Psychological Bulletin
2009, Vol. 135, No. 1, 94–120

0033-2909/09/$12.00 DOI: 10.1037/a0014212

Does Incubation Enhance Problem Solving? A Meta-Analytic Review

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A meta-analytic review of empirical studies that have investigated incubation effects on problem solving is reported. Although some researchers have reported increased solution rates after an incubation period (i.e., a period of time in which a problem is set aside prior to further attempts to solve), others have failed to find effects. The analysis examined the contributions of moderators such as problem type, presence of solution-relevant or misleading cues, and lengths of preparation and incubation periods to incubation effect sizes. The authors identified a positive incubation effect, with divergent thinking tasks benefiting more than linguistic and visual insight tasks from incubation. Longer preparation periods gave a greater incubation effect, whereas filling an incubation period with high cognitive demand tasks gave a smaller incubation effect. Surprisingly, low cognitive demand tasks yielded a stronger incubation effect than did rest during an incubation period when solving linguistic insight problems. The existence of multiple types of incubation effect provides evidence for differential invocation of knowledge-based vs. strategic solution processes across different classes of problem, and it suggests that the conditions under which incubation can be used as a practical technique for enhancing problem solving must be designed with care.

Keywords: incubation, problem solving, insight, meta-analysis

Anecdotal reports of the intellectual discovery processes of individuals hailed as geniuses (see, e.g., Ghiselin, 1985; Wallas, 1926; Woodworth & Schlosberg, 1954) share a common theme: A flash of insight pops unexpectedly into the mind of the individual after he or she has put an unsolved problem aside for a period of time, having failed in initial attempts to solve it. This temporary shift away from an unsolved problem that allows a solution to emerge seemingly as if from no additional effort is termed an *incubation period* (Wallas, 1926). Its importance in current thinking and practice is illustrated by a recent search in Google Scholar for the term *incubation* along with either *creativity*, *insight*, or *problem* that yielded 5,510 articles, with the search restricted to the years 1997 to 2007 and the subject areas to social sciences, arts, and humanities. An additional 1,970 articles were yielded when the subject areas business, administration, and economics were included. Yet there are many conflicting accounts of incubation, with some studies reporting strong effects (e.g., Smith & Blankenship, 1989) and others failing to find any effect at all (Olton & Johnson, 1976). This article aims to resolve the uncertainties surrounding the phenomenon by providing a statistical meta-analytic review of empirical studies of incubation. We suggest that it is only armed with the results of an integrative and quantitatively based review that progress in understanding the mechanisms that might underlie the phenomenon can be made.

One theoretical reason for studying incubation is because it is closely associated with insightful thinking. Indeed, Wallas (1926) proposed incubation as the second of four phases in problem solving (the others being preparation, illumination, and verification). Insight may be characterized as a sudden, unpredictable, and nonverbalizable solution discovery (e.g., Metcalfe & Weibe, 1987). Some researchers see the apparently unconscious nature of solution discovery as evidence that the processes required to achieve insight in problem solving are qualitatively different from those used to tackle problems that do not require insight (e.g., Jung-Beeman & Bowden, 2000; Wertheimer, 1985). Incubation might serve a valuable role in arbitrating between theories of insight, in particular between special-process theories based on unconscious mechanisms of spreading activation (e.g., Knoblich, Ohlsson, Haider, & Rhenius, 1999) and theories of insight as normal problem-solving processes based on conscious mechanisms of search (e.g., MacGregor, Ormerod, & Chronicle, 2001).

Understanding the role of incubation periods may also allow us to make use of them effectively to promote creativity in areas such as individual problem solving, classroom learning, and work environments. Educational researchers have tried to introduce incubation periods in classroom activity, and positive incubation effects in fostering students' creativity have been reported (Lynch & Swink, 1967; Medd & Houtz, 2002; Rae, 1997; Webster, Campbell, & Jane, 2006). However, in the absence of a comprehensive theory or model that can explain how and why positive incubation effects might emerge and under what conditions they are best fostered, no general pedagogic recommendations can be made.

Several hypotheses have been proposed to account for the alleged positive effects of incubation periods on problem solving, and they can be divided into two main kinds: conscious work and unconscious work. The conscious-work hypothesis holds that incubation effects are due to issues such as reduction of mental fatigue (Posner, 1973) or additional covert problem solving during the incubation period (Browne & Cruse, 1988; Posner, 1973). Both

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sources implicate changes in consciously controlled problem-solving activities during an incubation period. In contrast, the unconscious-work hypothesis suggests that positive incubation effects are the result of gradual and unconscious problem-solving processes that occur during an incubation period (Bowers, Regehr, Balthazard, & Parker, 1990; Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995; Simon, 1966; Smith, 1995; Smith & Blankenship, 1991; Yaniv & Meyer, 1987).

Three different unconscious processes have been proposed to account for incubation effects. The first involves eliciting new knowledge: Over time, activation will spread toward previously ignored but relevant memory items. Even if relevant items do not receive above-threshold activation, this process can still sensitize individuals to related concepts, and thus they will be more likely to make use of external cues to solve a problem. In addition, partially activated concepts may combine with others to yield fortuitous insightful ideas (Bowers et al., 1990; Smith, 1995; Smith & Blankenship, 1991; Yaniv & Meyer, 1987). The second hypothesis is selective forgetting: An incubation period will weaken the activation of inappropriate solution concepts that distract individuals during initial attempts, allowing a fresh view of the problem (Smith, 1995; Smith & Blankenship, 1991). The third hypothesis is problem restructuring: An individual's mental representation of a problem will be reorganized into a more appropriate and stable form after initial unsuccessful attempts. The individual is then more able to capitalize upon relevant external information or to rearrange problem information in a manner that allows a solution to be found more readily (Seifert et al., 1995). Problem restructuring might emerge either from switching the strategy used to search for moves to attempt (e.g., MacGregor et al., 2001) or from relaxing self-imposed inappropriate constraints on the problem representation (Knoblich et al., 1999). Studies of metacognition indicate that strategy switching can be unconscious (Newton & Roberts, 2005; Reder & Schunn, 1996; Siegler & Stern, 1998) and that different strategies compete for activation during the strategy selection process (Siegler & Stern, 1998).

The conscious- and unconscious-work accounts generate different predictions concerning the effects of activities that individuals engage in during an incubation period. According to the conscious-work account, individuals benefit most from an unfilled incubation period, as this gives them an opportunity either to relax, reduce fatigue, or continue working on the problem. In contrast, unconscious-work accounts suggest that unconscious problem-solving processes occur when individuals shift their attention away from the problem to other mental activities. Thus, a certain level of involvement in other tasks during an incubation period should facilitate postincubation problem solving.

A number of experimental studies have examined the role of task type during an incubation period. The experimental paradigms of these incubation studies are fairly uniform: The work of one group of participants is interrupted with an incubation period (having a break or performing other tasks) while solving a problem, whereas the other group works on the problem continuously. Performance differences between these two groups are then compared. The findings of the published studies do not give unconditional support to either the unconscious-work or the conscious-work account. Patrick (1986) found that participants who had a filled incubation period outperformed those who had an unfilled incubation period. However, Browne and Cruse (1988) reported the opposite pattern: Participants who took a rest during an incubation period performed better than those who had to perform tasks during an incubation period. There are also studies that report the same level of performance by participants with filled and unfilled incubation periods (Olton & Johnson, 1976; Smith & Blankenship, 1989). However, these studies vary in terms of the length of incubation period, the target problems tackled, and the nature of the interpolated tasks during the incubation period.

Because of inconsistent findings concerning incubation, some researchers have doubted the existence of the effect, in particular rejecting the unconscious-work hypotheses (Browne & Cruse, 1988; Olton & Johnson, 1976; Perkins, 1995). However, one explanation for conflicting findings is that there are procedural moderators other than task type that influence the occurrence of problem-solving processes during an incubation period, such as the length of the incubation period or the nature of the problem. The field lacks a comprehensive review that summarizes and evaluates these studies. There have been two reviews to date of relations between different procedural variables and the incubation effect, and both are qualitative in nature. Olton's (1979) review of past incubation studies led him to question the existence of an incubation effect, given that no experimental paradigm appeared to demonstrate an incubation effect reliably. Yet, a limited number of studies were available at that time: Only 10 incubation studies were included in his review. A recent review by Dodds, Ward, and Smith (in press) with more studies included suggested that several variables may interact to influence the effectiveness of an incubation period. However, the qualitative nature of their review led them to conclude that findings of past studies are too divergent and that more studies are needed to assess the impact of each variable and to identify the optimum settings for an incubation effect.

The wide variation in experimental parameters among studies makes it difficult to draw cross-experiment conclusions from a qualitative review. To overcome these problems, a systematic meta-analytic review is needed. Meta-analytic review allows a quantitative evaluation of research domains that describes the typical strength of the effect or phenomenon and also the relation of each moderator to the size of the effect by using statistical analysis methods (Rosenthal, 1995). The objectives of the current study were to carry out the first statistical meta-analysis of incubation studies to assess the effect size of the experimental incubation effect, and more important, the impact of potential moderators on the incubation effect size. However, in order to undertake the meta-analysis, we first need to identify the likely key moderators, which we achieve in the next section by reviewing the methods used in previous studies. A particular focus of this review is to identify moderators that might discriminate conscious-work and unconscious-work hypotheses and also the mechanisms (reduction of fatigue, additional work, activation of new information, forgetting, restructuring) that might underlie each hypothesis.

Potential Moderators

The Interpolated Task Used During the Incubation Period

Various types of interpolated task have been used in past studies, and they can be divided into tasks of high or low cognitive demand. Examples of high cognitive demand tasks include mental rotation, counting backwards, and visual memory tests, whereas reading is commonly adopted as a low cognitive demand task. High demand tasks should fully occupy the individual's mind and prevent further conscious work on the unsolved problem. Some studies have reported that undertaking a high cognitive demand task during an incubation period is beneficial to the problem-solving process (Kaplan, 1990; Patrick, 1986; Segal, 2004). Nonetheless, studies using low cognitive demand tasks that do not require individuals to focus their conscious attention on task performance have reported similar benefits (Beck, 1979; Silveira, 1972; Smith & Blankenship, 1989).

Length of the Incubation Period

Longer incubation periods may allow additional problem-solving activity or a greater degree of forgetting of misleading items or spreading of activation memory. Thus, problem solvers may show a larger performance improvement when they return to the problem after a long incubation period than after a short one. Some studies have reported evidence supporting this contention (Beck, 1979; Fulgosi & Guilford, 1968; Silveira, 1972; Smith & Blankenship, 1989). However, it is difficult to draw cross-experiment conclusions, because there is no standard operationalization of what constitutes "long" and "short" incubation periods. In Smith and Blankenship's (1989) study, for example, a 15-min incubation period was defined as a long incubation period, and they reported that participants receiving this length of incubation period performed better than those receiving a 5-min incubation period. However, in Beck's (1979) study, a 20-min incubation period was considered short, and participants' performance in this group did not differ from that of the control group. Kaplan (1990) suggested that to judge whether the incubation period is short or long, the length of time that problem solvers spend on initial attempts to solve (named the *preparation period* by Wallas, 1926) should also be taken into account. Kaplan found that a larger incubation effect was observed after increasing the ratio of the length of the preparation period to the incubation period. Thus, in addition to including incubation and preparation periods as separate moderators in the meta-analysis reported below, we also undertook a secondary analysis using the ratio of preparation to incubation time as an alternative moderator.

Length of the Preparation Period

During the preparation period, problem solvers gather information to formulate a problem representation and make initial attempts to solve, which may lead to an impasse. Although a problem may not be solved during the preparation period, this does not mean that the effort the problem solver spends on the problem is fruitless. Schank (1982, 1999) and VanLehn (1988) both suggested that failure in problem solving is important in the human learning process. Studies by Patalano and Seifert (1994) and Seifert et al. (1995) have found evidence of a Zeigarnik effect in insight problem solving (Zeigarnik, 1927, 1938), wherein individuals remembered the problems on which they got "stuck" better than those they solved immediately. Seifert et al. hypothesized that having a better memory for failed problems might help individuals return efficiently to the problem once relevant new information is encountered during an incubation period, thereby maximizing the chance of solving. Evidence concerning this prediction has been obtained in an empirical study carried out by Silveira (1972), showing that problem solvers performed better with longer preparation and incubation periods.

Nature of the Problem

Various different types of problem have been used in incubation studies. Some problems, which we term *creative problems* here, require individuals to produce multiple new ideas to meet a specific brief. For example, a verbal divergent-production task is the *consequences task* (e.g., "What would be the result if everyone suddenly lost the ability to read and write"; Fulgosi & Guilford, 1968). Typically, there is no right or wrong answer to this kind of problem, and performance is assessed in terms of the number of solution ideas that are generated.

