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Verbal Divergent Thinking Facilitated by a Pleasurable Incubation Interval

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Previous studies have uncovered various influencing factors of the incubation effect in creative problem solving. Often, tests of divergent thinking (DT) are used as estimates of the potential for creative problem solving. The impact of emotional state during the incubation interval on subsequent creative performance has not yet been investigated. A within-subject design was used in this study. Participants ($N = 44$) were asked to solve the instances problems (i.e., a verbal DT task) in four conditions (positive, neutral, negative incubation conditions, and a continuous working condition). During the incubation intervals, participants watched a series of emotion-appropriate videos to induce corresponding emotions. The results showed that participants' originality scores were higher after an incubation interval (regardless of the emotions induced) than when continuously working. Originality scores were the highest when positive emotion was induced during the incubation interval. These findings demonstrated that emotional state during the incubation interval influences the incubation effect. The findings are interpreted in the context of the unconscious work theory of incubation. Limitations and future directions are explored.

Keywords: incubation effect, creativity, emotion, divergent thinking, instances task

Divergent thinking (DT) is cognition that leads in various directions (Runco, 1999a). DT is involved in many creative efforts (Kaufman, Plucker, & Baer, 2008). Performance on DT tasks has been demonstrated to be a reliable predictor of creative potential (Runco & Acar, 2012). Many procedures have been proposed to enhance DT and creative thinking. One interesting procedure involves setting the task aside for a while (i.e., allowing an incubation period). The positive effect of the incubation period on later creative performance (e.g., generating highly original answers) is commonly referred to as the incubation effect, and has been demonstrated in many previous studies (Baird et al., 2012; Ellwood, Pallier, Snyder, & Gallate, 2009; Gilhooly, Georgiou, & Devery, 2013; Gilhooly, Georgiou, Garrison, Reston, & Sirota, 2012; Hao, Ku et al., 2014).

Numerous factors have been revealed to influence the incubation effect, such as the cognitive demand that the interpolated task elicits during the incubation interval (Baird et al., 2012; Browne & Cruse, 1988; Elsbach & Hargadon, 2006; Hao, Ku et al., 2014; Segal, 2004), the length of incubation period (Penney, Godsell, Scott, & Balsom, 2004), the presence of relevant or misleading cues during the incubation interval (Dodds, Smith, & Ward, 2002; Kohn & Smith, 2009; Sio & Rudowicz, 2007; Vul & Pashler, 2007), and the dissimilarity or similarity of interpolated and target tasks (Ellwood et al., 2009; Gilhooly et al., 2013). However, no previous study has examined emotional state during the incubation interval as an influencing factor of the incubation effect.

Emotions are mental states arising from personal evaluations of the world, which prompt a readiness to act (Oatley & Jenkins, 1996). The relation between emotion and creativity is currently receiving considerable attention. Although it is under debate whether positive emotions (Fernández-Abascal & Diaz, 2013; Isen, Daubman, & Nowicki, 1987; Isen, Johnson, Mertz, & Robinson, 1985; Stafford, Ng, Moore, & Bard, 2010) or negative emotions (Baas, De Dreu, & Nijstad, 2011; George & Zhou, 2002; Kaufmann & Vosburg, 1997; Van Kleef, Anastasopoulou, & Nijstad, 2010) are more likely to be broadly beneficial for creativity, there is a general consensus that creative cognition is influenced by emotions (see Baas, De Dreu, & Nijstad, 2008; Davis, 2009). Thus, it is reasonable to hypothesize that emotional states during the incubation interval could influence incubation effects in solving DT tasks. The primary question addressed in the present study was whether and how different emotions (i.e., positive, neutral, or negative) during the incubation interval influence subsequent DT performance.

Possible Effects of Emotions in the Incubation Interval

No previous study has explored the effects of emotions during the incubation interval on later creative performance. Several

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predictions for this question might be proposed, based on various theories accounting for the incubation effect.

According to the Explicit–Implicit Interaction (EII) model of creative thinking (Hélie & Sun, 2010), incubation involves unconscious implicit associative processes that demand little attentional capacity, unlike conscious, explicit, and rule-governed processes. The *unconscious work theory* of the incubation effect (Dijksterhuis & Meurs, 2006; Gilhooly et al., 2013; Gilhooly et al., 2012) suggests that activation of nodes in semantic networks during an incubation interval could automatically spread to remote but relevant nodes, thereby positively affecting creative cognition. Previous studies have revealed that positive emotion serves as a cue to safety and elicits an exploratory orientation (Schwarz, 1990, 2002), which may in turn promote the automatic spread of semantic activation from an activated concept to related associations and recruit comparatively inaccessible information from long-term memory (Ashby, Isen, & Turken, 1999; Friedman & Förster, 2010; Rotteveel & Phaf, 2007; Storbeck & Clore, 2008; Topolinski & Deutsch, 2012). From this perspective, it would be predicted that an incubation interval with positive emotion would produce a larger incubation effect in solving DT problems than an interval with neutral or negative emotion.

