Don't Wait to Incubate: Immediate v. 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 with earlier studies exhibiting a range of methodological problems. The issue is theoretically important as a demonstration of Immediate Incubation effects would strengthen the case for the involvement of unconscious work in incubation effects.

The present experiment used a creative divergent thinking task (Alternative Uses) and separate experimental groups had incubation periods which were either Delayed or Immediate and consisted of either spatial or verbal tasks. Control groups were tested without incubation periods. Checks were carried out for intermittent conscious work on the target task during the incubation periods.

Significant incubation effects were found and were stronger for Immediate Incubation than for Delayed Incubation. Performance was not different between verbal and spatial incubation conditions. No evidence for intermittent conscious working was found. The results supported a role for unconscious work in creative divergent thinking, particularly in the case of Immediate Incubation.

Creative problems are generally defined as problems which 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 solution ideas occurring, 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., Poincaré, 1913; Ghiselin, 1952; Csikszentmihalyi, 1996). In his well known four stage analysis of creative problem solving, Wallas (1926, p.80) labelled a stage in 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 (a) *insight* problems, in which there is a single solution, but the solver has to develop a new way of representing or structuring the task to reach solution and (b) *divergent* problems, in which there is no single correct solution but as many novel and useful ideas as possible are sought. The prototypical divergent task, which was the task used in the present study, is the Alternative Uses task, in which participants are asked to generate as many uses different from the normal use to 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 time (preparation time) and 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 post-incubation work period.

Performance of the incubation group is contrasted with that of a control group who work continuously on the target task for a time equal to the sum of the preparation and post-incubation conscious working time of the incubation group. A recently developed variant (*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 on the target problem, followed by uninterrupted work on the target problem (Djiksterhuis & Meurs, 2006).

Previous studies of Delayed and Immediate Incubation effects

There is now considerable evidence from laboratory studies for the efficacy of Delayed Incubation, *i.e.*, that setting a problem aside after a period of work is beneficial (see Dodds, Ward & Smith, 2003, for a qualitative review). A recent meta-analysis by Sio and Ormerod (2009), of 117 studies identified a positive effect of Delayed Incubation, where the overall average effect size was in the low-medium band (mean d = .32) over a range of insight and divergent tasks. For divergent tasks considered separately, the mean d was larger at .65, which may be considered to be in the high-medium band of effect sizes. Overall, the basic 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 were presented. In the realm of decision problems, Nordgren, Bos and Dijksterhuis (2011) found that Delayed Incubation produced better decisions than 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 paper 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 three minute distractor task (Immediate Incubation) before generating uses, compared 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 pre-known and therefore could reflect memory retrieval rather than generation of subjectively novel responses (Quellmalz, 1985). Gilhooly, Fioratou, Anthony and Wynn (2007) developed a self report method for assessing subjective novelty which 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 (2007) 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 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, compared to unsolved trials without Immediate Incubation. However, it may be noted that some theorists (e.g., Weisberg, 2006, p.468) dispute 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 which is novel for the participant rather than one already known.

Overall, the evidence in favour of a beneficial effect of Immediate Incubation in creative tasks is rather weak, being based on one study of a divergent task which did not require novel responses (Dijksterhuis & Meurs, 2006) and a study (Zhong *et al*., 2008) using a convergent task (the RAT) to 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 will now outline the main theories regarding incubation effects.

Theories of Incubation effects

1. *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 re-addressed – but would be expected 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 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 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*., 2003; Sio & Ormerod, 2009). The study reported here incorporated suitable checks for intermittent conscious work on the target task during the incubation period.

2. *"Fresh look":* This view (e.g., Simon, 1966; Segal, 2004; 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 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 expect a beneficial effect of Immediate Incubation because with

Immediate Incubation, there is no time for sets or fixations to develop, and so forgetting of misleading approaches cannot occur.

3. *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 et al., 2004) and "unconscious thought" (Dijsterhuis & Nordgren, 2006) but we will generally use the term "unconscious work" in this paper. 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, 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 the findings.

