolated incubation task. However, an immediate-incubation effect would not be consistent with a fresh-look explanation but could involve some intermittent conscious work and/or some unconscious work. The present study aimed to clarify the contributions of the three types of processes in explaining immediate and delayed incubation, without assuming that one and only one process can explain all of the findings.

Theories of incubation: Previous studies

What has previous research suggested regarding the possible mechanisms of incubation?

Dijksterhuis and Meurs (2006) argued, as outlined above, that in the immediate-incubation paradigm the fresh-look approach may be ruled out, as there is no period of initial work in which misleading fixations and sets could be developed. Thus, if immediate incubation is shown to be effective, the unconscious-work hypothesis must remain in contention for immediate-incubation effects, and would also be a candidate explanation for delayed incubation. Dijksterhuis and Meurs took the beneficial effects of the immediate-incubation paradigm on a divergent task in their Experiment 3 as support for the role of unconscious work in incubation. However, as already mentioned, the task in this study did not clearly meet the usual criteria for a creative task, and the scoring did not distinguish infrequent from genuinely novel responses. Hence, this study does not unequivocally address creative thinking as against free recall of possibly rare, but previously experienced, events from episodic and semantic memory.

Snyder et al. (2004) also found evidence consistent with unconscious work from a study using the delayed-incubation paradigm, but with a surprise return to the target task. Although the return to the main task was unexpected, beneficial effects were found, suggesting that automatic continuation of unconscious work could have occurred when the task was set aside. It should be noted, however, that Snyder et al.

used a task that simply required production of uses for a piece of paper, as against the generation of novel uses, so their task did not necessarily involve creative thinking rather than recall.

It is of interest that both Segal (2004) and Dijksterhuis and Meurs (2006) used interpolated tasks during their incubation periods that were different in character from the target tasks. Segal's target task was spatial, while the interpolated tasks were verbal; Dijksterhuis and Meurs's target task was verbal, but the interpolated task was spatial. From Dodds et al.'s (in press) extensive review, the issue of similarity between the target and interpolated tasks does not appear to have been addressed hitherto. The similarity relationship between target and interpolated tasks could be important, in that the main competing hypotheses suggest different effects of similarity. If unconscious work is the main process, then interpolated tasks similar to the target task should interfere with any unconscious work using the same mental resources, and so lead to weaker (or even reversed) incubation effects when compared with the effects of dissimilar interpolated tasks. On the other hand, the selective-forgetting mechanism suggests that interpolated tasks similar to the target task would cause greater interference, which would lead to more forgetting and enhanced incubation benefits.

Hélie, Sun, and Xiong (2008) found that more executively demanding interpolated tasks reduced reminiscence scores for the free recall of pictures when a surprise free recall was required after the interpolated task. In their study, participants studied booklets of pictures for a set period, freely recalled the items, and then did various interpolated activities before being retested with free recall of the pictures. The reminiscence score was the number of new items recalled on the second test. The results were consistent with Hélie and Sun's (2010) explicit–implicit interaction model, which can be applied to creative problem solving and which allows for unconscious, implicit processes to occur in parallel with conscious, explicit processes. However, Hélie et al.'s (2008) target task was free recall rather than creative thinking, so it does not speak directly to divergent thinking, which is the focus of the present study.

Ellwood, Pallier, Snyder, and Gallate (2009) found a beneficial effect on the number of postincubation responses of a dissimilar interpolated task in a delayed-incubation experiment. However, their study used a fluency-of-uses task rather than a novel-uses task. Also, as Ellwood et al. pointed out, although their findings are consistent with an explanation in terms of unconscious work, an explanation in terms of selective relief of fatigue could also be invoked to account for the effects of similarity between the incubation and target tasks. On this view, for example, a spatial delayed-incubation task very different from a main verbal task could allow for more recovery from specific fatigue of verbal processes than would an intervening verbal task. The present study includes tests of the effects of incubation–target task similarity in an immediate-incubation paradigm, where fatigue can be ruled out, as well as in a delayed-incubation paradigm in which fatigue relief could be a factor.