Other problems require individuals to discover a specific target solution that is known in advance by the experimenter. Problems of this kind that have been studied in the literature on incubation are generally of a type described as *insight problems*, in that they require the solver to reject initial solution ideas by achieving insight into an alternative strategy or knowledge domain. The insight problems used in the incubation studies can be divided into visual problems, which typically require the solver to consider a visuospatial array (e.g., the nine-dot problem; Scheerer, 1963), and linguistic problems, which typically require the solver to consider linguistic information related to the problem. The *remote associates task* (RAT; S. A. Mednick, 1962) is one of the most commonly used linguistic problems in incubation studies. In each RAT, three stimulus words are presented to individuals, who then have to think of a fourth word that can form an association with each of the three words. For example, if the three stimulus words of a RAT are *electric*, *wheel*, and *high*, the fourth word can be *chair*. Bowden and Jung-Beeman (2003b) have developed a pool of remote associates problems and collected normative data regarding the resolution rates and response times for the problems. The classification of insight problems into visual- and linguistic-based categories is supported by research findings from Gilhooly and Murphy (2005) showing that solving visual and linguistic insight problems requires different types of cognitive skills.

In the remainder of this article, we refer to problem types as creative, visual, and linguistic. Descriptions of the types of problem used in incubation studies are illustrated in Appendix A. Problem type is likely to be an important determinant of incubation, because it seems likely that each type creates different task demands. For instance, the nine-dot problem appears to require the solver to restructure an initially faulty or incomplete problem representation in searching for a representation that allows solution, whereas the consequences task appears to require the activation of as wide a range of different concepts as possible. One question the meta-analysis allows us to address is whether an incubation period favors one type of problem more than another.

The Presence of Solution-Relevant Cues

Some unconscious processes proposed to explain incubation effects are purely internal and thus independent of the external environment, such as the inhibition of irrelevant memory (Smith, 1995; Smith & Blankenship, 1991) and the recombination of partially activated concepts (Bowers et al., 1990). Others stress interactions with the external environment, such as the proposal that spreading activation can partially activate previously ignored relevant memory and therefore sensitize the problem solver to chance encounters with related stimuli (Seifert et al., 1995). A few studies have examined the effects of the presence of cues during an incubation period (Browne & Cruse, 1988; Dodds, Smith, & Ward, 2002; Dorfman, 1990; Dreistadt, 1969; Olton & Johnson, 1976). Most failed to find any positive effect of cues on the incubation effect. However, the failure reported in these studies may be due to other factors, such as the difficulty of the unsolved problems. In order to have a fair evaluation of the impact of this moderator, we first have to isolate the effect of other moderators on the incubation effect.

Misleading Cues

Another factor that may influence the occurrence of incubation effects is the presence of misleading cues. Smith and Blankenship (1989) carried out a series of experiments to examine the effect of an incubation period on solving RATs, in which participants had to find a word that might accompany each of three presented words. Smith and Blankenship presented cues (shown here in italics) comprising misleading associates and the target word next to each of the three stimulus words. An example of a misleading RAT is: SHIP *ocean*, OUTER *space*, CRAWL *floor*. The target solution is *space*. Performance improvements after an incubation period were observed only when participants solved tasks containing misleading cues. They concluded that a problem solver who is fixated on misleading information benefits more from an incubation period. The misleading cues data provide critical support for forgetting-based explanations of incubation. The presence of misleading cues is therefore one of the potential moderators examined in this meta-analysis.

The Meta-Analysis

The variables mentioned above were the potential moderators of incubation chosen for this meta-analysis. Note that other potential moderators might have been included (e.g., number of trials, participant characteristics), but we focused on those we believe are fundamental to discriminating differing theoretical accounts of incubation.

The statistical meta-analysis that follows addressed two questions: First, is there reliable evidence for incubation; and second, what are the most influential moderators? To address the first question, we computed the effect size of the incubation effect reported in each available study. Given that the variability among effect sizes is likely to be greater than that resulting from subject-level sampling, a random-effects model was adopted in this meta-analysis. A heterogeneity test was carried out to verify this assumption, and then the weighted mean under the assumption of random-effects model was computed and assessed to determine if it was significantly larger than zero.

To address the second question, we carried out weighted least-squares linear regressions using the aforementioned moderators as predictor variables and the incubation effect size in each study weighted by the inverse of its variance as the criterion variable. The results of the regression show the independent contributions of each potential moderator to the incubation effect, while controlling for all other moderators. This approach allows us to summarize the past studies systematically even though they vary widely in number and type of experimental parameters. In addition, interactions between different moderators, such as the nature of the interpolation task during the incubation period and the nature of the problem, were examined.

Literature Search

We collected publications that contained studies relevant to a meta-analysis of incubation through a search of the ERIC, PsycINFO, PsycARTICLES, and MEDLINE databases using the keyword *incubat**, intersected with one of *fixation*, *creativ**, *divergent**, *insight**, or *problem*. Then, references given in all the obtained articles were systematically searched for additional relevant publications. There is a concern that studies with statistically significant results are more likely to get published than those without significant results, and this may lead to a biased retrieval of studies. To ameliorate this to some extent, we carried out similar literature searches in the ProQuest Digital Dissertations database and used Google Scholar for retrieving doctoral dissertations, unpublished articles, and conference articles concerning the incubation effect. In total, 37 relevant publications were identified and obtained. Studies meeting the following criteria were assimilated in the analysis:

1. The settings and difficulty of the problems were the same among all the experimental conditions.
2. The total length of time that participants could spend on solving the problem consciously was the same among all the conditions.
3. The study included a control (no-incubation) group, and participants in that group worked on the problem continuously.
4. Participants' problem-solving performance in pre- and postincubation periods was measured.
5. The study reported information that allowed the computation of an effect size.

The first and second selection criteria ensured that tasks were presented in an identical way among different conditions and that any between-conditions performance differences could be attributed to differences in settings of the incubation period. The inclusion of Criterion 3, a control condition (no break between the first and the second attempts at the problem), is essential to provide a baseline against which performance in incubation conditions can be compared. Only publications that assessed the problem-solving performance in both first and second attempts were included in the analysis (Criterion 4). Therefore, some studies (e.g., Sio & Rudowicz, 2007; Yaniv & Meyer, 1987) that did not assess postincubation problem-solving performance were excluded. The information required for computing effect sizes is discussed in the section *Estimation of Effect Sizes*. Eight publications were excluded because the experimental studies contained within them failed to meet one or more of the mentioned criteria. The specific reasons for excluding the publications are described in Table 1,

Table 1
Summary of Incubation Studies

Year	Author	Problem	Misleading cues in problems	Preparation period	Incubation period	Incubation task	Cues during incubation period	Other factors	Incubation effect reported	Included in meta-analysis
1964	Mednick et al. (Experiment 1)	RAT	No	1 min	Not specified	Analogy vs. analogy + cues	Yes		Yes, in analogy + cues condition	No, no control group
1964	Mednick et al. (Experiment 2)	RAT	No	1 min	Not specified	Analogy vs. analogy + cues	Yes	Cue relevance and correctness; problem-solving ability	Yes, in high-ability group in analogy + cues condition	No, no effect size information
1967	Gall & Mendelsohn	RAT	No	2 min	0, 25 min	Nonverbal vs. free associates + cues	Yes		No	Yes, estimated from $p <$ value
1968	Fulgosi & Guilford	Consequences task	No	2 min	0, 10, 20 min	Number series (10 and 20 min)	No		Yes, in 20-min condition	Yes, estimated from $p <$ value and statement of significance
1969	Dreistadt	Farm & tree planting problems	No	5 min	0, 8 min	Guess card vs. guess card + cues	Yes	In control condition, half the participants received cues	Yes, with cues, farm problem only	Yes
1969	Murray & Denny	Saugstad's ball problem	No	5 min	0, 5 min	Syllogisms, and tracing complex sequences of digits/numbers	No	Problem-solving ability	Yes, in low-ability group	Yes
1972	Fulgosi & Guilford	Consequences Task	No	2 min	0, 30, 60 min	Number series (30 and 60 min)	No		Yes, in 30-min condition	No, no effect size information
1972	Dominowski & Jenrick (Experiment 1)	Hat rack problem	No	5 min	0, 10 min	Free association vs. anagram	Yes	One group received cues throughout	No	Yes, estimated from statement of significance
1972	Dominowski & Jenrick (Experiment 2)	Hat rack problem	No	3 min	0, 3 min	Free association vs. anagram	No	One group received cues; problem-solving ability	No	Yes, estimated from statement of significance
1972	Silveira (Experiment 1)	Necklace problem	No	3 min vs. 13 min	0, 30, 210 min	Read + free activity	No		Yes	Yes
1972	Silveira (Experiment 2)	Necklace problem	No	13 min	0, 210 min	Read + free activity	No		Yes	Yes
1972	Silveira (Experiment 3)	Consequences task	No	2 min	210 min	Read + free activity	No		No	No, no control group
1974	Peterson	Anagram	No	0.33 min	1.8 min	Other anagram	No	Task difficulty	Yes	Yes
1975	Bennett	RAT	No	1 min	10 min	Hear music vs. mathematics problems	No		No	No, no control group
1976	Olton & Johnson	Farm problem	No	10 min	0, 15 min	Rest vs. Stroop + count backward vs. review problem vs. lecture vs. hear music	Yes		No	Yes
1979	Beck	Verbal divergent-thinking task	No	12 min	0, 20, 30 min	Relax vs. write essay	No		Yes, with longer incubation period	Yes
1985	Brockett	Brick task and RAT	No	10 min (brick task), 0.33 min (RAT)	0, 20 min	Questionnaires	No		Yes	Yes
1986	Patrick	RAT	No	2 min	0, 5 min	Conversation vs. mental rotation	No		Yes, in mental rotation condition	Yes, estimated from $p <$ value and statement of significance
1987	Yaniv & Meyer	Rare-word definition task	No	Not specified	Not specified	Questionnaire	No		Yes	No, no postincubation performance measure
1988	Browne & Cruse (Experiment 2)	Farm problem	No	20 min or 25 min	0, 5 min	Hear music, draw graph, memorize text	Yes		No	Yes

(*table continues*)

Table 1 (*continued*)

Year	Author	Problem	Misleading cues in problems	Preparation period	Incubation period	Incubation task	Cues during incubation period	Other factors	Incubation effect reported	Included in meta-analysis
1989	Smith & Blankenship (Experiment 1)	Rebus	Misleading or useful cues	0.5 min	0, 5, 15 min	Rest vs. music perception	No	Useful cues presented for second attempt	Yes, 15-min > 5-min incubation and control group	Yes
1989	Smith & Blankenship (Experiment 2)	Rebus	Misleading or useful cues	0.5 min	0, 5, 15 min	Rest vs. music perception	No		Yes, 15- and 5-min incubation > control group	Yes
1989	Smith & Blankenship (Experiment 3)	Rebus	Misleading or useful cues	0.5 min	0, 10, 15 min	Rebus with music perception, mathematics, or rest	No		Yes, no difference among incubation conditions	Yes, estimated from $p <$ value
1989	Smith & Blankenship (Experiment 4)	Rebus	Yes, misleading or useful cues	0.5 min	0, 5 min	Read vs. mathematics	No		Yes, in read story condition	Yes, estimated from $p <$ value and statement of significance
1990	Dorfman (Experiment 3)	Word puzzle task	No	0.49 min	0, 5, 15 min	Word problems vs. word problems + cues	No		Yes, in both incubation conditions	Yes
1990	Dorfman (Experiment 4)	Word puzzle task	No	0.49 min	0, 3, 8, 13 min	Number series + cues			No	Yes, estimated from statement of significance
1990	Kaplan (Experiment 1)	Consequences task	No	2 min	0, 30 min	Psychometric test battery	No		Yes	Yes
1990	Kaplan (Experiment 2)	Consequences task	No	2 min	0, 32 min	Mathematics + lecture	No		Yes	Yes
1990	Kaplan (Experiment 3)	Consequences task	No	2 min	0, 30 min	Lecture	No		No	Yes, estimated from statement of significance
1990	Kaplan (Experiment 4)	Consequences task	No	4.57 min	28.08 min	Mathematics and insight problems	No		Yes	Yes
1991	Smith & Blankenship (Experiment 1)	RAT	Yes	0.5 min	0, 5 min	Read science fiction	No	Problem-solving ability	Yes, with misleading cues, greater for low-ability participants	Yes
1991	Smith & Blankenship (Experiment 2)	RAT	Yes	1 min	0, 5 min	Read science fiction	No	Problem-solving ability	Yes, with misleading cues	Yes
1991	Smith & Blankenship (Experiment 5)	RAT	Yes	0.5 min	0, 0.5, 2 min	Free association	No	Problem-solving ability	Yes, with misleading cues, less for low-ability participants	Yes, estimated from $p <$ value and statement of significance
1992	Goldman et al.	Anagram	No	0.25 min	0, 20, 1,440 min	General knowledge + free activity	No		Yes, in 1,440-min condition	Yes
1992	Houtz & Frankel	Life-relevant problem	No	10 min	10 min	Anagram task	No		Yes	Yes
1997	Torrance-Perks (Experiment 1)	Word completion problems	Yes	0.5 min	0, 10 min	Rest + lexical decision vs. rest + lexical decision + cues	Yes		No	Yes
1997	Torrance-Perks (Experiment 2)	Candle & radiation problems, RAT	Yes, misleading cues	1 min (RAT and candle problem), 5 min (radiation problem)	0, 8 min	Memory (candle); read (radiation); analogy (RAT)	Yes		No	Yes
1998	Hansberry (Experiment 2)	Riddles	Yes	1 min	0, 15 min	RAT	No		No	Yes