Theories of incubation: previous studies

What does previous research suggest 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 (2006) 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, Mitchell, Ellwood and Yates (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. Even although the return to the main task was unexpected, beneficial effects were found, suggesting 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 generation of novel uses and so their task did not necessarily involve creative thinking as against 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 (2003) extensive review, the issue of similarity between 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 effects of dissimilar interpolated tasks. On the other hand, the selective forgetting mechanism would suggest that interpolated tasks similar to the target task would cause greater interference which would lead to more forgetting and enhanced incubation benefits.

Helie, Sun and Xiong (2008) found that more executively demanding interpolated tasks reduced reminiscence scores for free recall of pictures when a surprise free recall was required after the interpolated task. In this study, participants studied booklets of pictures for a set period, freely recalled the items, then did various different interpolated activities before being re-tested 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 Helie & Sun's (2010) Explicit-Implicit Interaction model that can be applied to creative problem solving and which allows for unconscious implicit processes in parallel with conscious explicit processes. However, the target task in Helie *et al.* (2008) was free recall rather than creative thinking and so it does not speak directly to divergent thinking which is the focus of the present paper.

Ellwood, Pallier, Snyder and Gallate (2009) found a beneficial effect on number of responses post-incubation of a dissimilar interpolated task in a Delayed Incubation experiment. However, this 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 incubation and target tasks. On this view, for example, a spatial Delayed Incubation task very different from a main verbal task could allow 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 effects of varying incubation activities (verbal v. spatial), detailed below, used a clearly creative verbal divergent task (alternate uses), scored for novelty as well as fluency, unlike Ellwood *et al*. (2009) or Helies *et al.* (2008). Thus, the present study is clearly focussed 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.

Experiment

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 positioning of the incubation periods (which were 4 minutes long) was either after 5 minutes 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 minutes divergent production to draw a line after their last response up to that point.

Participants. 184 (123 female, 61 male) students at the University of Hertfordshire.

Design. A 2 (incubation position: immediate v. delayed.) X 3 (interpolated task: none v. verbal v. spatial) independent groups design was used. The Ns per experimental group were as follows: 4 mins Delayed Incubation and spatial interpolated task (N = 25); 4 mins Delayed Incubation and verbal interpolated task (N = 22); 4 mins Immediate Incubation and spatial interpolated task (N =30) and 4 mins Immediate Incubation and verbal interpolated task (N = 30). There were also 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 participants were told that they would be asked to write down possible uses for a brick different from the usual use; after 5 minutes working, participants were told that they would be returning to the brick uses task later in the study. During

the 4 mins 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 further 2 minutes periods 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 were assigned randomly to anagrams or mental rotation for 4 minutes. After the Immediate Incubation period they worked on the brick uses task for 7 minutes without a break.

Control participants worked on the uses task for 7 minutes without any incubation periods and carried out mental rotations and anagrams for 4 minutes each. The order of the three tasks in the control groups was randomised. The control rotation and anagram measures were compared with performance on the same tasks when 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 they had reported were subjectively novel *i.e*. 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 uses and Figure 2 the average numbers of self judged novel uses produced over a total of 7 mins on the uses task with 0 mins of incubation (Control data) or 4 mins of Delayed or 4 mins of Immediate Incubation with spatial or verbal interpolated tasks (mental rotations and anagrams). From these Figures it seems that both Immediate and Delayed incubation periods were beneficial compared to control conditions and that Immediate Incubation produced better performance than Delayed Incubation.

INSERT FIGURES 1 & 2 ABOUT HERE

Anova indicated that there was a significant effect of type of interpolated activity (none/verbal/spatial) on the number of uses reported (F (2, 178) = 7.89, p <0.001, part η^2 = .08) and on the number of self judged novel uses (F(2, 178) = 11.49, p < 0.001, part η^2 = .11). *Post hoc* tests indicated significant differences between no incubation and both mental rotation and anagram filled incubation for number of uses (p<0.05) and for self judged novelty (p <0.05). No significant differences were found between verbal and spatial incubation conditions.

Anova indicated that there was a significant effect of position of incubation (delayed/immediate) on the number of uses reported (F (1, 178) = 6.39, p <0.05, part η^2 = .04) and on the number of self judged novel uses (F(1, 178) = 10.03, p < 0.01, part η^2 = .05), with immediate incubation being more beneficial for both measures.