Present study: Outline

The present study of the effects of varying incubation activities (verbal vs. spatial), detailed below, used a clearly creative verbal divergent task (alternative uses), scored for novelty as well as fluency, unlike the tasks of Ellwood et al. (2009) or Hélie et al. (2008). Thus, the present study is clearly focused on incubation effects in creative thinking. The study used both immediate and delayed incubation with spatial and verbal intervening tasks, so that the resource overlap predictions of the selective-forgetting and unconscious-work hypotheses, as well as the issue of the possible effects of differential fatigue relief, could be addressed. The main aims of the study were to determine the extent to which immediate incubation is indeed helpful in divergent creative tasks (which previous research had not clearly addressed) and to assess the relative contributions of intermittent-work, unconscious-work, and fresh-look mechanisms of incubation in such tasks.

Method

In this experiment, the target task was the divergent production of alternative uses for a brick, which we classed as a verbal task. The incubation period (which was 4 min long) was positioned either after 5 min of conscious work or immediately after the initial divergent-task instructions. The activities during the incubation period were either verbal (anagrams) or spatial (mental rotation tasks). All participants were instructed after 5 min of divergent production to draw a line after their last response up to that point.

Participants

A group of 184 (123 female, 61 male) students at the University of Hertfordshire took part in the experiment.

Design

A 2 (incubation position: immediate vs. delayed.) × 3 (interpolated task: none vs. verbal vs. spatial) independent-groups design was used. The *n*s per experimental group were as follows: $n = 25$ with 4 min delayed incubation and a spatial interpolated task, $n = 22$ with 4 min delayed incubation and a verbal interpolated task, $n = 30$ with 4 min immediate incubation and a spatial interpolated task, and $n = 30$ with 4 min immediate incubation and a verbal interpolated task. We also ran separate control groups for the delayed- and immediate-incubation conditions (ns = 47 and 30, respectively) that provided baseline performance data for target and interpolated tasks in the absence of incubation periods.

Procedure

In the delayed-incubation conditions, the participants were told that they would be asked to write down possible uses for a brick different from the usual use; after 5 min of working, participants were told that they would be returning to the brick-uses task later in the study. During the 4-min incubation periods, participants either undertook verbal tasks (anagrams) or spatial tasks (mental rotation items) presented in booklets. Sets of 73 five-letter single-solution anagrams (from Gilhooly & Hay, 1977) and 48 mental rotation items (from Peters et al., 1995) were used, and performance was scored in terms of correct solutions during the period allowed. After the delayed incubation periods, there were a further 2 min of work on the brick-uses task.

In the immediate-incubation conditions, participants were given the standard instructions about the brick-uses task and immediately told that the experimenter wanted them to do another task first, after which they would return to the uses task, and they were assigned randomly to anagrams or mental rotation for 4 min. After the immediate incubation period, they worked on the brick-uses task for 7 min without a break.

Control participants worked on the uses task for 7 min without any incubation periods and carried out mental rotations and anagrams for 4 min each. The order of the three tasks in the control groups was randomized. The control rotation and anagram measures were compared with performance on the same tasks when they were used as intervening activities during the incubation periods. The control uses-task measures were compared with performance on the uses task in the incubation conditions.

At the end of the brick-uses task, participants reviewed their response sheets and were asked to indicate (by circling) which of the uses that they had reported were subjectively novel—that is, had first occurred to them during the task rather than being previously known from past direct experience or through films, books, television, and so on. Gilhooly et al. (2007) found that this was a valid measure of personal originality.

Results

Incubation effects

Figure 1 shows the average numbers of brick uses, and Fig. 2 the average numbers of self-judged novel uses produced over the total of 7 min on the uses task with 0 min of incubation (control data) or 4 min of delayed or immediate incubation with spatial or verbal interpolated tasks (mental rotations or anagrams). From these figures, it seems that both immediate and delayed incubation periods were beneficial as compared to the control conditions and that immediate incubation produced better performance than did delayed incubation.

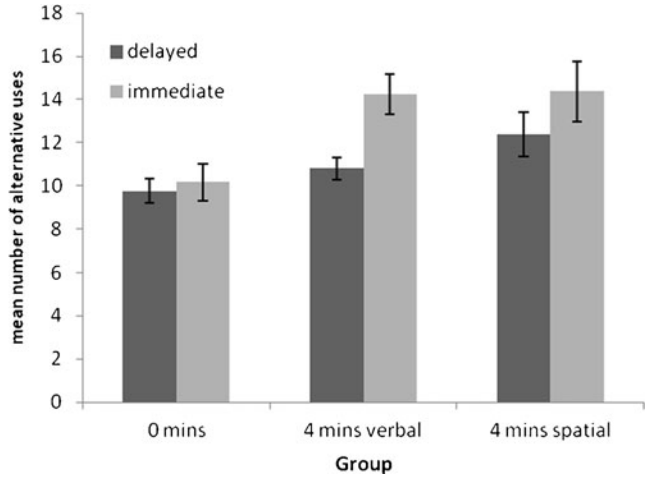

Fig. 1 Mean numbers of alternative uses produced during delayed and immediate incubation using verbal or spatial interpolated tasks. Error bars represent ± 1 *SEM*