(*table continues*)

Table 1 (*continued*)

Year	Author	Problem	Misleading cues in problems	Preparation period	Incubation period	Incubation task	Cues during incubation period	Other factors	Incubation effect reported	Included in meta-analysis
1998	Hansberry (Experiment 3)	RAT	Yes	0.5 min	0, 10 min	RAT	No	Problem-solving ability	No	Yes
1999	Henley (Experiment 3.2)	Anagram	No	0.25 min	0, 1,440 min	Free activity	No		No	Yes, estimated from statement of significance
1999	Henley (Experiment 4)	Anagram	No	0.93 min	0, 1,440 min	Free activity	No		No	Yes, estimated from statement of significance
1999	Jamieson (Experiment 1)	RAT	Yes	0.33 min	0, 5 min	Mathematics	No		No	Yes
1999	Jamieson (Experiment 2)	RAT	Yes	0.33 min	0, 5 min	Mathematics	No		No	Yes
2002	Dodds et al. (Experiment 1)	RAT	No	0.5 min	15 min	Insight problem with: Drawing vs. make a word test vs. make a word test + cues	Yes	Cues (answer, relevant information, or related word)	Yes, when answer or unrelated word presented during incubation	No, no control group
2002	Dodds et al. (Experiment 2)	RAT	No	0.5 min	0, 15 min	Insight problem with: Drawing vs. make a word test vs. make a word test + cues	Yes	Cues (answer, relevant information, or related word)	Yes, when answer presented during incubation	Yes
2002	Medd & Houtz	Creative writing	Yes	10 min	0, 10 min	Unrelated writing task vs. related writing task	No	Prompt to think about problem during incubation	Yes, if working on related task during incubation	Yes, estimated from $p <$ value and statement of significance
2002	Moss	RAT	No	0.5 min	15 min	Verbal reasoning task + cues	Yes	Tasks described as solvable or unsolvable; problem-solving ability	Yes, interaction between ability and problem type	No, no control group
2003	Seabrook & Dienes	Anagram	No	0.25 min	7 min	Word generation tasks	Yes	Cues (irrelevant or relevant)	Yes, in relevant-cue group	Yes, estimated from $p <$ value.
2004	Both et al.	Anagram	No	1.67 min	0, 6 min	Letter search; questionnaire	No		Yes	Yes
2004	Both et al.	Anagram	Yes	1.67 min	0, 6 min	Letter and digit search; questionnaire	Yes		Yes	Yes
2004	Penney et al. (Experiment 1)	Anagram	No	5.75 min	15, 180 min	Word completion + cues vs. inactivity	No		Yes, in 15-min condition	No, no control group
2004	Penney et al. (Experiment 2)	Anagram	No	5.75 min	15, 1,440 min	Word completion + cues vs. inactivity	No		Yes, in 15-min condition	No, no control group
2004	Penney et al. (Experiment 3)	Anagram	No	5.75 min	0, 30, 120 min	Word completion + cues vs. inactivity	No		Yes	Yes
2004	Segal	Insightful mathematic puzzle	No	20 min	0, 4, 12 min	Read vs. word puzzle	No		Yes, with word puzzle	Yes
2004	Snyder et al.	Divergent-thinking task	No	5 min	5 min	Conversation	No		Unknown	No
2005	Christensen & Schunn	Insight puzzle	No	Not specified	Not specified	Analogy or distractor rating task	Yes	Cues (analogous cue or distractor cue)	Yes, in analogous cue condition	No, no control group
2007	Sio & Rudowicz	RAT	Yes	1 min	0, 2 min	Mental rotation task + mathematics task vs. listening to music	No	Chess expertise; cues to chess expertise were related, neutral, or misleading	Yes, experts more sensitive to relevant concepts after incubation	No, no postincubation performance measure
2007	Vul & Pashler (Experiment 1)	Anagram	No	1 min	0, 5 min	Video game	No	Task difficulty	No	Yes
2007	Vul & Pashler (Experiment 2)	RAT	Yes	1 min	0, 5 min	Video game	No	Task difficulty	Yes, in the fixation group	Yes

Note. RAT = remote associates task.

which also describes the settings of studies included in the meta-analysis. Of the remaining 29 publications, 20 were refereed journal articles, 8 were doctoral dissertations, and 1 was a conference article. The ratio of the refereed to other studies is 2.2:1, which is within the suggested range of 128:1 to 1:1 for including unpublished studies in an effort to avoid publication bias (Thornton & Lee, 2000). Most publications included multiple experiments, thereby allowing a reasonable sample size of independent studies ($N = 117$) to be achieved.

Coding Procedure

Many of the experiments reported in the selected publications had two or more experimental conditions, such as incubation periods of different lengths or different types of task in the incubation period. For the sake of the meta-analysis, experiments with more than one incubation condition were broken down into independent studies with one incubation condition and one control condition. The same control group may be included in more than one independent study and compared with more than one incubation condition. For example, in Goldman, Wolters, and Winograd's (1992) experiment, there were control, short incubation period, and long incubation period conditions. The experiment was decomposed into two studies, one consisting of the control and short incubation period conditions and the other consisting of the control and long incubation period conditions. To avoid inflating the degrees of freedom available, we split the number of participants in the control condition across studies entered into the analysis, a method advocated by Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, and van IJzendoorn (2007).

There were also studies that had more than one control condition. In such cases, the control condition that had the most similar setting to the incubation condition was chosen. For example, in Hansberry's (1998) third experiment, participants had to solve a list of RATs under one of three conditions: two control and one incubation. In one control condition, the RATs were presented individually for 60 s. In the other control condition, as well as in the incubation condition, each RAT was presented in two separate 30-s blocks. Data from the latter control condition were therefore used in computing the effect size, because this control condition and the incubation condition had the closest settings in terms of RAT presentation.

After separating the experiments into independent studies, a standard system was used to code each study. Background information on each independent study (author, publication year, and the number of participants in each condition), as well as potential moderator variables, were extracted. Table 2 presents the coding system used in this meta-analysis. Appendix B presents the information we extracted from each independent study by using the coding system.

Table 2
Coding System

Variable	Coding description
Author	Author(s) of the study
Year	Year the study was published
Total	Total number of participants
Problem type	0 = *creative problem* (e.g., consequences task) 1 = *visual problem* (e.g., farm problem, radiation problem) 2 = *linguistic problem* (e.g., remote associates task, anagram, rebus)
Misleading cues	0 = *no misleading cues* 1 = *misleading cues embedded in the problem*
Preparation period	Amount of time spent on each problem before the incubation period (in minutes)
Incubation period	Length of the incubation period (in minutes)
Incubation task	0 = *rest* 1 = *low cognitive demand task* (e.g., drawing a picture, reading) 2 = *high cognitive demand task* (e.g., mental rotation task, memory test)
Cues	Presence of relevant cues during the incubation period 0 = *no cue* 1 = *yes*

Estimation of Effect Sizes

The effect size, Cohen's *d*, was computed for each study entered into the meta-analysis. Cohen's *d* in this meta-analysis comprised the difference in mean problem-solving performance scores between the control and incubation conditions divided by their pooled standard deviation (Hedges & Olkin, 1985). In some cases, effect sizes had to be calculated from *t* and *F* values, frequencies, or *p* values. If a *p*-less-than value was given instead of an exact *p* value, the *p*-less-than value was treated as an exact value, and an estimate of Cohen's *d* was generated. For studies that did not include any of the abovementioned information but only provided statements of nonsignificant differences between the control and incubation groups, the Cohen's *d* was assumed to be zero. Among the studies that included multiple incubation conditions, some provided a statement of nonsignificant performance differences among the incubation conditions and reported only the overall performance difference between the control and the incubation conditions. In such cases, all incubation conditions were assumed to have generated the same magnitude of incubation effect sizes. Of the 117 effect sizes, 88 were extracted directly from the means and standard deviations, *t* value, *F* value, frequencies, or *p* value; 8 were computed from a *p*-less-than value; and 21 were estimated from statements of significance.

In some incubation studies, problem-solving performance was assessed along more than one dimension. For example, in the study carried out by Vul and Pashler (2007), participants' performance on RATs was measured in terms of the time spent on solving RATs and the number of correct solutions. In such cases, we computed a single effect size by averaging the effect size from each measure (cf. Durlak & Lipsey, 1991).

Following Hedge and Olkin's (1985) suggestion for removing bias caused by small-sample studies, we computed an unbiased effect size estimate by multiplying the effect size of each single study by a factor of $1–3/[4(\text{total } N - 2) - 1]$, where total *N* is the total number of participants of that study. Any unbiased effect size larger than 2 *SD*s from the group mean was considered an outlier and was recoded to the value of the effect size found at 2 *SD*s, following a procedure for reducing the bias caused by extreme effect sizes reported by Lipsey and Wilson (2001).

Heterogeneity Analysis

In this analysis, we predicted that the variance in magnitude of the unbiased effect sizes among studies was not due simply to sampling error but instead to the difference in settings of each study (e.g., length of incubation period, nature of incubation task, presence of cues). Therefore, analyses of the effect sizes should be carried out under the assumption of a random-effects model. To confirm the assumption of a heterogeneous distribution of effect sizes, we carried out a heterogeneity test before running any analyses on the effect sizes. The standard measure of heterogeneity is Cochran's Q test. The Q statistic is the weighted[1] sum of the squared difference between the unbiased effect size estimate of each independent study and the weighted average unbiased effect size estimate across studies. Q is distributed as a chi-square statistic with $k - 1$ degrees of freedom, where k is the number of independent studies. If Cochran's Q test for heterogeneity is statistically significant (Q is larger than the chi-square value with $k - 1$ degrees of freedom), the assumption of the random-effects model is supported.

Publication Bias

Prior to investigating the impact of potential moderators, we undertook a preliminary analysis to assess if a publication bias existed in the selection of studies despite the inclusion of unpublished studies. A funnel plot of sample size against unbiased effect size estimates was created. In the absence of any publication bias, it is expected that the plot would be a funnel shape, such that the amount of scatter about the mean effect size deceases with increasing sample size. In addition to checking the presence of publication bias qualitatively, we carried out a weighted least-squares linear regression using the unbiased effect size estimates as the dependent variable and the sample sizes weighted by the inverse of the variance in a random-effects model, which is the sum of the between-studies variance[2] (random variance component) and within-study variance of the unbiased effect size. The regression slope (unstandardized coefficient of the predictive variable) would be expected to approach zero if there is no publication bias (Macaskill, Walter, & Irwing, 2001). The outcome of this analysis is reported below.

Regression Model Testing

Due to the wide variation in experiment settings among incubation studies, observed incubation effect size differences may reflect the combined impact of different moderators. Hence, weighted least-squares regression analyses were carried out to reveal the true impact of each moderator on incubation effects. The regression analyses were organized into two main sections. In the first section, the incubation studies were first classified into different groups, in terms of the type of problem used, the cognitive load of the incubation tasks, the presence of misleading cues, and the presence of relevant cues during an incubation period. Within each subgroup, the random variance component of the studies was computed. A larger than zero random variance component implies that the variability of effect sizes within these studies is not simply due to subject-level sampling error (Lipsey & Wilson, 2001). A weighted least-squares regression analysis was carried out as a follow-up analysis to model the effect sizes. The unbiased effect size estimate weighted by the inverse of the variance was the outcome variable of the regression analysis. The predictor variables included problem type, misleading cues, (solution-relevant) cues, incubation task, preparation period, and incubation period. The categorical variables were represented with an appropriate number of dummy-coded vectors. The categories (with the associated predictor variable following in parentheses) of creative problem (problem type), rest (incubation task), no misleading cues (misleading cues), and no cue (cues) were used as reference groups in the analysis, and their coefficients were restricted to zero.

The second section of the analyses investigated the general impact of the moderators on the incubation effect sizes. In this section, all the incubation studies were grouped together, and a weighted least-squares regression analysis was carried out to investigate the general impact of each moderator. Again, the weighted unbiased effect size was the outcome variable of the regression analysis. The predictor variables were problem type, misleading cues, cues, incubation task, preparation period, and incubation period. Another weighted least-squares regression was carried out to examine the interaction between the categorical variables problem type and incubation task. The predictor variables of the regression model were the appropriate number of dummy-coded vectors and the multiplicative terms of these two categorical variables, as well as the variables misleading cues, preparation period, incubation period, and cues. A more detailed description of the selection of the dummy-coded vectors and the multiplicative terms of problem type and incubation task is presented in Appendix C.