The *beneficial forgetting theory* of the incubation effect (Penaloza & Calvillo, 2012; Smith & Blankenship, 1991) suggests that old ideas and sets weaken in the incubation interval because of forgetting, thus allowing a fresh view of the problem when efforts are resumed. Negative emotions (especially sadness and depression) have been found to be frequently associated with difficulties in recalling old information. This is because, according to the cognitive-effort account of depressive deficits in memory (Ellis & Ashbrook, 1988; Hasher & Zacks, 1979; Hertel & Rude, 1991; Roy-Byrne, Weingartner, Bierer, Thompson, & Post, 1986), negative emotion (relative to neutral or positive emotion) reduces or uses a larger portion of the limited capacity of conscious attention and lowers the attentional resources necessary for recalling information. If this is accurate, an incubation interval with negative emotion would be associated with a larger incubation effect than an interval with positive or neutral emotion. That is, after a negative emotional incubation interval, old ideas or sets are less likely to be recalled, and a fresh start is facilitated.

It must be pointed out that there is an alternative prediction for the effects of negative emotion in the incubation interval. The dual pathway to creativity model (De Dreu, Baas, & Nijstad, 2008; Nijstad, De Dreu, Rietzschel, & Baas, 2010) suggests that negative emotion enhance persistence and perseverance in performing creativity task. This implies that negative emotion during the incubation interval would elicit more perseveration in working on target DT problems than positive or neutral emotion. As a result, participants would be less likely to forget the old ideas or sets during the negative emotional incubation interval, which, based on the beneficial forgetting theory, would impair later creative performance. If this is the case, an incubation interval with negative emotion would be associated with a smaller incubation effect than an interval with positive or neutral emotion.

The *fatigue recovery theory* of the incubation effect suggests that the incubation interval is a cognitive respite period that allows reduction of mental fatigue and the rejuvenation of problem-solving skills (Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995). This theory predicts that different emotions might exert similar impacts on the incubation effect if the effects of mental effort during the incubation interval are controlled or excluded.

The *intermittent conscious work theory* of the incubation effect proposes that people might actually do conscious work during the incubation interval, at least off and on; thus, performance would be improved when the target problem is readdressed (Browne & Cruse, 1988; Seifert et al., 1995; Weisberg, 2006). This theory predicts that emotions during the incubation interval would be ineffective on later creative performance.

The Present Study

In the present study, the *delayed-incubation paradigm* (Gilhooly et al., 2012) was utilized to assess the effects of emotions during the incubation interval on DT performance. Participants were asked to solve a series of DT problems in positive, neutral, and negative incubation conditions, as well as in a continuous working (control) condition. Participants' performance among these four conditions was then compared. Moods, defined as stable affective experiences that are usually weakly tied to external situations (Forgeard, 2011), have been found to influence creative cognition (Fernández-Abascal & Diaz, 2013; Newton, 2013), as has enjoyment of the experimental tasks (Zenasni & Lubart, 2011). For this reason, participants' mood and enjoyment of the experimental task were measured prior to and after the main experiment. This allowed an assessment of whether mood and enjoyment had any impact on incubation effects.

Competing hypotheses would be proposed based on various theories of the incubation effect. The unconscious work theory predicts better DT performance in the positive emotional incubation condition, relative to the neutral and negative conditions. The beneficial forgetting theory predicts that DT performance in the negative condition would be better (on the basis of the cognitive-effort account of depressive deficits in memory) or worse (on the basis of the dual pathway to creativity model) than in the neutral and positive conditions. The fatigue recovery and the intermittent conscious work theories predict no effect of emotion in the incubation interval on DT performance. Moreover, the DT performance in three incubation conditions (no matter what emotions are induced) would be better than that in the control condition, given that a large number of studies have demonstrated that a break benefits creative cognition much more than dose continuously working (see Sio & Ormerod, 2009).

Method

Participants

The recruitment message about the experiment was posted on the most popular social networking site (i.e., RenRen) among Chinese college students, as well on the public notice boards in the campus. Forty-four healthy undergraduates (25 females; age: M = 20 years old, SD = 1.41, Range: 17–23 years old) were recruited from the East China Normal University. The recorded individual information showed that they majored in various academic disciplines (e.g., psychology, literature, biology, education, etc.). Participants were asked to solve verbal DT problems in three incubation conditions and one control condition. They gave written informed consent before the experiment, and received about 6.5

USD for their participation after the experiment. As a check on whether these participants actually engaged in performing the interpolated tasks during incubation intervals, 40 other undergraduates (22 females; age: M = 20.89, SD = 1.76) were recruited to work on the same interpolated tasks without being in the context of incubation. Their performance on the interpolated tasks was used as the data of comparison sample (see details in Assessment of Intermittent Conscious Work). They received 2.5 USD for their participation. The protocol of the experiment was approved by the Institutional Ethics Committee at East China Normal University.