An analysis of variance (ANOVA) indicated a significant effect of the type of interpolated activity (none/verbal/spatial) on the number of uses reported [$F(2, 178) = 7.89$, $p < .001$, $\eta_p^2 = .08$] and on the number of self-judged novel uses [$F(2, 178) = 11.49$, $p < .001$, $\eta_p^2 = .11$]. Post hoc tests indicated significant differences between no incubation and incubation tasks of both mental rotations and anagrams for number of uses ($p < .05$) and for self-judged novelty ($p < .05$). No significant differences were found between the verbal and spatial incubation conditions.

An ANOVA indicated a significant effect of the position of incubation (delayed/immediate) on the number of uses reported [$F(1, 178) = 6.39$, $p < .05$, $\eta_p^2 = .04$] and on the number of self-judged novel uses [$F(1, 178) = 10.03$, $p < .01$, $\eta_p^2 = .05$], with immediate incubation being more beneficial for both measures.

There were no significant interactions between the type of incubation activity and the position of incubation activity on the number of uses or on self-judged novelty.

Pre- and postincubation performance in delayed-incubation conditions

In the delayed-incubation conditions, data were available for the uses-task performance measures separately for the 5-min preincubation period and the 2-min postincubation period and for the first 5 min and last 2 min of use production in the control (no-incubation) condition. These data were examined

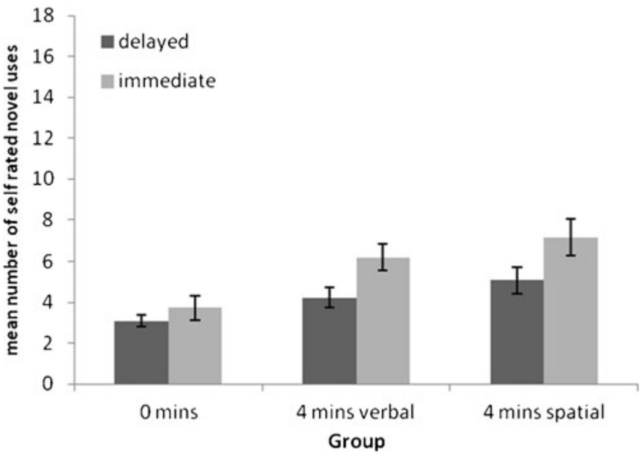

Fig. 2 Mean numbers of self-rated novel uses produced by the delayed- and immediate-incubation groups using verbal or spatial interpolated tasks. Error bars represent ± 1 *SEM*

to check that any benefits in performance relative to controls were concentrated in the postincubation (last 2-min) period. One-way ANOVAs were carried out on the effects of incubation activity (none/verbal/spatial) on uses totals and uses novelty in the first and last 2 min of work (pre- and post-incubation periods in the incubation conditions). The mean scores are shown in Table 1.

The first-5-min scores for both uses totals and novelty were not significantly different between the incubation activity conditions (none/verbal/spatial). However, the measures in the last 2 min (postincubation in the incubation conditions) were significantly different between the conditions. For uses totals, $F(2, 91) = 3.45$, $p < .05$, $\eta_p^2 = .07$, and for uses novelty, $F(2, 91) = 6.54$, $p < .01$, $\eta_p^2 = .11$. Thus, the effects of the delayed-incubation manipulation were concentrated in the postincubation period, during which incubation produced more responses and more novel responses than did no incubation, as would be expected.

Performance over the first 5 min and the last 2 min in immediate-incubation conditions

All uses-task performance in the immediate-incubation conditions was postincubation, but it was possible to compare the first 5 min (which corresponded to the preincubation time in the delayed condition) and the last 2 min (which corresponded to the postincubation time in the delayed condition).

One way ANOVAs were carried out on the effects of incubation activity (none/verbal/spatial) on both uses totals and uses novelty for the first-5-min and the last-2-min work periods. The mean scores are shown in Table 2.