Results

There were 117 studies included in this meta-analysis. The total number of participants was 3,606, and the median number of participants per study was 25. An unbiased effect size estimate was computed for each independent study. Among these studies, 85 reported positive effect sizes. The unbiased effect size estimates ranged from −0.71 to 4.07, and the median effect size was 0.26. The unweighted mean of the unbiased effect size estimate was 0.41, with a standard deviation of 0.71. The upper and lower bounds of the 95% confidence interval were 0.54 and 0.28. Unbiased effect sizes larger than 2 *SD*s from the mean were recoded to

[1] The weighting was the inverse of the within-study variance of the effect estimate, and the formula for the within-study variance was [(2 × square root of total N) + (N of experimental × N of control × square root of the unbiased effect size)]/(2 × total N × N of experimental × N of control), where N is the number of participants in that condition (Cooper & Hedges, 1994). Three studies were excluded when computing the weighted average unbiased effect size estimate and the Cochran's Q value because they had a within-subjects design, and thus all participants were involved in both control and incubation conditions. Thus, the weighting formula could not apply to them.

[2] The between-studies variance was equal to [Q − (k − 1)]/c, where Q is the Cochran's Q value and k is the number of studies. The formula for c was [(the sum of the inverse of the within-study variance) – (the sum of the square of the inverse of the within-study variance)]/(the sum of the inverse of the within-study variance) and was suggested by Cooper and Hedges (1994).

the value of the effect size found at 2 *SD*s. Table 3 gives the stem-and-leaf display showing the distribution of the unbiased effect sizes. The unweighted mean of the adjusted unbiased effect size estimate was 0.36, with a standard deviation of 0.51. The upper and the lower bounds of the 95% confidence interval were 0.26 and 0.45. The confidence interval does not include zero, implying that the estimate of the mean unbiased effect size is significantly larger than zero.

The heterogeneity statistic, Cochran's Q, was 173.99, and was significantly larger than the chi-square critical value, $df = 113$, $p < .001$. This supports the use of the random-effects model. The variance of each unbiased effect size in the random-effects model was the sum of the between-studies variance and within-study variance of the unbiased effect size. The between-studies variance, also called the random variance component, among these incubation studies was .0834. The mean of the weighted unbiased effect size was 0.29, with a standard deviation[3] of 0.04, and the 95% confidence interval was 0.21, 0.39. The nonzero confidence interval implies that the weighted mean is significantly larger than zero. This answers our first question, showing the existence of a positive incubation effect.

Figure 1 presents the funnel plot of sample size against the estimated unbiased effect size of each study in the meta-analysis. We carried out a weighted least-squares regression using unbiased effect sizes weighted by the inverse of the variance as the dependent variable and sample size as the predictive variable. The regression coefficient of the predictive variable was not significantly different from zero (standardized $\beta = -.08$, $p = .41$), suggesting the absence of publication bias. Thus, no correction has been made for publication bias.

Table 3
Stem-and-Leaf Display of 117 Unbiased Effect Sizes

Stem	Leaf
−0.7	1
−0.5	9, 8, 8
−0.4	1
−0.3	8, 5, 3
−0.2	
−0.1	8, 7, 4, 4, 0
−0.0	3
0.0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 3, 4, 5, 5, 6, 6, 7, 9, 9
0.1	0, 0, 0, 0, 0, 1, 1, 3, 4, 4, 4, 5, 7, 7
0.2	1, 4, 5, 8, 8
0.3	1, 4, 6, 6, 7
0.4	0, 0, 1, 2, 2, 4, 5, 7, 7, 8, 8, 9
0.5	0, 2, 2, 6, 6, 6, 6, 6, 6, 7
0.6	2, 2, 4, 5, 6, 6, 6
0.7	0, 1, 2, 4, 4
0.8	6
0.9	9, 9
1.0	5, 5, 7, 7, 8, 9
1.1	7
1.2	
1.3	
1.4	
1.5	
1.6	8
1.7	0
1.8	2, 2, 2, 2

Note. Outliers were recoded.

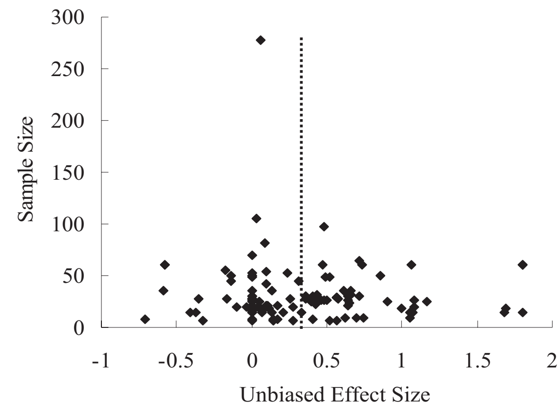

Figure 1. Funnel plot of the studies included in this meta-analysis. The dotted line indicates the mean unbiased effect size.

Table 4 presents the weighted mean, standard deviation, 95% confidence interval, and random variance component in each subgroup of each categorical moderator. Six of the subgroups (linguistic problems, creative problems, absence of misleading cues, absence of relevant cues, high cognitive load task, unoccupied incubation period) had larger than zero random variance components. New weightings, under the assumption of a random-effects model, were computed for each of the subgroups. Weighted least-squares regression analyses were carried out to find the moderators that accounted for the effect size variability among these subgroups. Small numbers of studies using creative tasks and studies having unoccupied incubation periods preclude the possibility of regression analyses with these moderators. An effect of applying a weighting to this regression analysis is to underestimate the original standard error of each unstandardized coefficient. Thus, we computed an adjusted standard error by dividing the original standard error by the square root of the mean square residual, a procedure suggested by Lipsey and Wilson (2001). The corrected standard error was used in the significance test (z test) of each unstandardized coefficient.

Tables 5,6,7, and 8 present a summary of the regression analysis results of each subgroup. With the subgroup of studies using linguistic problems, low cognitive load tasks generated larger incubation effects than did rest alone ($\beta = .54$, $p < .05$). Also, there was an interaction between problem type and incubation task with this subgroup, such that that low cognitive load tasks facilitated the incubation effect only when solving linguistic problems.

With the absence of misleading cue and absence of relevant cue subgroups, regression analyses revealed that, in the absence of these cues, individuals solving visual problems had smaller incubation effects than did those solving creative and linguistic problems. There was also a positive impact of longer preparation periods on the incubation effect sizes. The cognitive load of the incubation

[3] The standard deviation of the weighted mean, also known as the standard error, was calculated as the square root of $1/\Sigma w_i$, and the 95% confidence interval was calculated as the weighted mean ± 1.96 times the standard deviation of the weighted mean (Hedges & Olkin, 1985).

Table 4
The Random Variance Component, Weighted Mean, Standard Deviation, Standard Error, and 95% Confidence Interval of the Effect Size Estimate by Each Categorical Moderator

Moderator	Problem type: Linguistic	Problem type: Verbal	Problem type: Creative[a]	Misleading cues: Yes	Misleading cues: No[a]	Incubation task: High load	Incubation task: Low load	Incubation task: Rest[a]	Relevant cues: Yes	Relevant cues: No[a]
Number of studies	65	35	14	29	85	76	22	16	32	82
Random variance component	.00281	0	.37418	0	.12004	.06478	0	.30000	0	.10409
Mean	0.22	0.26	0.29	0.35	0.32	0.24	0.52	0.46	0.24	0.34
Standard deviation	0.05	0.08	0.14	0.09	0.06	0.05	0.10	0.18	0.09	0.06
95% confidence interval	0.32, 0.13	0.41, 0.10	0.55, 0.02	0.53, 0.17	0.43, 0.20	0.35, 0.13	0.72, 0.32	0.82, 0.11	0.41, 0.07	0.45, 0.22
Mean comparison with the reference group	$t(77) = -0.43$	$t(47) = -0.19$		$t(112) = 0.30$		$t(90) = 1.17$	$t(36) = 0.28$		$t(112) = 0.90$	

Note. The lower confidence intervals of all the weighted unbiased effects are larger than zero, suggesting that the mean is significantly larger than zero, $p < .05$.
[a] The reference groups in mean comparisons.

tasks did not have any impact on the magnitude of the incubation effects in these two subgroups. Note, however, that the presence or absence of these effects with these specific subgroups does not necessarily imply converse effects in other subgroups, hence a shift to analysis of general impacts of each moderator.

In the second stage of the analysis, a weighted least-squares regression analysis was carried out to look at the general impact of each moderator on the incubation effect sizes. A summary of the regression analysis results is presented in Table 9. The negative coefficients associated with visual problems and linguistic problems indicate that individuals solving these two types of insight problem showed a smaller incubation effect than did individuals solving creative problems. A z test was carried out to compare the coefficients of the visual problem and linguistic problem groups. The result was not statistically significant ($z = -1.25$, $p > .05$), suggesting the magnitude of the incubation effect for visual and linguistic insight problems was comparable.

The length of the preparation period was found to have a significant impact on the magnitude of the incubation effect ($\beta = .03$, $p < .05$). Three bivariate correlations were carried out to check for positive relationships between the length of the preparation period and the magnitude of the weighted incubation effect when solving the three types of problem. There was a statistically significant positive correlation between the weighted incubation effect size and the length of the preparation period with visual problems, $r(35) = .40$, $p = .02$, and creative problems, $r(14) = .60$, $p = .03$, but not with linguistic problems, $r(65) = -.04$, $p = .75$.

We carried out another weighted least-squares regression analysis to examine the interaction between problem type and incubation task, using misleading cues, preparation period, incubation period, cues, and an appropriate number of dummy vectors and the multiplicative terms of the variables problem type and incubation task as predictor variables. Table 10 presents the results of this

Table 5
Regression Model for Linguistic Problem Studies (N = 65)

Variable	Sum of squares	*df*	Mean square	*F*	*p* value
ANOVA significance test					
Model	13.42	5	2.68	3.15*	.01
Residual	5.24	59	0.85		
Total	63.66	64			

	Summary of the regression model: Unstandardized β	Standardized β	Corrected SE_β	*z* score
Incubation task				
High cognitive load task	.06	.06	.21	0.27
Low cognitive load task	.54*	.43	.25	2.15
Misleading cues	.15	.17	.12	1.24
Ratio of the preparation period to the incubation period	.15	.12	.19	0.80
Relevant cue	−.04	−.04	.13	−0.30

Note. Random variance component =.00281, $R^2 = .21$. Another regression with the same predicting variables, except replacing the variable ratio of length of the preparation to the incubation period by the variables incubation period and preparation period, was carried out. The pattern of the results was comparable, but it had lower explanatory power, and a lower significance level, $R^2 = .20$, $F(6, 58) = 2.47$, $p = .034$. Neither the variable preparation period nor incubation period was significant. ANOVA = analysis of variance.
* $p < .05$.

Table 6
Regression Model for Misleading Cue Studies ($N = 85$)

Variable	Sum of squares	*df*	Mean square	*F*	*p* value
		ANOVA significance test			
Model	2.25	7	2.89	3.56*	.002
Residual	62.62	77	0.81		
Total	82.87	84			

	Summary of the regression model			
	Unstandardized β	Standardized β	Corrected SE_β	*z* score
Problem type				
Visual problem	−.59*	−.51	.19	−3.02
Linguistic problem	−.31	−.29	.18	−1.74
Incubation task				
High cognitive load task	−.18	−.14	.22	−0.80
Low cognitive load task	.06	.04	.26	0.23
Length of the incubation period	<.001	.055	<.001	0.45
Length of the preparation period	.03*	.36	.01	2.16
Relevant cue	−.03	−.02	.16	−0.20

Note. Random variance component =.12004, $R^2 = .24$. ANOVA = analysis of variance.
$^* p < .05$.

regression analysis. To examine the interaction effects, we examined the coefficient differences between their multiplicative terms to see if they were significantly larger than zero by using *z* tests. The details of equations for computing the coefficient difference can be found in Appendix C. Table 11 presents the coefficient differences between multiplicative terms.

With creative problems, undertaking high cognitive load tasks was associated with smaller incubation effects than with low cognitive load tasks or rest during the incubation period ($C_jH_j - C_jR_j = -.91$, $p < .05$; $C_jH_j - C_jL_j = -.79$, $p = .08$, where C refers to creative problems, H to high cognitive demand tasks, R to rest, and L to low cognitive demand tasks, all in study j). When solving linguistic and visual problems, no differences were found for incubation periods filled with low or high cognitive load tasks or rest. However, this regression model has a problem in exploring the interaction between problem type and incubation task. Among studies examining the role of an incubation period with creative problems, 12 out of 14 employed high cognitive load tasks, and the remaining 2 studies employed rest during the incubation period. This unbalanced distribution may cause bias when examining the interaction between incubation task and problem type. Hence, another regression analysis was carried out that excluded studies using creative problems. This third regression model included the variables misleading cues, preparation period, cues, the dummy variables of problem type (excluding creative problem) and incubation task, and their multiplicative variables. Appendix D pre-

Table 7
Regression Model for No Relevant Cue Studies ($N = 82$)

Variable	Sum of squares	*df*	Mean square	*F*	*p* value
		ANOVA significance test			
Model	29.34	6	4.89	7.35*	<.001
Residual	49.94	75	0.67		
Total	79.28	81			

	Summary of the regression model			
	Unstandardized β	Standardized β	Corrected SE_β	*z* score
Problem type				
Visual problem	−.79**	−.66	.19	−4.10
Linguistic problem	−.22	−.21	.18	1.24
Incubation task				
High cognitive load task	−.25	−.22	.21	−1.20
Low cognitive load task	.16	.12	.25	0.64
Length of the incubation period	<.001	.02	0	0.13
Length of the preparation period	.05**	.51	.02	3.01
Misleading cue	.09	.07	.18	0.53

Note. Random variance component =.10409, $R^2 = .37$. ANOVA = analysis of variance.
$^* p < .05$. $^{**} p < .001$.