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

Pre- and post-incubation performance in Delayed Incubation conditions.

In the Delayed Incubation conditions data were available for the uses task performance measures separately for the 5 mins pre-incubation period and the 2 mins post-incubation period and for the first 5 mins and the last 2 mins of use production in the control (no incubation) condition. These data were examined to check that any benefits in performance relative to controls were concentrated in the post-incubation (last 2 mins) 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 mins work (pre- and post-incubation periods in the incubation conditions). The mean scores are shown in Table 1.

INSERT TABLE 1 ABOUT HERE

The first 5 minutes scores for Uses totals and novelty were not significantly different between the incubation activity conditions (none/verbal/spatial). However, the measures in the last 2 mins (post-incubation in the incubation conditions) were significantly different between the conditions. For Uses totals, $F(2, 91) = 3.45$, $p < .05$, part $\eta^2 = .07$, and for Uses novelty scores, $F(2,91) = 6.54$, $p < 0.01$, part $\eta^2 = .11$. Thus, the effects of the Delayed incubation manipulation are concentrated in the post-incubation period, in which incubation produces more responses and more novel responses than no-incubation, as would be expected.

First 5 mins and last 2 mins performance in Immediate Incubation conditions

All Uses task performance in the Immediate Incubation conditions is post-Incubation but it was possible to compare the first 5 minutes (which correspond to the pre-incubation time for the Delayed case) and the last 2 mins (which correspond to the post-incubation time in the delayed condition).

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

Both the first 5 mins and the last 2 mins scores for Uses totals and novelty were significantly different between the incubation activity conditions (none/verbal/spatial). For the first 5 mins Uses totals, $F(2, 87) = 3.29$, $p < .05$, part $\eta^2 = .07$, and for the last 2 mins, $F(2,87) = 7.01$, $p < 0.01$, part $\eta^2 = .14$. Similarly, For the first 5 mins Uses novel scores , $F(2, 87) = 4.54$, $p < .05$, part $\eta^2 = .09$, and for the last 2 mins, $F(2,87) = 5.78$, $p < 0.01$, part $\eta^2 = .12$. Thus, the effects of the Immediate incubation manipulation were apparent in immediately, in the first 5 mins, as would be expected, and persisted into the final 2 mins.

INSERT TABLE 2 ABOUT HERE

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 carried out in control conditions for 4 mins and as interpolated tasks for 4 mins in the incubation conditions. The Intermittent Work hypothesis makes a one-tailed prediction that performance would be impaired on a task when it is used as the 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 the incubation period.

INSERT FIGURE 3 ABOUT HERE

However, from Figure 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 performances. 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 Uses, Mental Rotations and Anagrams, should be considered, as possibly depressing control performance and thus masking any effects of intermittent work for the experimental groups. The control participants did the Uses, Mental Rotation and Anagram tasks in counterbalanced orders. Anova found 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 control and incubation groups on the interpolated tasks does 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 full attention to the rotation task, given the correct rate of about 4 in 4 minutes. The numbers of rotation items attempted were, of course, higher than the correct rates, with means of 6.68 (SD=2.62) in control (delayed) 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 the controls, with means, 18.91 (SD = 9.02) and 14.06 (SD = 5.86) respectively, $F(1,67)= 7.02$, $p < 0.01$.) although they did not differ in numbers correct. In the immediate incubation conditions again slightly more items were attempted for rotations in the incubation condition (mean = 9.17, SD = 2.81) than in controls (mean = 8.87, SD = 3.95) and numbers of anagrams attempted were very similar in incubation (mean = 12.58, SD = 7.57) and control conditions (mean = 12.70, SD = 6.89); these differences were not significant. We may note

that, as with correct scores, these results for anagrams and rotations attempted in 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 compared to controls.