Both the first-5-min and the last-2-min scores for uses totals and novelty were significantly different between the incubation activity conditions (none/verbal/spatial): for the first-5-min uses totals, $F(2, 87) = 3.29$, $p < .05$, $\eta_p^2 = .07$, and for the last-2-min uses totals, $F(2, 87) = 7.01$, $p < .01$, $\eta_p^2 = .14$; similarly, for the first-5-min novel scores, $F(2, 87) = 4.54$, $p < .05$, $\eta_p^2 = .09$, and for the last-2-min novelty scores, $F(2, 87) = 5.78$, $p < .01$, $\eta_p^2 = .12$. Thus, as would be expected, the effects of the immediate incubation manipulation were apparent immediately, in the first 5 min, and persisted into the final 2 min.

Effects of interpolation on the interpolated incubation period tasks

As a check on the intermittent-conscious-work hypothesis, we compared performance on the rotation and anagram tasks when they were carried out in control conditions for 4 min and as interpolated tasks for 4 min in the incubation conditions. The intermittent-work hypothesis makes a one-tailed prediction that performance should be impaired on a task when it is used as an interpolated incubation activity, relative to controls, as participants would be distracted from the interpolated task by the main target task if they were intermittently working on the main task during incubation.

However, from Fig. 3 it appears that carrying out mental rotation as an interpolated task during incubation periods did not impair correct mental-rotation performance, and *t* tests found no significant differences between interpolated and control performance. Also, there were no significant impairments between anagram solution rates when anagrams were done as an incubation activity or as a stand-alone activity.

The possibility of fatigue effects for the control groups, who did the alternative-uses task, mental rotations, and

Table 1 Delayed incubation: Pre- and postincubation scores for total brick uses and brick use novelty over incubation task conditions (control/verbal/spatial)

Control ($N = 47$)		Verbal ($N = 22$)		Spatial ($N = 25$)		Control ($N = 47$)		Verbal ($N = 22$)		Spatial ($N = 25$)	
M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
First 5 min/Preincubation Brick Uses						Last 2 min/Postincubation Brick Uses					
7.90	3.24	8.59	3.67	9.60	4.09	1.85	1.25	2.21	1.06	2.76	1.85
First 5 min/Preincubation Brick Novelty						Last 2 min/Postincubation Brick Novelty					
2.31	1.77	2.86	1.91	3.52	2.51	0.77	0.78	1.36	0.95	1.56	1.22

Table 2 Immediate incubation: First-5-min and last-2-min scores for total brick uses and brick use novelty over incubation task conditions (control/verbal/spatial)

Control (*N* = 30)		Verbal (*N* = 30)		Spatial (*N* = 30)		Control (*N* = 30)		Verbal (*N* = 30)		Spatial (*N* = 30)	
M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
First 5 min Brick Uses						Last 2 min Brick Uses					
8.67	3.97	11.23	3.92	11.54	6.02	1.50	1.41	3.03	1.84	2.83	2.14
First 5 min Brick Novelty						Last 2 min Brick Novelty					
3.00	2.90	4.37	2.91	5.53	3.88	0.73	0.86	1.83	1.53	1.63	1.50

anagrams, should be considered, as possibly depressing their performance and thus masking any effects of intermittent work for the experimental groups. The control participants did the tasks in counterbalanced orders. An ANOVA revealed no significant order effects for any of the tasks. That is, the control scores were not depressed due to possible fatigue effects, and the lack of significant differences between the control and incubation groups on the interpolated tasks did not reflect fatigue. The control anagram and rotation scores tended to be lower than the incubation groups' scores, but not significantly.

It may be suggested that the participants did not give their full attention to the rotation task, given the correct rate of about four rotations in 4 min. The numbers of rotation items attempted were, of course, higher than the correct rates, with means of 6.68 (SD = 2.62) in the control and 7.12 (SD = 3.14) in the relevant incubation condition (delayed), and these figures were not significantly different. In the case of anagrams, the delayed-incubation group attempted more anagrams than did the controls, with means of 18.91 (SD = 9.02) and 14.06 (SD = 5.86), respectively, $F(1, 67) = 7.02$, $p < .01$, although the groups did not differ in numbers correct. In the immediate-incubation