Table 8
Regression Model for High Cognitive Load Incubation Task Studies (N = 75)

Variable	Sum of squares	*df*	Mean square	*F*	*p* value
		ANOVA significance test			
Model	7.36	6	1.47	1.53	.19
Residual	66.19	69	0.96		
Total	73.55	74			

	Summary of the regression model			
	Unstandardized β	Standardized β	Corrected SE_β	*z* score
Problem type				
Visual problem	−.41*	−.34	.20	−2.01
Linguistic problem	−.28	−.30	.17	−1.58
Length of the incubation period	−.01	−.12	.01	−0.87
Length of the preparation period	.02	.21	.02	1.31
Misleading cue	.08	.06	.16	0.51
Relevant cue	.09	.08	.14	0.62

Note. Random variance component =.06478, $R^2 = .10$. ANOVA = analysis of variance.
* $p < .05$.

sents a detailed description of the selection of the dummy-coded vectors and the multiplicative terms. The results of this analysis are presented in Table 12, and the coefficient differences between the multiplicative terms are presented in Table 13.

The regression results indicated an interaction between problem type and incubation task. When solving linguistic problems, a low cognitive load task generated significantly larger incubation effects than did rest ($Li_jL_j - Li_jR_j = .45$, $p = .05$, where *Li* refers to linguistic problems, *L* to low cognitive demand tasks, and *R* to rest, all in study *j*). The difference between low and high cognitive loads was in the same direction but did not reach significance, and there was no significant difference between the rest condition and the high cognitive load condition. When solving visual problems, the effect sizes among the three incubation conditions were comparable. This pattern of findings is consistent with the previous regression analysis results. In addition, the exclusion of creative problem studies makes the positive impact of a low cognitive load incubation period on linguistic problems more significant.

The model using the variables preparation period and incubation period was found to be not significant, and the variable preparation period was not significant in the analysis. This may be due to the decrease in the number of studies included in the current regression model. Moreover, as mentioned above, a positive association between the length of preparation period and incubation effect size was found when solving visual and creative problems. Thus, the exclusion of creative problem studies appears to decrease the significance of the variable preparation period and the significance

Table 9
Regression Model for All Studies (N = 114)

Variable	Sum of squares	*df*	Mean square	*F*	*p* value
		ANOVA significance test			
Model	25.56	8	3.20	4.08	<.001
Residual	82.22	105	0.78		
Total	107.79	113			

	Summary of the regression model			
	Unstandardized β	Standardized β	Corrected SE_β	*z* score
Problem type				
Visual problem	−.60**	−.52	.15	−3.61
Linguistic problem	−.31*	−.31	.14	−1.96
Misleading cues	.16	.13	.12	1.16
Incubation task				
Low cognitive load	.14	.10	.18	0.72
High cognitive load	−.16	−.15	.14	−1.02
Preparation period	.03*	.35	.01	2.29
Incubation period	<.001	.04	<.001	<0.001
Cue presented	−.01	−.01	.11	−0.09

Note. Random variance component = .0834, $R^2 = .24$. ANOVA = analysis of variance.
* $p < .05$. ** $p < .001$.

Table 10
Regression Model for All Studies—Interactions (N = 114)

Variable	Sum of squares	*df*	Mean square	*F*	*p* value
		ANOVA significance test			
Model	35.60	12	2.97	4.15	<.001
Residual	72.18	101	0.72		
Total	107.78	113			

	Summary of the regression model			
	Unstandardized β	Standardized β	Corrected SE_{β}	*z* score
Problem Type × Incubation Task				
Visual Problem × Low Cognitive Load Task	0.17	0.08	0.35	0.50
Visual Problem × High Cognitive Load Task	0.90*	0.61	0.35	2.60
Linguistic Problem × Low Cognitive Load Task	0.72	0.43	0.38	1.93
Linguistic Problem × High Cognitive Load Task	1.00*	0.97	0.38	2.59
Problem type				
Visual problem	−1.29**	−1.10	0.32	−4.00
Linguistic problem	−1.24**	−1.21	0.40	−3.14
Incubation task				
High cognitive load task	−0.91**	−0.81	0.30	−3.00
Low cognitive load task	−0.12	−0.09	0.33	−0.38
Misleading cues	0.24	0.19	0.15	1.54
Length of the incubation period	<0.001	0.018	<0.001	<0.001
Length of the preparation period	0.03*	0.01	0.01	1.97
Answer was presented	0.03	0.03	0.13	0.26

Note. Random variance component = .08340, R^2 = .33. ANOVA = analysis of variance.
* $p < .05$. ** $p < .001$.

level of the regression model that used preparation period as one of the predictor variables.

Discussion

The meta-analysis supports the existence of incubation effects and also identifies some potential moderators, including the problem type, length of the preparation period, and the incubation task. Individuals solving creative problems were more likely to benefit from an incubation period than individuals solving linguistic and visual problems. Longer preparation periods gave rise to larger incubation effects. When solving linguistic problems, a low cognitive load task gave the strongest incubation effects.

We suggest that the positive incubation effects found with creative problems are a direct reflection of their multiple-solution nature. When solving a creative problem, individuals benefit from performing a wide search of their knowledge to identify as many relevant connections as possible with the presented stimuli. Each time individuals reapproach the problem, they improve their performance by extending the search to previously unexplored areas of their knowledge network. Incubation appears to facilitate the widening of search of a knowledge network in this fashion.

Linguistic and visual problems typically have only one possible solution. In order to solve them, individuals have to explore their memory or environment to look for specific relevant knowledge or to adapt a specific strategy. Widening search to new items of knowledge may not be facilitative if the solution to a problem lies within already activated knowledge that is currently represented inappropriately. Under this account, incubation supports knowledge activation, but it does not support restructuring.

Another finding of the meta-analysis was the beneficial effect of an incubation period filled with low demand tasks on solving linguistic problems. A positive effect of a filled incubation period on problem solving compared with rest during the incubation period undermines the conscious-work hypothesis that incubation effects are due to the mental fatigue reduction (Posner, 1973). There remains a possibility, of course, that a sufficiently light load might allow additional covert problem solving compared with a heavier task load (Browne & Cruse, 1988; Posner, 1973), but this does not explain why a light load should be more facilitative than rest alone.

The positive effect of a light cognitive load may indicate competition between controlled and automatic processes in solving linguistic problems. It has been suggested with remote associates task (RAT) performance that only strong (and in this context, incorrect) associates are accessed when individuals focus their attention on seeking solutions, whereas remote associates are more likely to be accessed when an individual's cognitive resources are allocated in a diffuse manner (Ansburg & Hill, 2003; Finke, Ward, & Smith, 1992; Martindale, 1995). During an incubation period, low demand tasks may occupy part of the problem solver's attention, preventing the focused concentration that yields strong associates. Resting during an incubation period may allow individuals to continue consciously working on the problem, whereas performing high demand tasks may shift attention entirely to that interpo-

Table 11
Summary of Coefficient Differences of the Original Regression Model

Multiplicative terms	Coefficient difference	Corrected *SE*	*z* score
$Li_jH_j - Li_jR_j$	0.08	.49	0.17
$Li_jL_j - Li_jR_j$	0.60	.50	1.21
$Li_jL_j - Li_jH_j$	0.52	.70	0.74
$V_jH_j - V_jR_j$	−0.01	.46	−0.03
$V_jL_j - V_jR_j$	0.05	.48	0.10
$V_jL_j - V_jH_j$	0.06	.66	0.09
$C_jH_j - C_jR_j$	−0.91*	.30	−3.00
$C_jL_j - C_jR_j$	−0.12	.33	−0.38
$C_jL_j - C_jjH_j$	0.79†	.45	1.77
$V_jH_j - C_jH_j$	−0.39	.47	−0.82
$Li_jH_j - C_jH_j$	−0.25	.55	−0.45
$Li_jH_j - V_jH_j$	0.14	.72	0.19
$V_jL_j - C_jL_j$	−1.11*	.47	−2.36
$Li_jL_j - C_jL_j$	−0.52	.55	−0.95
$Li_jL_j - V_jL_j$	0.60	.72	0.82
$V_jR_j - C_jR_j$	−1.29**	.32	−4.00
$Li_jR_j - C_jR_j$	−1.24**	.40	−3.14
$Li_jR_j - V_jjR_j$	0.04	.51	0.08

Note. *Li* = linguistic problem; *H* = high cognitive demand task; *R* = rest; *L* = low cognitive demand task; *V* = visual problem; *C* = creative problem; *j* = study *j*.
* $p < .05$. ** $p < .001$. † $p = .08$.

lated task, leading to a narrow rather than diffused attentional focus. The impact of performing high demand tasks is analogous to the *verbal overshadowing effect* reported by Schooler, Ohlsson, and Brooks (1993), in which the act of verbalizing can impair performance by focusing individuals' attention inappropriately on verbalizable components of a task. The suggested role of light-load incubation tasks receives indirect support from recent findings that show that visual search can be more efficient when performed concurrently with an unrelated task than when performed alone (Smilek, Enns, Eastwood, & Merikle, 2006). They suggest that the dual-task condition prevents a narrow attentional focus in searching for stimuli.

With visual problems, the magnitude of the incubation effect was independent of the setting of an incubation period (filled or unfilled). Differences between visual and linguistic insight problems may arise through a greater reliance on strategic search rather than knowledge activation in the former than the latter. MacGregor et al. (2001) proposed that in solving the nine-dot problem, individuals select and execute moves that maximally reduce the distance between current and goal states, essentially drawing lines that connect as many dots as possible. While there remain moves available that satisfy a criterion of satisfactory progress (in this case, the ratio of dots cancelled to lines available), individuals will persevere with an initial representation of the problem that, in the case of the nine-dot problem, does not include consideration of space outside the dot array. According to MacGregor et al.'s account, individuals must experience a failure to find moves that meet a criterion of satisfactory progress before they change their initial representation of the problem, thereby including space outside the dot array in their attempts. An incubation period would be helpful only if the problem solvers became aware of the necessity of a strategy shift, but according to MacGregor et al. they are

Table 12
Regression Model for Studies Excluding Creative Problem (N = 100)

Variable	Sum of squares	*df*	Mean square	*F*	*p* value
		ANOVA significance test			
Model	15.04	8	1.88	2.04*	.05
Residual	83.92	91	0.92		
Total	98.96	99			

	Summary of the regression model			
	Unstandardized β	Standardized β	Corrected SE_β	*z* score
Problem Type × Incubation Task				
Visual Problem × Low Cognitive Load Task	−.21	−.12	.28	−0.77
Visual Problem × High Cognitive Load Task	.09	.08	.24	0.38
Problem type				
Visual problem	−.15	−.15	.21	−0.68
Incubation task				
High cognitive load task	−.01	−.01	.18	−0.05
Low cognitive load task	.45*	.41	.20	2.27
Misleading cues	.13	.13	.11	1.10
Length of the preparation period/incubation	.08	.20	.05	1.56
Answer was presented	.01	.01	.11	0.13

Note. Random variance component = .00031, R^2 = .15. Another regression was carried out with the same variables, replacing the variable "ratio of length of preparation to incubation period" with incubation period and preparation period. The regression model was not significant, $F(9, 90) = 1.27$, $p = .10$. Neither the variable preparation period nor incubation period was significant. ANOVA = analysis of variance.
* $p < .05$.

Table 13
Summary of Coefficient Differences of the Original Regression Model

Multiplicative terms	Coefficient difference	Corrected *SE*	*z* score
$Li_jH_j - Li_jR_j$	−.01	.17	−0.05
$Li_jL_j - Li_jR_j$	.45*	.20	2.27
$Li_jL_j - Li_jH_j$	.46	.26	1.76
$V_jH_j - V_jR_j$	.08	.30	0.28
$V_jL_j - V_jR_j$	.24	.34	0.69
$V_jLj - V_jH_j$	.15	.45	0.34
$V_jH_j - Li_jH_j$	−.06	.32	−0.17
$V_jL_j - Li_jL_j$	−.36	.35	−1.03
$V_jR_j - Li_jR_j$	−.15	.21	−0.68

Note. *Li* = linguistic problem; *H* = high cognitive demand task; *R* = rest; *L* = low cognitive demand task; *V* = visual problem; *j* = study *j*.
* $p < .05$.

unlikely to do so unless they encounter criterion failure as a result of reaching impasse. Seifert et al. (1995) offered an alternative account that also points to the criticality of experiencing failure and impasse for eventual success in insight problem solving.