Although type of interpolated activity in the incubation periods did not seem to affect level of Uses performance, it may have been that over participants, those who gave more attention to the interpolated tasks might then do worse on the target tasks as they would have less scope for Intermittent Work on the target task during incubation than those who attended less to the interpolated tasks. Thus, on the Intermittent Work hypothesis, negative correlations might be expected between interpolated tasks and the target task. In the Immediate Incubation conditions, anagrams correct in incubation correlated r (28) = -0.19, ns, with total Uses and 0.11, ns, with Novel uses; Rotations correct in incubation correlated r (28) = 0.31, ns, with total Uses and 0.36, $p < 0.05$, with Novel uses. In the Delayed Incubation conditions, Uses totals after the incubation period correlated r (23) = 0.11, ns, with anagrams correct in incubation and r (20) = 0.03, ns, with Rotations correct in incubation; finally, Novel uses after the incubation period correlated r (23) = -0.07, ns, with anagrams correct and 0.18, ns, with Rotations correct in incubation. The only significant correlation (2-tail tests) out of the eight is against the direction predicted by the Intermittent Work hypothesis, being 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 performed as interpolated activities during the incubation periods as against when they are performed as control activities. No such negative effects were found. If anything, effects were in

the opposite direction to that predicted on the Intermittent Work hypothesis. Further, the Intermittent Work hypothesis would expect negative correlations between performance on the interpolated tasks and performance on the target Uses task but no significant correlations in the predicted direction were found in any of the incubation conditions. Indeed, only two out of eight coefficients were 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 controls, which constructively replicates Dijksterhuis and Meurs's (2006) finding of Immediate Incubation effects with a clearly creative divergent thinking task requiring novel uses and the result held over two types of incubation activity (spatial and verbal). Further, Immediate Incubation was more efficacious than Delayed Incubation in the creative task used here. The different effects of Immediate and Delayed Incubation suggests that different process mixtures are involved in the two forms of incubation. A possible interpretation is that with Delayed Incubation, where conscious work is carried out for a period before incubation, relatively strong "sets" could build up and so the Delayed Incubation period could involve both beneficial forgetting and unconscious work. Thus, Delayed Incubation is handicapped relative to Immediate Incubation for which "sets" would be expected to be non-existent or at least weaker, as sets have less time to be established and strengthened. The Immediate Incubation period could involve only unconscious work without the need to overcome sets. That Immediate Incubation followed by conscious work was better for creative performance in the uses task than Delayed Incubation after conscious work is the opposite of Nordgren *et al.*'s (2011) finding with a decision task and presumably reflects differences between divergent creative thinking compared to convergent decision making. The decision task required participants to absorb a number of facts about the options and that stage may benefit from initial

conscious study; in contrast, the uses task draws on already stored semantic memory of object characteristics and requirements for various functions to be carried out.

Our conclusion in favour 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 unconscious work might take? Is it really possible that unconscious work could be just like conscious work but carried out without conscious awareness? Perhaps it is better thought of as involving spreading activation along associative links as against being 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 Alternate Uses task. This was addressed in a think aloud study by Gilhooly et al., (2007) which found that participants used strategies, such as scanning the object's properties ("it's heavy") and using the retrieved properties to cue uses ("Heavy objects can hold down things like sheets, rugs, tarpaulin and so on, so a heavy brick could do those things too"). However, it seems unlikely that unconscious work could simply duplicate the form of conscious work but without awareness. 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 which is 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 stay unconscious. For example, using rules and working memory to multiply two 3 digit numbers (e.g., 364 x 279 = ?) seems impossible without having highly activated representations in working memory of the numbers, the goal and intermediate results, and such representations are necessarily conscious. Unconscious multiplication of even moderately large numbers, not previously practised, seems impossible. (With practice of course, it would be possible to store many 3 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 a 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, Bowden, Haberman, Frymaire, Arambel-Liu, Greenblatt, Reber & Kounios, 2004) without requiring activation levels to rise above the threshold of consciousness. In Helie and Sun's recent (2010) 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 over 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. On 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 be highly accessible when the use reporting stage begins.