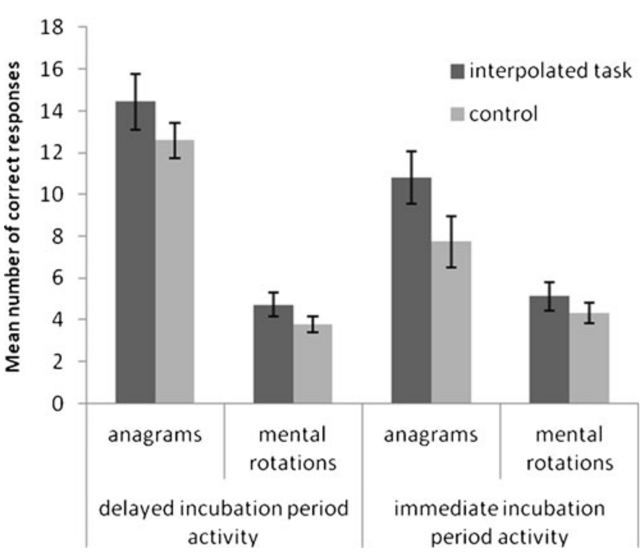

Fig. 3 Mental rotation and anagram performance when carried out as an interpolated (incubation) task or as a control task. Error bars represent ± 1 *SEM*

conditions, again, slightly more items were attempted for rotations in the incubation condition (M = 9.17, SD = 2.81) than in the controls (M = 8.87, SD = 3.95), and the numbers of anagrams attempted were very similar in the incubation (M = 12.58, SD = 7.57) and control (M = 12.70, SD = 6.89) conditions; these differences were not significant. We may note that, as with the correct scores, these results for anagrams and rotations attempted in the control and incubation conditions are generally counter to the one-tailed prediction of the intermittent-work hypothesis, that performance should be impaired on interpolated tasks relative to controls.

Although the type of interpolated activity in the incubation periods did not seem to affect the level of the groups' use performance, it may be that, over participants, those who gave more attention to the interpolated tasks might have done worse on the target tasks, as they would have had less scope for intermittent work on the target task during incubation than those who attended less to the interpolated tasks. Thus, according to the intermittent-work hypothesis, negative correlations might be expected between performance on the interpolated and target tasks. In the immediate-incubation conditions, the correlations for anagrams correct in incubation were $r(28) = –.19$, n.s., with total uses, and .11, n.s., with novel uses; for rotations correct in incubation, the correlations were $r(28) = .31$, n.s., with total uses, and .36, $p < .05$, with novel uses. In the delayed-incubation conditions, the correlations for uses totals after the incubation period were $r(23) = .11$, n.s., with anagrams correct in incubation, and $r(20) = .03$, n.s., with rotations correct in incubation; and finally, for novel uses after the incubation period, the correlations were $r(23) = –.07$, n.s., with anagrams correct, and .18, n.s., with rotations correct in incubation. The only significant correlation (in two-tailed tests) out of the eight was in the direction opposite from the one predicted by the intermittent-work hypothesis—that is, positive rather than negative.

Discussion

First, it seems that the intermittent-work hypothesis can be ruled out, since under that hypothesis we would have expected an impairment of performance on the anagram and rotation tasks when they were performed as interpolated activities during the incubation periods, relative to when they are performed as control activities. No such negative effects were found. If anything, the effects were in the direction opposite the one predicted by the intermittent-work hypothesis. Furthermore, the intermittent-work hypothesis predicts negative correlations between performance on the interpolated tasks and on the target-uses tasks, but no significant correlations were found in the predicted direction in any of the incubation conditions. Indeed, only two of the eight correlations were even in the predicted, negative direction. Thus, we conclude that the effects of incubation found here cannot be explained by the intermittent-work hypothesis.

Immediate incubation produced better performance than the control condition, which constructively replicates Dijksterhuis and Meurs's (2006) finding of immediate-incubation effects with a clearly creative divergent-thinking task requiring novel uses, and our result held over two types of incubation activity (spatial and verbal). Furthermore, immediate incubation was more efficacious than delayed incubation for the creative task used here. The different effects of immediate and delayed incubation suggest that different process mixtures are involved in the two forms of incubation. A possible interpretation is that, with delayed incubation, in which conscious work is carried out for a period before incubation, relatively strong "sets" could build up, so the delayed incubation period could involve both beneficial forgetting and unconscious work. Thus, delayed incubation is handicapped relative to immediate incubation, in which "sets" would be expected to be nonexistent, or at least weaker, because sets would have less time to be established and strengthened. The immediate incubation period thus could involve only unconscious work, without the need to overcome sets. We found immediate incubation followed by conscious work to be better for creative performance in the uses task than was delayed incubation *after* conscious work, which is opposite Nordgren et al.'s (2011) finding with a decision task, and presumably reflects differences between divergent creative thinking as compared to convergent decision making. The decision task required participants to absorb a number of facts about the options, a stage that may benefit from initial conscious study; in contrast, the uses task draws on already stored semantic memory of object characteristics and of the requirements for various functions.