If the hypothesis that visual problems require impasse for a strategy switch to occur is correct, a long preparation period (i.e., preincubation problem solving) should be more likely to yield benefits from subsequent incubation with visual problems because it allows individuals to reach impasse prior to incubation. The results of the regression analysis and the follow-up bivariate correlations are consistent with this prediction, showing a statistically significant positive correlation between the incubation effect size and the length of the preparation period with visual problems.

A positive correlation between the length of the preparation period and incubation effect size was also found with creative problems. A long preparation period may allow individuals to exhaust search in one domain, making it more likely for them to explore a new domain in the second phase of solving. A positive correlation was not found when solving linguistic problems, though this may simply reflect the small variability in length of preparation period among studies using linguistic problems (the preparation period of 82% of these studies ranged from 0.5 to 1 min).

The meta-analysis reveals that embedding misleading cues in the problems was not a significant predictor overall. This result is in contrast with previous reports (e.g., Smith & Blankenship, 1989, 1991), which suggested that incubation effects arise through forgetting of inappropriate information. The true effect of misleading cues is underestimated in our regression analyses, as we examined only the overall effect of misleading cues on problem solving in general. There were 29 independent studies included in this meta-analysis that examined the impact of misleading cues; 25 of them examined the impact on linguistic problems, the rest on visual problems. The weighted means of the effect size estimates of these studies for each problem type by the presence of misleading cues were as follows: linguistic with misleading cue: $M = 0.36$, $SD = 0.09$; linguistic without misleading cue: $M = 0.17$, $SD = 0.06$; visual with misleading cue: $M = 0.18$, $SD = 0.39$; visual without misleading cue: $M = 0.26$, $SD = 0.08$. For studies employing linguistic problems, the presence of misleading cues induced a larger incubation effect, but an opposite pattern of results was found in studies employing visual problems, suggesting that the impact of misleading cues may be modality specific. In order to test whether the presence of misleading cues affects incubation with linguistic problems alone, we ran a weighted one-way analysis of variance to compare the incubation effect sizes of studies using linguistic problems that included misleading cues (25 studies) against studies using linguistic problems that did not include misleading cues (40 studies), $F(1, 65) = 3.04$, $MSe = 3.00$, $p = .08$. Thus, where problem materials involve linguistic stimuli, getting rid of misleading concepts may be the key to task solution, in contrast with visual problems in which the key may be to restructure the knowledge that is currently active. The effect of misleading cues also offers some support for the selective-forgetting hypothesis, but this effect may be task specific.

In contrast with previous reports (e.g., Dominowski & Jenrick, 1972; Dreistadt, 1969; Mednick, Mednick, & Mednick, 1964), the moderator presence of solution-relevant cues was not found to be a significant predictor of incubation effects. It has been hypothesized that, during an incubation period, unconscious processes such as spreading activation sensitize individuals to solution concepts and make them more likely to utilize externally presented cues. To examine this hypothesis, researchers have presented the answers of unsolved problems during an incubation period and compared their postincubation performance with that of participants not receiving any cues during the incubation period (e.g., Dominowski & Jenrick, 1972; Dodds, Smith, & Ward, 2002). Findings of these studies are equivocal, but it does appear that problem solvers do not always make use of solution-relevant cues, even when the cue includes the solution itself. For example, Chronicle, Ormerod, and MacGregor (2001) found that presenting the nine-dot problem with a shaded background in the shape of the solution did not lead to significant levels of facilitation, even when the relevance of the shading was drawn to participants' attention. However, because of the small number of studies that presented solution-relevant cues (three with linguistic, seven with visual problems, none with creative problems) and the wide variation in experimental parameters among these studies, it is impossible to carry out further statistical analysis.

In summary, the meta-analysis results support the existence of incubation effects, though there appears to be a range of effects specific to particular tasks and performance conditions. When attempting to solve creative problems that require a wide search of knowledge, individuals benefit from an incubation period. Problems that involve reaching some kind of insight into a unique solution do not always benefit from incubation under all conditions. In the case of linguistic problems, such as the RAT, there is a modest incubation effect but only where the incubation period is filled with a low cognitive demand task. One possible explanation is that performing low cognitive demand incubation tasks allows the occurrence of some unconscious problem-solving processes, such as spreading activation and selective forgetting. In the case of visual problems, incubation effects arise only where there has been a sufficiently long preparation period prior to incubation for the problem solver to have entered a state of impasse. Only under these conditions can an incubation period contribute to the strategic shift needed to restructure a problem representation. Thus, the theoretical positions of spreading activation, selective forgetting, and restructuring each receive support. However, evidence for each appears to be specific to particular problem types.

Spreading activation and strategic search are basic mechanisms underlying different types of general cognitive process. For instance, the adaptive control of thought—rational (ACT-R) computational framework (Anderson, 1994) utilizes both these mechanisms. Different researchers have successfully adapted this model to simulate a wide range of noninsight problem-solving processes. Examining the occurrence of incubation effects in terms of fundamental cognitive processes would offer important findings for developing a computational model of insight problem solving.

Although the conscious-work hypothesis receives little support here, the meta-analysis leaves open the possibility that unconscious processes may reflect forgetting, activation of new knowledge, or restructuring. Further experimental studies might focus on comparing the occurrence of these different unconscious processes during an incubation period in different experimental settings. One methodology that might allow such comparisons was employed by Sio and Rudowicz (2007), who examined the occurrence of spreading activation by measuring individuals' sensitivity to answers of the unsolved RATs before and after filled and unfilled incubation periods. They found that the spreading-activation process occurred only in the filled incubation period condition and in a fixated mind, though this study did not measure postincubation period performance.

Given the outcome that both spreading activation and restructuring might arise from an incubation period, depending on the task, then proponents of both the current views of insight problem solving may take some comfort from the results. The evidence from the linguistic problems is consistent with release from inappropriate constraints (Knoblich et al., 1999), whereas evidence from the visual problems is consistent with restructuring that results from a strategic shift following impasse (MacGregor et al., 2001). Given that these theoretical alternatives have to date been explored only with different task sets, it seems quite possible that a complete account of insight might need both theoretical components. Such a view may well be consistent with the account of insight offered by Kershaw and Ohlsson (2004), who proposed a multiple-source account of the difficulties individuals encounter in insight problem solving.

The finding of a positive impact of an incubation period on solving creative thinking problems supports the contention that incubation periods help the elicitation of new ideas. Incubation is a concept central to many methodologies for encouraging creative decision making, especially among management science and business communities (e.g., Rickards, 1991), and this result may be taken as supporting the inclusion of an incubation phase in such methodologies.

It should be noted that, despite efforts to include studies from sources other than peer-reviewed journals, the meta-analysis may be influenced by a bias in favor of reporting significant effects at the expense of null effects. Thus, incubation effects may be to some extent overstated in this meta-analysis, a problem common to all meta-analyses. Nonetheless, the reasonably large effect sizes found with creative problems indicates that, with this class of problem at any rate, incubation is a potentially valuable mechanism for fostering creative thought.

Clearly, the empirical data on incubation are not straightforward. As a consequence, the traditional narrative review approach is not amenable to drawing strong cross-study conclusions. It is perhaps disappointing that relatively few published studies met the necessary criteria for inclusion in the meta-analysis, since a failure either to measure postincubation performance or to provide effect size information limits the conclusions that can be drawn from them. Nonetheless, sufficient studies remain for the meta-analysis to be undertaken and to reveal some intriguing results.

One remaining problem is the relatively narrow range of problem types that have been explored. For instance, the majority of studies that explored incubation effects with linguistic problems, which is the majority of studies overall, used the RAT. It is unclear whether the RAT can be considered an insight problem or a linguistic completion task, suggesting it may not be representative of all linguistic problem-solving tasks. Bowden and Jung-Beeman (2003a) have found that participants claimed that they solved RATs sometimes with insight and sometimes without insight. Further studies should aim to explore task-specific experimental settings for maximizing the incubation effect with a wider range of tasks. A further research issue of value might also be to explore individual differences in incubation effects. For example, if the role of incubation is to encourage diffused attention, then individuals who show a propensity toward allocating attention broadly (e.g., as measured via field dependence) may benefit differentially from an incubation period. Also, studies have revealed that strategy switching is related to working memory capacity (Geary, Hoard, Byrd-Craven, & DeSoto, 2004). Thus, memory capacity may also interact with incubation effects in solving visual problems.

One the whole, the results of this meta-analysis support the existence of multiple types of problem-specific incubation effect. We suggest that the concept of incubation can be understood only through a close examination of the problems to which it is applied and the conditions under which it is elicited.

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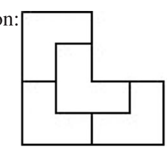
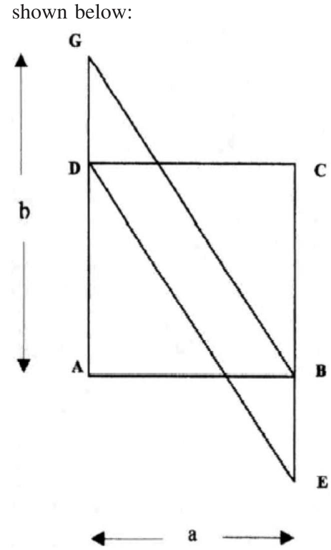
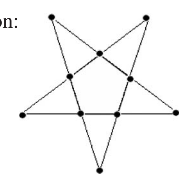
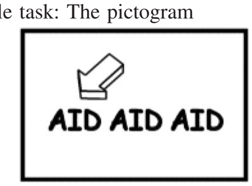
Appendix A

Task Descriptions

Task type	Description	Solution or sample task
Creative problems		
Brick task	Participant has to list all the uses he or she can think of for a brick	
Consequences task	Participant has to list as many consequences of an event as he or she can foresee	Sample task: What would be the results if everyone suddenly lost the ability to read and write?
Creative writing		Sample task: Write about three concrete objects: a Koosch ball, a wooden type of propeller, and a triangular frisbee
Visual insight problems		
Candle problem	Participant has to support a candle on a wall by using some matches and a box of tacks	Solution: Use a tack to attach box to the wall, then drip some wax onto the box and mount the candle on the box
Farm problem	Participant has to divide an L-shaped farm into four parts that have the same size and shape	Solution: 
Hat rack problem	Participant has to construct a stable hat rack by using two boards and a clamp	Solution: Wedge the two boards between the ceiling and the floor, holding them in place with the clamp, with the clamp also serving as a hook
Insightful mathematic problem	Participant has to compute separately the area of the square and that of the parallelogram shown below: 	Solution: Restructure the given shape into partially overlapping triangles ABG and ECD. The sum of their area is $2 \times ab/2 = ab$
Necklace problem	Participant is given four pieces of chain, each made up of three links; he or she has to join all the pieces by opening and closing only three links	Solution: Open all three links of one chain, and join the other three chains together

(*table continues*)

Table (*continued*)

Task type	Description	Solution or sample task
Radiation problem	A patient has an inoperable tumor in the middle of the body. There is a ray at a strong intensity that can destroy the tumor, but the ray also harms the healthy tissue that it travels through. At low intensities, the ray will spare the healthy tissue but will not destroy the tumor. Participant has to think out a way to use the ray to destroy the tumor without damaging healthy tissue.	Solution: Direct multiple low-intensity rays simultaneously toward the tumor from different directions
Saugstad's ball problem	Participant has to transfer steel balls from a drinking glass to a cylinder from a distance of 8 ft by using the following objects: a nail, a pair of pliers, a length of string, a pulley, elastic bands, and a newspaper. The glass sits on a moveable frame.	Solution: Bend the nail into a hook then attach it to the string. Use it to drag back the frame and remove the balls. Transfer balls into the cylinder using a tube constructed of newspaper and elastic band.
Tree problem	Participant has to plant 10 trees in five rows with four trees in each row	Solution:  (The dots represent trees)
Linguistic insight problems		
Anagram	Participant has to rearrange the scrambled letters to form a new word	Sample task: The scambled letters are "t s l t i n e," and one possible solution is *silent*
Remote associates task (RAT)	Three words are presented to the participant, and he or she has to think of a word that can form associations with each one	Sample task: The three stimulus words are *blue*, *cake*, and *cottage*, and one possible solution is the word *cheese*
Rebus	Participant has to figure out the phrase portrayed by the pictogram	Sample task: The pictogram  The answer is *first aid*
Riddle		Sample task: A wine bottle is half-filled and corked. How can you drink all of the wine without removing the cork from the bottle? Answer: The cork can be opened by pushing it in.
Word associates task	Six words are presented to the participant; he or she has to think out a word that can form an association with each of them	Sample task: The six stimulus words are *school*, *chair*, *jump*, *noon*, *heels*, and *wire*, and one possible solution is the word *high*
Word fragment completion task	Participant has to complete a word that has various letters missing	Sample task: The stimulus is "OC_ _N" and one possible answer is *ocean*