A possible difficulty in 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 non-verbal 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 verbal 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. Helie and Sun's (2010) Explicit-Implicit Interaction model of creative thinking explicitly makes this prediction and draws on supporting results which however come from reminiscence memory tasks rather than creative thinking tasks. The selective forgetting mechanism of the Fresh Look approach makes the opposite predictions regarding the effects of the interpolated tasks to those made by the unconscious work hypothesis. 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 the Fresh Look (selective forgetting) hypotheses regarding the effects of type of incubation activity. In this regard, our results on 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, there were some differences between this study and the Ellwood *et al*. study which may be relevant. Ellwood *et al*. did not inform their participants that the target task would be returned to after incubation. In our study the goal of returning was stated and this may be an important factor affecting the incubation process. Future studies will address this issue. A second major difference is that Ellwood *et al*., actually used a fluency task that simply required reporting of uses for a piece of paper but not original or novel uses. That the Ellwood *et al*., task was not tapping 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. Openness typically correlates well with creative divergent test performance (Batey & Furnham, 2008). Also, it may be noted that our results included novelty scores which Ellwood *et al*., 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, then both types of incubation activity could have similar effects according to the Unconscious Work and Selective Forgetting hypotheses for Delayed Incubation. Future research will aim to address this point by using creative tasks that are a 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 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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Table 1.

Pre- and post incubation scores for total Brick uses and Brick use novelty over incubation conditions (Control - none/verbal/spatial).

Delayed Incubation

First 5 mins/Pre-incubation Brick Uses						Last 2 mins/Post-incubation Brick Uses					
Control (N = 47)		Verbal (N=22)		Spatial (N = 25)		Control (N=47)		Verbal (N = 22)		Spatial (N=25)	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
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 mins/Pre-incubation Brick Novelty						Last 2 mins/ Post-incubation Brick Novelty					
Control (N = 47)		Verbal (N=22)		Spatial (N = 25)		Control (N=47)		Verbal (N = 22)		Spatial (N=25)	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
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.

First 5 mins and last 2 mins scores for total Brick uses (and Brick use novelty) over incubation conditions (Control - none/verbal/spatial).

Immediate Incubation

First 5 Minutes Brick Uses						Last 2 minutes Brick Uses					
Control (N = 30)		Verbal (N=30)		Spatial (N =30)		Control (N=30)		Verbal (N = 30)		Spatial (N=30)	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
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 Minutes Brick Novelty						Last 2 minutes Brick Novelty					
Control (N = 30)		Verbal (N=30)		Spatial (N =30)		Control (N=30)		Verbal (N = 30)		Spatial (N=30)	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
3.00	2.90	4.37	2.91	5.53	3.88	0.73	0.86	1.83	1.53	1.63	1.50

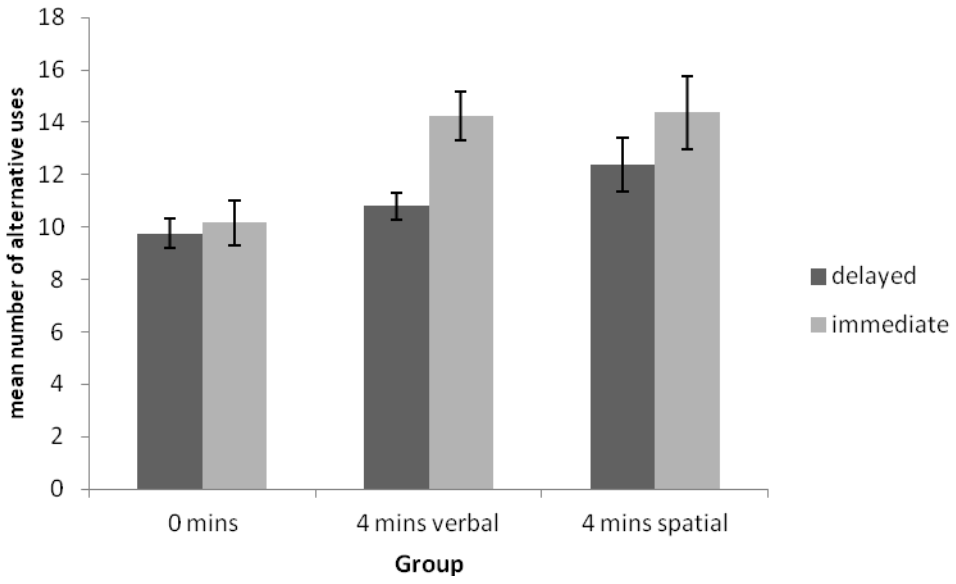

Figure 1. Mean number of alternative uses produced during delayed and Immediate Incubation using verbal or spatial interpolated tasks. Error bars represent ±1 SEM.