Experimental Task

The instances task (Wallach & Kogan, 1965) was used as the target task. This task requires respondents to generate as many examples as possible from a common category, such as "list as many things as you can that move on wheels." The instances is a well-established DT task and has been widely used in a number of studies on DT (see Kaufman et al., 2008; Runco, 1999a; Runco & Mraz, 1992; Runco & Okuda, 1991). To construct a battery of instances problems that were used in current experiment, we presented 60 categories (e.g., things that can burn, things that can transfer information, things that can hurt people, etc.) to 10 graduate students. They were asked to generate as many examples as possible from a category in 3 min; then the 40 categories (tasks) within which the students generated the most ideas were chosen. Thus, 40 instances problems were available in this study.

Experimental Procedure

A within-subject design was used in this study. A participant was presented with a total of 40 different instances problems. Each individual solved 10 problems (10 trials) in each of the four blocks (i.e., positive, neutral, negative, and control; see Figure 1). The sequences of blocks were balanced for all participants following a Latin square design. The 40 instances problems were randomly arranged into each of the four blocks for every participant. Participants were allowed to rest for 1 min between each pair of blocks. In the instruction about how to solve the instances problem, participants were encouraged to try their best to produce ideas that would be thought of by no one else, as suggested by Harrington (1975), Runco (1999a), and Torrance (1995).

In the positive, neutral, or negative block, the duration of solving an instances problem (or a trial) was 95 s (see Figure 1). Specifically, the participant was first asked to (mentally) generate ideas of examples for an item presented on the computer screen for 10 s, with no overt response allowed. In the next 30 s, he or she was asked to watch a video to induce the corresponding emotion. Then, the participant self-rated the valence and arousal levels of his or her momentary emotional state during a 10-s interval (see details in emotion inductions) and answered a four-choice question about the content of the video (e.g., "what color was the car that had the accident?") in another 10 s. Afterward, he or she resumed (mentally) working on the same instances problem for 20 s, and then orally reported as many ideas as possible in 10 s. Because participant gave responses in a comparatively short period of 10 s, reporting ideas orally seems better than writing ideas down, for the later is a little time-consuming. The oral reporting of ideas was widely used in previous studies on DT (Fink et al., 2009; Fink et al., 2010; Friedman & Förster, 2002; Hao, Yuan, Hu, & Grabner, 2014). Moreover, "mental generation" and the data based on such method have been demonstrated to be sensitive to different experimental conditions (Benedek, Beaty, et al., 2014; Benedek, Schickel, Jauk, Fink, & Neubauer, 2014; Fink et al., 2012; Shah et al., 2013). In the control block, the participant worked continuously on an in-

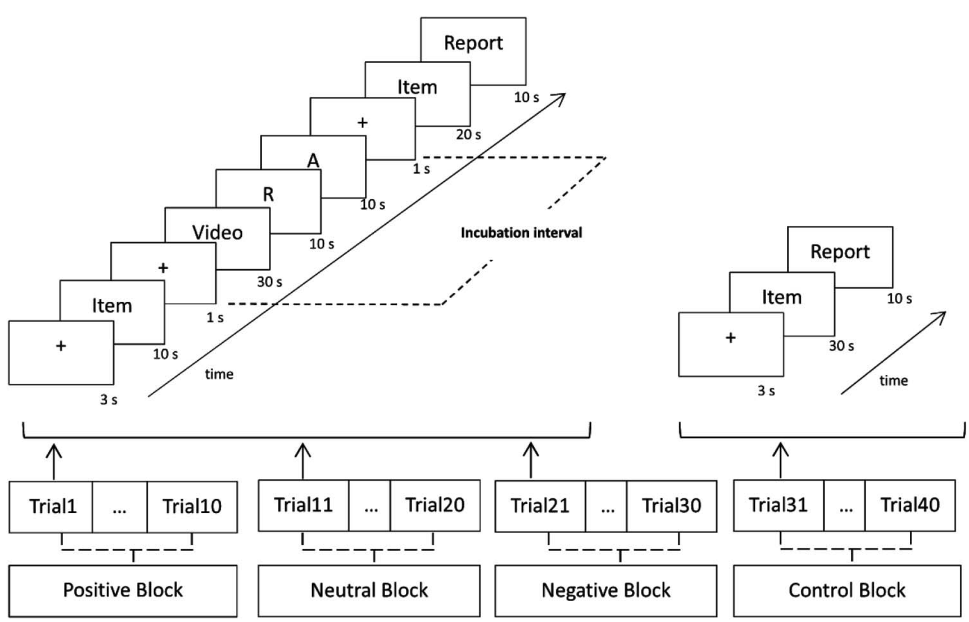

Figure 1. Illustration of the experimental paradigm. A participant was asked to solve 40 different instances problems, with 10 problems (10 trials) in each of the four blocks. + = the fixation; Item = an instances problem; R = rate valence and arousal of emotional state; and A = answer question about video content.

stances problem for 30 s without an incubation interval, and then reported as many ideas as possible in 10 s (see Figure 1). Note that the participant was allotted a period of 30 s to work on each instances problem in each of the four conditions (i.e., positive, neutral, negative, and control). The entire experiment lasted for approximately 70 min.