Appendix B

Information Extracted From Each Independent Study

ID No.	Year	Author	Total *N*	Problem type[a]	Presence of misleading cues[b]	Preparation period in minutes	Incubation period in minutes	Incubation task type[c]	Presence of relevant cues[d]	Unbiased effect size
1	1967	Gall & Mendelsohn	60	2 (RAT)	0	2	25	2 (nonverbal task)	0	−0.58
2	1967	Gall & Mendelsohn	60	2 (RAT)	0	2	25	2 (associations training)	1	−0.58
3	1968	Fulgosi & Guilford	50	1 (consequences task)	0	2	10	2 (number series task)	0	0
4	1968	Fulgosi & Guilford	49	1 (consequences task)	0	2	20	2 (number series task)	0	0.52
5	1969	Dreistadt	20	1 (farm problem)	0	5	8	1 (guess playing card)	0	0.34
6	1969	Dreistadt	20	1 (farm problem)	0	5	8	1 (guess playing card)	1	1.68
7	1969	Dreistadt	20	1 (tree problem)	0	5	8	1 (guess playing card)	0	0.21
8	1969	Dreistadt	20	1 (tree problem)	0	5	8	1 (guess playing card)	1	2.80
9	1969	Murray & Denny (Experiment 1)	36	1 (Saugstad's ball problem, low ability group)	0	5	5	2 (multiple choice syllogisms and traced sequences of numbers and letters)	0	0.62
10	1969	Murray & Denny (Experiment 2)	36	1 (Saugstad's ball problem, high ability group)	0	5	5	2 (multiple choice syllogisms and traced sequences of numbers and letters)	0	−0.59
11	1972	Dominowski & Jenrick	27	1 (hat rack problem)		5	10	2 (free association)	0	0
12	1972	Dominowski & Jenrick	30	1 (hat rack problem)		3	3	2 (free association)	0	0
13	1972	Silveira (Experiment 1)	18	1 (necklace problem)	0	3	30	1 (read book)	0	0.11
14	1972	Silveira (Experiment 1)	18	1 (necklace problem)	0	3	210	1 (read book for 30 min and free activity for 3 hr)	0	0.06
15	1972	Silveira (Experiment 1)	18	1 (necklace problem)	0	13	30	1 (read book)	0	0.17
16	1972	Silveira (Experiment 1)	18	1 (necklace problem)	0	13	210	1 (read book for 30 min and free activity for 3 hr)	0	0.42
17	1972	Silveira (Experiment 2)	32	1 (necklace problem)	0	13	210	1 (read book for 30 min and free activity for 3 hr)	0	0.44
18	1974	Peterson	24	1 (anagram)		0.33	1.8	Anagram	1	0.65
19	1976	Olton & Johnson	21	1 (farm problem)	0	10	15	0 (rest)	0	0.10
20	1976	Olton & Johnson	21	1 (farm problem)	0	10	15	2 (Stroop test + counting backward)	0	0.11
21	1976	Olton & Johnson	21	1 (farm problem)	0	10	15	2 (review the problem)	1	0.10
22	1976	Olton & Johnson	21	1 (farm problem)	0	10	15	2 (have lecture)	1	0
23	1976	Olton & Johnson	20	1 (farm problem)	0	10	15	0 (listen to music)	0	−0.10
24	1976	Olton & Johnson	20	1 (farm problem)	0	10	15	0 (rest)	1	0.10
25	1976	Olton & Johnson	20	1 (farm problem)	0	10	15	2 (have lecture)	1	−0.03
26	1979	Beck	60	0 (verbal divergent-thinking task)	0	12	20	0 (relax)	0	2.19
27	1979	Beck	60	0 (verbal divergent-thinking task)	0	12	30	2 (write essay)	0	1.07
28	1979	Beck	60	0 (verbal divergent-thinking task)	0	12	20	0 (relax)	0	4.07
29	1979	Beck	60	0 (verbal divergent-thinking task)	0	12	30	2 (write essay)	0	4.04
30	1985	Brockett	30	0 (brick task)	0	10	20	2 (questionnaire)	0	0.42
31	1985	Brockett	30	2 (RAT)	0	0.33	20	2 (questionnaire)	0	0.37
32	1986	Patrick	30	2 (RAT)	0	2	5	2 (conversation)	0	0
33	1986	Patrick	30	2 (RAT)	0	2	5	2 (mental rotation task)	0	0.66
34	1988	Browne & Cruse (Experiment 2)	60	1 (farm problem)	0	20	5	0 (listen to music)	0	0.47
35	1988	Browne & Cruse (Experiment 2)	53	1 (farm problem)	0	20	5	1 (graph drawing)	1	0.24

(*table continues*)

Table (*continued*)

ID No.	Year	Author	Total *N*	Problem type[a]	Presence of misleading cues[b]	Preparation period in minutes	Incubation period in minutes	Incubation task type[c]	Presence of relevant cues[d]	Unbiased effect size
36	1988	Browne & Cruse (Experiment 2)	55	1 (farm problem)	0	20	5	2 (memory test)	0	−0.18
37	1989	Smith & Blankenship (Experiment 1)	26	2 (rebus)	1	0.5	5	0 (rest)	0	0.45
38	1989	Smith & Blankenship (Experiment 1)	26	2 (rebus)	1	0.5	5	2 (music perception task)	0	0.48
39	1989	Smith & Blankenship (Experiment 1)	26	2 (rebus)	1	0.5	15	0 (rest)	0	0.49
40	1989	Smith & Blankenship (Experiment 1)	26	2 (rebus)	1	0.5	15	2 (music perception task)	0	0.50
41	1989	Smith & Blankenship (Experiment 2)	25	2 (rebus)	1	0.5	5	0 (rest)	1	0.05
42	1989	Smith & Blankenship (Experiment 2)	25	2 (rebus)	1	0.5	5	2 (music perception task)	1	0.05
43	1989	Smith & Blankenship (Experiment 2)	25	2 (rebus)	1	0.5	15	0 (rest)	1	0.40
44	1989	Smith & Blankenship (Experiment 2)	25	2 (rebus)	1	0.5	15	2 (music perception task)	1	0.40
45	1989	Smith & Blankenship (Experiment 3)	29	2 (rebus)	1	0.5	10	2 (rebus)	1	0.56
46	1989	Smith & Blankenship (Experiment 3)	29	2 (rebus)	1	0.5	15	0 (rebus + rest)	1	0.56
47	1989	Smith & Blankenship (Experiment 3)	29	2 (rebus)	1	0.5	15	2 (rebus + math)	1	0.56
48	1989	Smith & Blankenship (Experiment 3)	29	2 (rebus)	1	0.5	15	0 (rebus + music)	1	0.56
49	1989	Smith & Blankenship (Experiment 3)	29	2 (rebus)	1	0.5	15	2 (rebus)	1	0.56
50	1989	Smith & Blankenship (Experiment 4)	49	2 (rebus)	1	0.5	5	1 (read story)	0	0
51	1989	Smith & Blankenship (Experiment 4)	49	2 (rebus)	1	0.5	5	2 (math task)	0	0.49
52	1990	Dorfman (Experiment 3)	15	2 (word associate task)	0	0.49	15	2 (number series task)	0	0
53	1990	Dorfman (Experiment 3)	15	2 (word associate task)	0	0.49	5	2 (number series task)	0	1.07
54	1990	Dorfman (Experiment 4)	27	2 (word associate task)	0	0.49	3	2 (number series task)	0	0
55	1990	Dorfman (Experiment 4)	27	2 (word associate task)	0	0.49	8	2 (number series task)	0	0
56	1990	Dorfman (Experiment 4)	26	2 (word associate task)	0	0.49	13	2 (number series task)	0	0
57	1990	Kaplan (Experiment 1)	278	0 (consequences task)	0	2	30	2 (psychometric test battery)	0	0.06
58	1990	Kaplan (Experiment 2)	64	0 (consequences task)	0	2	32	2 (division problem)	0	0.71
59	1990	Kaplan (Experiment 3)	36	0 (consequences task)	0	2	30	2 (lecture)	0	0
60	1990	Kaplan (Experiment 4)	20	0 (consequences task)	0	4.57	28.08	2 (division and insight problem)	0	1.08
61	1991	Smith & Blankenship (Experiment 1)	18	2 (RAT)	1	0.5	5	1 (read science fiction)	0	1.70
62	1991	Smith & Blankenship (Experiment 1)	21	2 (RAT)	0	0.5	5	1 (read science fiction)	0	0.64
63	1991	Smith & Blankenship (Experiment 2)	30	2 (RAT)	0	1	5	1 (read science fiction)	0	0.36
64	1991	Smith & Blankenship (Experiment 2)	30	2 (RAT)	1	1	5	1 (read science fiction)	0	0.72
65	1991	Smith & Blankenship (Experiment 5)	16	2 (RAT)	0	0.5	2	2 (free associations task)	0	0
66	1991	Smith & Blankenship (Experiment 5)	18	2 (RAT)	0	0.5	0.5	2 (free associations task)	0	0
67	1991	Smith & Blankenship (Experiment 5)	17	2 (RAT)	1	0.5	0.5	2 (free associations task)	0	0.99

(*table continues*)

Table (*continued*)

ID No.	Year	Author	Total *N*	Problem type[a]	Presence of misleading cues[b]	Preparation period in minutes	Incubation period in minutes	Incubation task type[c]	Presence of relevant cues[d]	Unbiased effect size
68	1991	Smith & Blankenship (Experiment 5)	18	2 (RAT)	1	0.5	2	2 (free associations task)	0	0.99
69	1992	Goldman et al.	36	2 (anagram)	0	0.25	20	2 (general knowledge questionnaire)	0	0.13
70	1992	Goldman et al.	36	2 (anagram)	0	0.25	1,440	2 (general knowledge questionnaire + free activity)	0	0.66
71	1992	Houtz & Frankel	105	1 (creative writing)	0	10	10	1 (anagram)	0	0.03
72	1997	Torrance-Perks (Experiment 1)	15	2 (word fragment completion)	0	0.5	10	0 (rest + lexical decision test)	0	−0.38
73	1997	Torrance-Perks (Experiment 1)	15	2 (word fragment completion task)	0	0.5	10	0 (rest + lexical decision test)	1	−0.41
74	1997	Torrance-Perks (Experiment 1)	15	2 (word fragment completion)	1	0.5	10	0 (rest + lexical decision test)	0	0.14
75	1997	Torrance-Perks (Experiment 1)	15	2 (word fragment completion)	1	0.5	10	0 (rest + lexical decision test)	1	0.07
76	1997	Torrance-Perks (Experiment 2)	8	1 (candle problem)	0	1	8	2 (memory test: cues presented as one of the stimuli)	1	0.17
77	1997	Torrance-Perks (Experiment 2)	8	1 (candle problem)	0	1	8	2 (memory test)	0	−0.71
78	1997	Torrance-Perks (Experiment 2)	8	1 (radiation problem)	0	5	8	1 (read story: analogy to the problem)	1	0.41
79	1997	Torrance-Perks (Experiment 2)	8	1 (radiation problem)	0	5	8	1 (read unrelated story)	0	0
80	1997	Torrance-Perks (Experiment 2)	8	2 (RAT)	0	1	8	2 (analogy: have the same solution as the unsolved RAT)	1	0.15
81	1997	Torrance-Perks (Experiment 2)	7	2 (RAT)	0	1	8	2 (neutral analogy)	0	0.14
82	1997	Torrance-Perks (Experiment 2)	7	1 (candle problem)	1	1	8	2 (memory test: cue presented a one of the stimuli)	1	0.56
83	1997	Torrance-Perks (Experiment 2)	7	1 (candle problem)	1	1	8	2 (memory test)	0	−0.33
84	1997	Torrance-Perks (Experiment 2)	7	1 (radiation problem)	1	5	8	1 (read story: analogy to the problem)	1	0.52
85	1997	Torrance-Perks (Experiment 2)	7	1 (radiation problem)	1	5	8	1 (read unrelated story)	0	0
86	1997	Torrance-Perks (Experiment 2)	7	2 (RAT)	1	1	8	2 (analogy: have the same solution as the unsolved RAT)	1	0.14
87	1997	Torrance-Perks (Experiment 2)	7	2 (RAT)	1	1	8	2 (neutral analogy)	0	0.28
88	1998	Hansberry (Experiment 2)	32	2 (riddle)	0	1	15	2 (RAT)	0	0.66
89	1998	Hansberry (Experiment 3)	20	2 (RAT)	0	0.5	10	2 (RAT)	0	0.04
90	1998	Hansberry (Experiment 3)	20	2 (RAT)	1	0.5	10	2 (RAT)	0	0.28
91	1999	Henley (Experiment 3.2)[e]	48	2 (anagram)	0	0.25	1,440	1 (free activity)	0	0
92	1999	Henley (Experiment 4)[e]	26	2 (anagram)	0	0.93	1,440	1 (free activity)	0	0
93	1999	Jamieson (Experiment 1)	52	2 (RAT)	0	0.33	5	2 (math problem)	0	0
94	1999	Jamieson (Experiment 2)	52	2 (RAT)	0	0.33	5	2 (math problem)	0	0.10
95	2002	Dodds et al. (Experiment 2)	45	2 (RAT)	0	0.5	0.5	2 (insight problem + make a word task)	2	0.31
96	2002	Dodds et al. (Experiment 2)	45	2 (RAT)	0	0.5	0.5	2 (insight problem + make a word task)	1	−0.14
97	2002	Dodds et al. (Experiment 2)	42	2 (RAT)	0	0.5	0.5	2 (insight problem + make a word task)	0	0.10