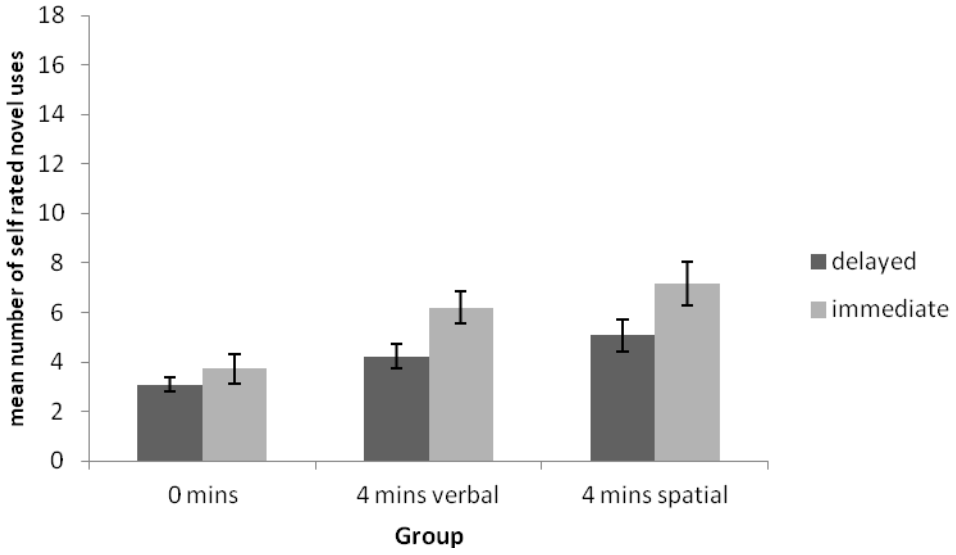

Figure 2. Mean number of self rated novel uses produced by Delayed and Immediate Incubation groups using verbal or spatial interpolated tasks. Error bars represent ±1 SEM.

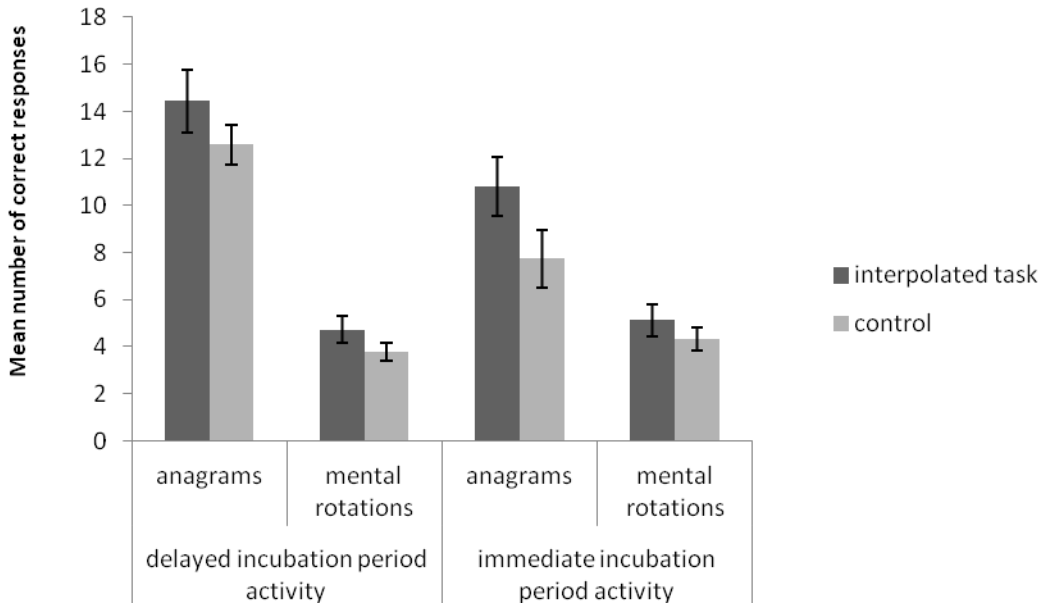

Figure 3. Mental Rotation and anagram performance when carried out as an interpolated (incubation) task or as control task. Error bars represent ±1 SEM.