Title
Divergent Thinking: Cognitive Predictors and Problem Incubation

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Abstract
Incubation effects have been frequently examined and demonstrated in convergent but not divergent thinking. In the current study, we assessed whether passage comprehension and visual fluid intelligence predict divergent thinking in a verbal consequences test and whether there is an incubation effect upon performance on this test (i.e., greater benefit of extra work on a problem after distracting attention temporarily away from it, compared to a control condition without task interruption). We found that passage comprehension (but not visual fluid intelligence) predicted fluency, originality, and flexibility of divergent thinking. The predictive relationships involving originality and flexibility were mediated by fluency. There was no incubation effect on these measures, contrasting with findings from two peer-reviewed studies that demonstrated an effect of incubation on originality (Fulgosi & Guilford, 1968) and fluency (Fulgosi & Guilford, 1972) of divergent thinking. Future studies are needed to investigate under what conditions divergent thinking benefits from incubation.

Introduction
An incubation effect occurs when a problem solution benefits from an extra work period when the initial and extra period of work are separated by a task phase during which attention is distracted away from the problem (incubation) compared to when the two work periods occur in immediate succession (control).

Paucity of studies: Incubation effects have been frequently examined and often (but not always) demonstrated in convergent (Dodds, Ward, & Smith, 2004) but not divergent thinking (DT). To our knowledge, only two peer-reviewed, published studies have demonstrated an effect of incubation on the originality (Fulgosi & Guilford, 1968) and fluency (Fulgosi & Guilford, 1972) of DT. It is not known whether these effects of incubation are robust or under what specific conditions they occur.
Practical relevance: Intelligence analysts frequently encounter open-ended problems when interpreting texts and other source materials. Coping with this cognitive challenge requires optimal DT for considering not only common but also uncommon solutions that are potentially more relevant. Understanding which at task conditions promote DT and what linguistic and cognitive factors predict it may help to optimize the problem solving performance of these professionals (Haarmann, 2007).

Predictor measures: We reasoned that individual differences in complex verbal processing (e.g., passage comprehension), fluid intelligence (Eysenck, 2003), and creative convergent thinking (Smith & Blankenship, 1991) should predict DT when finding non-obvious solutions to problems posed in written scenarios, particularly solutions that are original, unique, and span a range of semantic categories.

Purpose 1: Test whether there is an incubation effect on DT

Purpose 2: Test whether passage comprehension, fluid intelligence, and creative convergent thinking predict DT

Methods

Participants (two sessions each)

- Intelligence analysts from the U.S. Department of Defense (USG employees, N = 25, 13 female, 23-57 yrs old, average age 39 yrs, average experience as an analyst 8 years)
- Students from the University of Maryland College Park (UMD students, N = 28, 22 female, 22-41 yrs old, average age 25 yrs)

Incubation experiment (Session 1)

Design

Incubation condition: wp1 incubation wp2

Control condition: wp1 wp2

Key: Trial events following presentation of an item on a consequences test (see below for details). wp1 = work period 1 (4 minutes), wp2 = work period 2 (4 minutes), incubation = performing a visual-spatial motor task (i.e., playing the computer game Tetris for 20 minutes).

Condition was manipulated within-subjects. Order of condition was counterbalanced across participants. Items were counterbalanced across condition.
Details of consequences test

**Materials:** four scenarios; matched for difficulty, linguistic, & conceptual structure; two scenarios per condition

**Example scenario:** “A new restaurant is experiencing a problem with serving its many diners in a timely manner. The restaurant is not able to hire sufficient wait staff causing unacceptably long waiting times for the diners. At this time, the new restaurant is unable to easily hire any more waiters. What other options could be available to this new restaurant in order to reduce waiting times for its diners?”

**Instructions:** generate as many useful alternative measures for solving the company’s problem, not involving an obvious solution mentioned in the scenario (e.g., hire more waiters to reduce serving time) and encompassing both common and uncommon (i.e., new and original) answers. Type your answers (answers and RTs were recorded).