(*table continues*)

Table (*continued*)

ID No.	Year	Author	Total *N*	Problem type[a]	Presence of misleading cues[b]	Preparation period in minutes	Incubation period in minutes	Incubation task type[c]	Presence of relevant cues[d]	Unbiased effect size
98	2002	Dodds et al. (Experiment 2)	70	2 (RAT)	0	0.5	0.5	2 (insight problem + drawing test)	0	0
99	2002	Medd & Houtz	15	1 (creative writing)	0	10	10	2 (writing)	1	1.05
100	2002	Medd & Houtz	15	1 (creative writing)	0	10	10	2 (writing)	0	0
101	2003	Seabrook & Dienes[e]	60	2 (anagram)	0	0.25	7	2 (word generation)	1	0.74
102	2004	Both et al.	98	2 (anagram)	0	1.67	6	2 (search letter and answer questionnaire)	0	0.48
103	2004	Both et al.	82	2 (anagram)	0	1.67	6	2 (search letter and answer questionnaire)	0	0.09
104	2004	Penney et al. (Experiment 3)	9	2 (anagram)	0	5.75	30	1 (free activity)	1	0.74
105	2004	Penney et al. (Experiment 3)	9	2 (anagram)	0	5.75	120	1 (free activity)	1	1.05
106	2004	Penney et al. (Experiment 3)	9	2 (anagram)	0	5.75	30	1 (free activity)	0	0.62
107	2004	Penney et al. (Experiment 3)	9	2 (anagram)	0	5.75	120	1 (free activity)	0	0.70
108	2004	Segal	20	1 (insightful mathematic problem)	0	20	4	1 (read paper)	0	1.17
109	2004	Segal	21	1 (insightful mathematic problem)	0	20	12	1 (read paper)	0	1.09
110	2004	Segal	20	1 (insightful mathematic problem)	0	20	4	2 (word puzzle)	0	0.90
111	2004	Segal	23	1 (insightful mathematic problem)	0	20	12	2 (word puzzle)	0	0.57
112	2007	Vul & Pashler (Experiment 1)	14	2 (anagram)	0	1	5	2 (video game)	0	−0.17
113	2007	Vul & Pashler (Experiment 1)	14	2 (anagram)	0	1	5	2 (video game)	0	−0.35
114	2007	Vul & Pashler (Experiment 1)	14	2 (anagram)	0	1	5	2 (video game)	0	0.36
115	2007	Vul & Pashler (Experiment 1)	14	2 (anagram)	0	1	5	2 (video game)	0	0.25
116	2007	Vul & Pashler (Experiment 2)	25	2 (RAT)	0	1	5	2 (video game)	0	0.86
117	2007	Vul & Pashler (Experiment 2)	25	2 (RAT)	1	1	5	2 (video game)	0	−0.14

Note. RAT = remote associates task.
[a]0 = *creative problem*; 1 = *visual problem*; 2 = *linguistic problem*. [b]0 = *no*; 1 = *yes, embedded in problem*. [c]0 = *rest*; 1 = *low cognitive demand task*; 2 = *high cognitive demand task*. [d]0 = *no*; 1 = *yes*. [e]Study had a within-subject design: An individual was in both incubation and control conditions; the weighting formula would not apply to this study, hence, it would be excluded from the regression analyses.

Appendix C

Description of the Regression Model for All Studies—Interactions

The regression model describing the interaction effect of nature of problem and incubation task on the weighted unbiased effect size estimate included the multiplicative terms between nature of problem (visual [*V*], linguistic [*Li*], creative [*C*]) and incubation task (high cognitive demand [*H*], low cognitive demand [*L*], rest [*R*]) as predictors. The regression model is specified as follows:

$$Y_j = \mathbf{a_j X_j} + b_1 Li_j H_j + b_2 Li_j L_j + b_3 Li_j R_j + b_4 V_j H_j + b_5 V_j L_j + b_6 V_j R_j + b_7 C_j H_j + b_8 C_j L_j + b_9 C_j R_j + k_j,$$

where Y_j is the weighted unbiased effect size estimation of the study *j* and $\mathbf{X_j}$ is a vector of other categorical and explanatory variables (misleading cues, cue, preparation period, and incubation period) of that study. $\mathbf{a_j}$ is the corresponding vector of coefficients. b_1 to b_9 are the coefficients of the multiplicative terms, and k_j is the error term. The dummy variables R_j and C_j are eliminated through substituting equations $Li_j + V_j + C_j = 1$ and $R_j + L_j + H_j = 1$ into the model. The transformed regression model is as follows:

$$Y_j = \mathbf{a_j X_j} + (b_3 - b_9)Li_j + (b_6 - b_9)V_j + (b_7 - b_9)H_j + (b_8 - b_9)L_j + (b_1 - b_7 - b_3 + b_9)Li_jH_j + (b_2 - b_8 - b_3 + b_9)Li_jL_j + (b_4 - b_7 - b_6 + b_9)V_jH_j + (b_5 - b_8 - b_6 + b_9)V_jL_j.$$

A regression analysis was carried out to find out the coefficient of each variable in the transformed model. To examine the interaction effect of nature of the problem and incubation task, we compared the difference between coefficients' multiplicative terms in the original model. For example, the coefficients of the compound dummies V_jR_j and C_jR_j were compared to check if an incubation period filled with low cognitive demand tasks would improve performance on visual problems more than on divergent thinking tasks. A comparison between the original and the transformed model indicated that the coefficient of each variable in the transformed model was actually the combination of the coefficients in the original model. The difference in the coefficients between the compound dummies in the original model could be found by reinterpreting the coefficient in the transformed model. Table C1 displays a list of coefficient differences between compound dummies in the original model and the equivalent combination of the coefficients in the transformed model.

Table C1

The Regression Coefficients in the Original and Transformed Regression Models

Coefficient difference between compound dummies in the original regression model	Combination of coefficients in the regression analysis
$Li_jH_j - Li_jR_j$	$Li_jH_j + H_j$
$Li_jL_j - Li_jR_j$	$Li_jL_j + L_j$
$V_jH_j - V_jR_j$	$V_jH_j + H_j$
$V_jL_j - V_jR_j$	$V_jL_j + L_j$
$C_jH_j - C_jR_j$	H_j
$C_jL_j - C_jR_j$	L_j
$V_jH_j - C_jH_j$	$V_jH_j + V_j$
$Li_jH_j - C_jH_j$	$Li_jH_j + Li_j$
$V_jL_j - C_jL_j$	$V_jL_j + V_j$
$Li_jL_j - C_jL_j$	$Li_jL_j + Li_j$
$V_jR_j - C_jR_j$	V_j
$Li_jR_j - C_jR_j$	Li_j

Note. Li = linguistic problem; H = high cognitive demand task; R = rest; L = low cognitive demand task; V = visual problem; C = creative problem; j = study j.

Appendix D

Description of the Regression Model for Studies Excluding Creative Problem

The third regression model describing the interaction effect of nature of problem and incubation task on the weighted unbiased effect size estimate included the multiplicative terms between nature of problem (visual [V], linguistic [Li]) and incubation task (high cognitive demand [H], low cognitive demand [L], rest [R]) as predictors. The regression model is specified as follows:

$$Y_j = \mathbf{a_j X_j} + b_1Li_jH_j + b_2Li_jL_j + b_3Li_jR_j + b_4V_jH_j + b_5V_jL_j + b_6V_jR_j + k_j,$$

where Y_j is the weighted unbiased effect size estimation of the study j, and $\mathbf{X_j}$ is a vector of other categorical and explanatory variables (misleading cues, cue, preparation period, and incubation period) of that study. $\mathbf{a_j}$ is the corresponding vector of coefficients. b_1 to b_9 are the coefficients of the multiplicative terms, and k_j is the error term. The dummy variables Li and R_j were eliminated through substituting equations $Li_j + V_j = 1$ and $R_j + L_j + H_j = 1$ into the model. The transformed regression model is as follows:

$$Y_j = \mathbf{a_j X_j} + (b_6 - b_3)V_j + (b_1 - b_3)H_j + (b_2 - b_3)L_j + (b_3 - b_1 - b_6 + b_4)V_jH_j + (b_5 - b_2 - b_6 + b_3)V_jL_j.$$

A regression analysis was carried out to find out the coefficient of each variable in the transformed model. To examine the

(*Appendixes continue*)

interaction effect of nature of the problem and incubation task, we compared the difference between coefficients' multiplicative terms in the original model. For example, the coefficients of the compound dummy variables V_jR_j and Li_jR_j were compared to check if an incubation period filled with low cognitive demand tasks would improve performance on visual problems more than on linguistic insight tasks. A comparison between the original and the transformed models indicated that the coefficient of each variable in the transformed model was actually the combination of the coefficients in the original model. The difference in the coefficients between the compound dummies in the original model could be found by reinterpreting the coefficient in the transformed model. Table D1 displays a list of coefficient differences between compound dummies in the original model and the equivalent combination of the coefficients in the transformed model.

Table D1

The Regression Coefficients in the Original and Transformed Regression Models

Coefficient difference between compound dummies in the original regression model	Combination of coefficients in the regression analysis
$Li_jH_jj - Li_jR_jj$	H_j
$Li_jL_jj - Li_jR_jj$	L_j
$Li_jL_jj - Li_jH_jj$	$L_j - H_j$
$V_jH_jj - V_jR_jj$	$V_jH_jj + H_j$
$V_jL_jj - V_jR_jj$	$V_jL_jj + L_j$
$V_jL_jj - V_jH_jj$	$V_jL_jj + L_j - V_jH_jj - H_j$
$Li_jH_jj - V_jH_jj$	$V_jH_jj + \mathrm{V}_j$
$Li_jL_jj - V_jL_jj$	$V_jL_jj + \mathrm{V}_j$
$Li_jR_jj - V_jR_jj$	V_j

Note. Li = linguistic problem; H = high cognitive demand task; R = rest; L = low cognitive demand task; V = visual problem; C = creative problem; j = study j.

Received December 11, 2007
Revision received August 13, 2008
Accepted August 14, 2008 ■

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Statement of Ownership, Management, and Circulation
(All Periodicals Publications Except Requester Publications)

1. Publication Title: Psychology Bulletin
2. Publication Number: 9 3 1 - 1 4 0
3. Filing Date: October 2008
4. Issue Frequency: Bimonthly
5. Number of Issues Published Annually: 6
6. Annual Subscription Price: Mbr $96 Indiv $208 Inst $600
7. Complete Mailing Address of Known Office of Publication *(Not printer) (Street, city, county, state, and ZIP+4®)*: 750 First Street, N.E., Washington, D.C. 20002-4242
Contact Person: Barbara Spruill
Telephone *(Include area code)*: 202 336-5578
8. Complete Mailing Address of Headquarters or General Business Office of Publisher *(Not printer)*: 750 First Street, N.E., Washington, D.C. 20002-4242
9. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor *(Do not leave blank)*
Publisher *(Name and complete mailing address)*
American Psychological Association
750 First Street, N.E.
Washington, D.C. 20002-4242
Editor *(Name and complete mailing address)*
Harris M. Cooper
Duke University
Box 90739, Durham, N.C. 27708-0739
Managing Editor *(Name and complete mailing address)*
Susan J.A. Harris
American Psychological Association
750 First Street, N.E., Washington, D.C. 20002-4242
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	Washington, D.C. 20002-4242

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☒ Has Not Changed During Preceding 12 Months
☐ Has Changed During Preceding 12 Months *(Publisher must submit explanation of change with this statement)*

PS Form **3526**, September 2007 *(Page 1 of 3 (Instructions Page 3))* PSN 7530-01-000-9931 **PRIVACY NOTICE:** See our privacy policy on www.usps.com

13. Publication Title: Psychological Bulletin
14. Issue Date for Circulation Data Below: July 2008

15. Extent and Nature of Circulation			Average No. Copies Each Issue During Preceding 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
a. Total Number of Copies *(Net press run)*			3125	3200
b. Paid Circulation *(By Mail and Outside the Mail)*	(1)	Mailed Outside-County Paid Subscriptions Stated on PS Form 3541(Include paid distribution above nominal rate, advertiser's proof copies, and exchange copies)	2149	2262
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c. Total Paid Distribution *(Sum of 15b (1), (2), (3), and (4))*			2756	2897
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e. Total Free or Nominal Rate Distribution *(Sum of 15d (1), (2), (3) and (4))*			221	224
f. Total Distribution *(Sum of 15c and 15e)*			2977	3121
g. Copies not Distributed *(See Instructions to Publishers #4 (page #3))*			148	79
h. Total *(Sum of 15f and g)*			3125	3200
i. Percent Paid *(15c divided by 15f times 100)*			93%	93%

16. Publication of Statement of Ownership
☒ If the publication is a general publication, publication of this statement is required. Will be printed in the January 2009 issue of this publication.
☐ Publication not required.

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Dir. Service Center Operations
Date: 10/6/08

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