Our conclusion in favor of the unconscious-work hypothesis as a viable mechanism is based on the benefits of immediate incubation, in which sets are unlikely to have been developed and in which we found no evidence for intermittent work. This leaves unconscious work as the likeliest explanation for the benefits of immediate incubation.

As mentioned in the introduction, the question arises of what form this unconscious work might take. Is it possible that unconscious work could be just like conscious work, but carried out without conscious awareness? Perhaps unconscious work would be better thought of as involving spreading activation along associative links, rather than as a rule- or strategy-governed activity?

To explore the idea that unconscious work might be a subliminal version of conscious work, it would seem useful to consider the nature of conscious processing in the alternative-uses task. This issue was addressed in a think-aloud study by Gilhooly et al. (2007), in which they found that participants used strategies such as scanning an object's properties (e.g., "a brick is heavy") and using the retrieved properties to cue uses (e.g., "heavy objects can hold down things like sheets, rugs, tarpaulin, etc., so a heavy brick could do those things, too"). However, it seems unlikely that unconscious work could simply duplicate the form of conscious work without awareness. The standard views in cognitive science are (a) that mental contents vary in activation levels, (b) that, above some high activation level, mental contents become available to consciousness, (c) that we are conscious of only a limited number of highly activated mental elements at any one time (that is, the contents of working memory), and (d) that strategy- or rule-based processing, as found in Gilhooly et al.'s think-aloud study, requires such highly activated (conscious) material as inputs and generates highly activated (conscious) outputs. That is, the kind of processing involved in conscious work requires the highly activated contents of working memory, of which we are necessarily aware, given that material is in consciousness if and only if it is above a high activation threshold. Thus, it seems logically impossible that unconscious processes could duplicate conscious processes in every respect and yet remain unconscious. For example, using rules and working memory to multiply two three-digit numbers (e.g., $364 \times 279 = ?$) seems impossible without having in working memory highly activated representations of the numbers, the goal, and the intermediate results, and such representations are necessarily conscious. Unconscious multiplication of even moderately large numbers, not previously practiced, seems impossible. (With practice, of course, it would be possible to store many three-digit multiplication results in long-term memory that could then be directly retrieved—a type of unconscious process—but this is not the same as mental multiplication.) Overall, then, we discount the idea that unconscious work or thought could be just the same as conscious work minus awareness of any mental content. What, then, might unconscious work consist of? Many theorists, such as Poincaré (1913), Campbell (1960), and Simonton (1995), have argued that unconscious work in incubation involves the quasi-random generation of associations between mental elements to produce novel combinations of ideas, some of which may be useful. Processes such as parallel spreading activation through a semantic network could serve to form remote and unusual associations (Jung-Beeman et al., 2004) without requiring activation levels to rise above the threshold of consciousness. In Hélie and Sun's (2010) recent explicit–implicit interaction model, incubation is regarded as involving unconscious implicit associative processes that demand little attentional capacity, in contrast with conscious, explicit, rule-governed attentionally demanding processes. According to Dijksterhuis and Nordgren's (2006) unconscious-thought theory (UTT), unconscious thought, or work, has the following characteristics: It is parallel, bottom-up, inexact, and—importantly for the present study—divergent, whereas conscious thought is serial, exact, and generally convergent. There is broad agreement among a number of theorists that unconscious thinking, or work—in the form of implicit associative processes based on spreading activation—is a possible explanation of incubation effects. According to the unconscious-work view then, a beneficial effect of immediate incubation would be expected, as a useful foundation of novel associations could be formed by spreading activation and could be highly accessible when the use-reporting stage begins.