**Scoring & Analysis:**

1. **Step 1:** extraction of gists of answers & their superordinate categories (inter-rater agreement averaged across the two participants groups: 96.5%)
2. **Step 2:** computation of dependent variables per participant per cell of design
   - **productivity:** number of distinct gists
   - **flexibility:** number of super-ordinate categories of answers
   - **originality:** average across-subject frequency of a participant’s answers (lower scores indicate higher originality)
   - **uniqueness:** percent of a participant’s answers that that participant (but none of the others) generated
3. **Step 3:** Mixed factor ANOVAs of Condition X Work period X Order on by-subject data plus planned comparisons

**Measures for correlation with consequences test (Session 2)**

**Passage comprehension:** Nelson-Denny reading comprehension test (Brown et al., 1993); materials consisted of passages at an adult education level; 20 minutes duration.

**Fluid intelligence:** Culture fair Intelligence Test (Institute for Personality and Ability Testing, Illinois); visual-spatial materials from Form A Scale 2; 20 minutes duration.

**Standard test of divergent thinking:** Verbal Torrance Test of Creative Thinking (Scholastic Testing Service, Inc, Illinois); materials describe situations requiring alternate solutions (e.g., list ways to improve a toy monkey so that children will have more fun playing with it); the duration of this test was about 45 minutes; scored for fluency, originality, and flexibility by Scholastic Testing Service.

**Creative convergent thinking test:** Remote Associates Test (RAT; Bowden & Jung-Beeman, 2003; Mednick, 1968); materials consisted of 30 triples of three weakly or unrelated stimulus words for which participants were given 30 seconds to generate an answer word that was related to all three stimulus words (e.g., French, Shoe, Car; Answer: Horn); the duration of the test was about 30 minutes; yielded a proportion correct score.
Results

Figure 1. Productivity of divergent thinking in the incubation experiment, as a function of work period and incubation condition, for UMD students and USG employees (WP1 = work period 1, WP2 = work period 2). Error bars indicate one standard error of the mean.
Figure 2. Originality of divergent thinking in the incubation experiment.

Figure 3. Uniqueness of divergent thinking in the incubation experiment.
**Figure 4.** Flexibility of divergent thinking in the incubation experiment.
Table 1. Pearson Correlation Coefficients for all measures for UMD students and USG employees combined (N = 51)

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CT = consequences test, * p < .05, ** p < .01, *** p < .001, ~ p < .1

Table 2. Partial Pearson correlation coefficients controlling for overall CT productivity for UMD students and USG employees combined (N = 51 unless noted)

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Experimental results
USG employees and UMD students (see Figures 1 through 4)
1. did not show an incubation effect on any of the DT measures
2. produced more original and unique solutions during work period 2 than 1 (all \( P<.05 \))

Correlation results
In USG employees and UMD students combined (see Tables 1 and 2)
3. passage comprehension predicted productivity of DT
4. passage comprehension predicted flexibility and originality of DT but not when DT productivity was factored out (Table 6)
5. fluid intelligence did not predict productivity, flexibility, and originality of DT
6. DT, as assessed with a standard test, was a good predictor of DT, as assessed with the experimental consequences task
7. Creative convergent thinking did not predict performance on the two DT tests (but see 8)
In USG employees – but not UMD students –

8. creative convergent thinking predicted flexibility of DT, when productivity of DT was controlled for

9. fluid intelligence predicted uniqueness of DT

Conclusions & future directions

- **Conditions under which incubation facilitates DT remain to be established:**
  Previous published studies report an incubation effect, but the present study did not obtain one. Incubation may help to overcome a focus on dominant ideas and introduce new ideas.

**Therefore, future research should consider the following factors:**
  - degree of mental fixation on ideas generated during the initial work period, as indexed for example by a slowdown in the rate of idea generation
  - forgetting of dominant but unhelpful ideas generated in the initial work period, due to
    - the passage of time (length of incubation period)
    - similarity of the representations evoked by the problem solving & distractor tasks (interference)
  - introduction of alternative ideas during incubation, for example, through priming

- **The distribution of useful creative ideas is not uniform across time and individuals**
  - More original ideas were produced in a second than first work period
  - Individuals who were better at passage comprehension showed more productive DT and, as a result, more flexible and original DT.

- **Creative convergent and divergent thinking may involve different information processing mechanisms**
  - Creative convergent thinking did not predict performance on both DT tasks, which is surprising since both types of thinking could be argued to rely on executive control mechanisms, particularly attentional control and retention in working memory

References


**Acknowledgements**

This material is based upon work supported, in whole or in part, with funding from the United States Government. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the University of Maryland, College Park and/or any agency or entity of the United States Government. We thank Kimberly Platt and Laura Fox for research assistance.