A possible difficulty of our results for the unconscious-work hypothesis is that it predicts that an incubation period on a presumed verbal task, such as the brick-uses task, should be more beneficial if the interpolated task is nonverbal rather than verbal. The rationale for this prediction is that verbal processing resources would be invoked in work on a verbal interpolated task, thus depleting the resources available for simultaneous unconscious work on the target task. A spatial interpolated incubation task would not compete with simultaneous unconscious verbal activity, and so should produce stronger incubation effects for a verbal main task. Hélie and Sun's (2010) explicit–implicit interaction model of creative thinking explicitly makes this prediction and draws on supporting results; however, these results came from reminiscence memory rather than creative-thinking tasks. The selective-forgetting mechanism of the fresh-look approach, on the other hand, leads to opposite predictions regarding the effects of interpolated tasks. However, neither hypothesis, both of which could apply to the delayed-incubation condition, was supported, as the type of interpolated activity did not affect target task performance. Thus, the present results did not support the predictions of the unconscious-work or of the fresh-look (selective-forgetting) hypotheses regarding the effects of the type of incubation activity. In this regard, our results on the effects of type of interpolated activity are contrary to those of Ellwood et al. (2009), which were in line with the unconscious-work hypothesis. However, some differences between the present study and that of Ellwood et al. may be relevant. For one thing, Ellwood et al. did not inform their participants that the target task would be returned to after incubation, whereas in our study the goal of returning was stated; this might be an important factor affecting the incubation process. Future studies will address this issue. A second major difference is that Ellwood et al. used a fluency task that simply required the reporting of uses for a piece of paper, rather than original or novel uses. That Ellwood et al.'s task did not tap creativity is indicated by the reported lack of correlation between performance on their target task and the personality characteristic of openness on a Big-5 personality test, because openness typically correlates well with creative divergent-test performance (Batey & Furnham, 2006). Also, it may be noted that our results included novelty scores, which Ellwood et al.'s did not.

Another explanation for the lack of any effect of the type of incubation activity in the present study is that we may have misclassified the uses task as a purely verbal task. Indeed, Gilhooly et al. (2007) did find protocol evidence of imagery processes in the uses task, and it may be that the uses task is better conceived as invoking both verbal and spatial processes. If so, both types of incubation activity could have similar effects, according to both the unconscious-work and selective-forgetting hypotheses for delayed incubation. Future research will aim to address this point by using creative tasks that are more purely spatial (e.g., mental synthesis with shapes; Pearson, Logie, & Gilhooly, 1999) or verbal (e.g., mental synthesis with words; Haught & Johnson-Laird, 2003).

Finally, we note that our results have a clear practical application. When faced with a task requiring that familiar objects be used in new ways, it seems that it would be helpful for respondents to put aside the task immediately and return to it after a period, allowing unconscious incubation processes to operate, before undertaking conscious work.

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References

Acker, F. (2008). New findings on unconscious versus conscious thought in decision making: Additional empirical data and meta-analysis. *Judgment and Decision Making, 3*, 292–303.

Batey, M., & Furnham, A. (2006). Creativity, intelligence, personality: A critical review of the scattered literature. *Genetic, Social, and General Psychology Monographs, 132*, 355–429.

Boden, M. A. (2004). *The creative mind: Myths and mechanisms* (2nd ed.). London: Routledge.

Campbell, D. T. (1960). Blind variation and selective retention in creative thought as in other knowledge processes. *Psychological Review, 67*, 380–400.

Csikszentmihalyi, M. (1996). *Creativity: Flow and the psychology of discovery and invention*. New York, NY: HarperCollins.

Dijksterhuis, A., & Meurs, T. (2006). Where creativity resides: The generative power of unconscious thought. *Consciousness and Cognition, 15*, 135–146.

Dijksterhuis, A., & Nordgren, L. F. (2006). A theory of unconscious thought. *Perspectives on Psychological Science, 1*, 95–109.

Dodds, R. A., Ward, T. B., & Smith, S. M. (in press). A review of the experimental literature on incubation in problem solving and creativity. In M. A. Runco (Ed.), *Creativity research handbook* (Vol. 3). Cresskill, NJ: Hampton Press.

Ellwood, S., Pallier, P., Snyder, A., & Gallate, J. (2009). The incubation effect: Hatching a solution? *Creativity Research Journal, 21*, 6–14.

Ghiselin, B. (1952). *The creative process: A symposium*. New York, NY: Mentor.

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*, 611–625.

Gilhooly, K. J., & Hay, D. (1977). Rated characteristics of 205 five letter words having single solution anagrams. *Behavior Research Methods & Instrumentation, 9*, 12–17.

Guilford, J. P. (1971). *The nature of human intelligence*. New York, NY: McGraw-Hill.

Guilford, J. P., Christensen, P. R., Merrifield, P. R., & Wilson, R. C. (1978). *Alternate uses: Manual of instructions and interpretations*. Orange, CA: Sheridan Psychological Services.

Haught, C., & Johnson-Laird, P. N. (2003). Creativity and constraints: The production of novel sentences. In R. Alterman & D. Kirsh (Eds.), *Proceedings of the 25th Annual Meeting of the Cognitive Science Society* (pp. 528–532). Mahwah, NJ: Erlbaum.

Hélie, S., & Sun, R. (2010). Incubation, insight, and creative problem solving: A unified theory and a connectionist model. *Psychological Review, 117*, 994–1024. doi:10.1037/a0019532

Hélie, S., Sun, R., & Xiong, L. (2008). Mixed effects of distractor tasks on incubation. In B. C. Love, K. McRae, & V. M. Sloutsky (Eds.), *Proceedings of the 30th Annual Meeting of the Cognitive Science Society* (pp. 1251–1256). Austin, TX: Cognitive Science Society.

Jung-Beeman, M., Bowden, E. M., Haberman, J., Frymiare, J. L., Arambel-Liu, S., Greenblatt, R., . . . Kounios, J. (2004). Neural activity when people solve verbal problems with insight. *PLoS Biology*, *2*, e97. doi:10.1371/journal.pbio.0020097

Newell, B. R., Wong, K. Y., Cheung, J. C. H., & Rakow, T. (2009). Think, blink or sleep on it? The impact of modes of thought on complex decision making. *Quarterly Journal of Experimental Psychology, 62*, 707–732.

Nordgren, L. F., Bos, M. W., & Dijksterhuis, A. (2011). The best of both worlds: Integrating conscious and unconscious thought best solves complex decisions. *Journal of Experimental Social Psychology, 47*, 509–511.

Payne, J., Samper, A., Bettman, J. R., & Luce, M. F. (2008). Boundary conditions on unconscious thought in complex decision making. *Psychological Science*, 1118–1123.

Pearson, D. G., Logie, R. H., & Gilhooly, K. J. (1999). Verbal representations and spatial manipulations during mental synthesis. *Journal of Cognitive Psychology, 11*, 295–314.

Peters, M., Laeng, B., Latham, K., Jackson, M., Zaiyouna, R., & Richardson, C. (1995). A redrawn Vandenberg and Kuse Mental Rotations Test: Different versions and factors that affect performance. *Brain and Cognition, 28*, 39–58.

Poincaré, H. (1913). *The foundations of science*. New York, NY: Science House.

Quellmalz, E. (1985). Test review of Alternate Uses. From J. V. Mitchell, Jr. (Ed.), *The ninth mental measurements yearbook* [Electronic version]. Retrieved from Buros Institute's *Test Reviews Online* website: www.unl.edu/buros

Rey, A., Goldstein, R. M., & Perruchet, P. (2009). Does unconscious thought improve complex decision making? *Psychological Research, 73*, 372–379.

Segal, E. (2004). Incubation in insight problem solving. *Creativity Research Journal, 16*, 141–148.

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 & J. E. Davidson (Eds.), *The nature of insight* (pp. 65–124). Cambridge, MA: MIT Press.

Simon, H. A. (1966). Scientific discovery and the psychology of problem solving. In R. Colodny (Ed.), *Mind and cosmos*. Pittsburgh, PA: University of Pittsburgh Press.

Simonton, D. K. (1995). Foresight in insight? A Darwinian answer. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight*. Cambridge, MA: MIT Press.

Sio, U. N., & Ormerod, T. C. (2009). Does incubation enhance problem solving? A meta-analytic review. *Psychological Bulletin, 135*, 94–120.

Snyder, A., Mitchell, J., Ellwood, S., Yates, A., & Pallier, G. (2004). Nonconscious idea generation. *Psychological Reports, 94*, 1325–1330.

Wallas, G. (1926). *The art of thought*. New York, NY: Harcourt Brace.

Weisberg, R. W. (2006). *Creativity: Understanding innovation in problem solving, science, invention, and the arts*. New York, NY: Wiley.

Zhong, C.-B., Dijksterhuis, A., & Galinsky, A. D. (2008). The merits of unconscious thought in creativity. *Psychological Science, 19*, 912–918.