Participants' oral responses for the instances problems were recorded by a voice recorder, and afterward transcribed by the experimenter using pencil and paper for further analysis.

Emotion Inductions

During the incubation interval in each trial of the positive, neutral, or negative block (see Figure 1), the participant was asked to watch a short emotion-appropriate video to induce a corresponding emotion, as in previous studies (Forgas & East, 2008; Forgeard, 2011; Phillips, Bull, Adams, & Fraser, 2002; Rottenberg, Ray, & Gross, 2006). Three groups of video clips (10 clips per group, 30 s per clip) were excerpted from comedy, tragic, and instructional movies (e.g., fix the refrigerator), respectively. The 10 videos in a group were randomly assigned to the incubation intervals of the 10 trials in the corresponding block for every participant. Immediately after the end of the video, the participant was asked to self-rate the valence and arousal levels of his or her emotional state by means of the Self-Assessment Manikin (SAM; Bradley & Lang, 1994), in which the participant selected one of nine ratings (valence: 1 = very pleasant, 9 = very unpleasant; arousal: 1 = very exciting, 9 = not exciting at all) illustrated by five cartoon figures and the points between any two figures.

Pre- and Postexperimental Tests

Prior to the experiment, participants' mood was measured by the item "How do you feel right now?" on a scale ranging from 1 (*very bad*) to 9 (*very good*; see Friedman & Förster, 2000, 2002). Immediately after finishing the experiment, the technique of self-reported mental effort ratings (Ayres, 2006; DeLeeuw & Mayer, 2008; Paas & Vanmerrienboer, 1993) was used to measure the participants' mental efforts during the incubation intervals. That is, participants were asked to rate the levels of mental efforts when performing the interpolated tasks (i.e., watching the video, self-rating emotions, and answering the question) during each of the positive, neutral, and negative blocks, using a 9-point scale ranging from 1 (*extremely low*) to 9 (*extremely high*). Enjoyment of the experimental task was measured by asking: "How did you like the experiment task?" using a scale from 1 (*not in the least*) to 9 (*very much*), as in previous studies (Friedman & Förster, 2000, 2002).

Assessment of Intermittent Conscious Work During the Incubation Interval

Any conscious work on the target problem during the incubation interval could impair participants' performance on the interpolated task. For this reason, as a check against the possibility of intermittent conscious work, participants' performance on the interpolated task during the incubation interval should be compared with that of a comparison group working on the same interpolated task, when not in an incubation condition. If there is no difference, it indicates participants have no conscious work on the target problems (Gilhooly et al., 2012). Therefore, 1 week after this experiment, 40 other undergraduates (no overlap with the participants in current experiment) were recruited as a comparison group. They were asked simply to watch videos, self-rate valence and arousal levels, and answer the same questions about video contents. The accuracy of their answers to the content questions was then compared with that of the participants in current experiment.

Assessment of Performance on Instances Problems

Participants' performances on instances problems were measured by fluency and uniqueness scores. Fluency scores were indicated by the total number of ideas listed per instances problem (Guilford, 1967; Runco, 1991, 1999a). Uniqueness scores were assigned for statistically unique responses (Runco, 1991, 1999a; Wallach & Kogan, 1965). Specifically, the ideas of all participants generated for a given instances problem were first collected into a comprehensive lexicon. Synonyms were identified, and ideas collapsed accordingly. If a response was literally unique (i.e., if only one person in the sample gave the response), then it was given a score of 1. All other responses received 0, regardless of how often they appeared. Thus, the fluency and uniqueness scores in solving an instances problem were easily counted for each participant. Then, the fluency or uniqueness scores for the solutions to 10 instances problems in each block were averaged for every participant. Finally, for each participant, four mean fluency scores and four mean uniqueness scores (i.e., in the four experimental conditions) were available. These scores were used to explore the effects of condition on creative performance.

As a second means for testing the hypotheses, a subjective scoring method for assessing originality was also used, following the procedures outlined in previous studies (see De Dreu, Nijstad, Baas, Wolsink, & Roskes, 2012; Gilhooly et al., 2013; Gilhooly et al., 2012; Hocevar, 1979). Six trained raters (graduate students) independently evaluated the originality of each idea reported by the participants on a 5-point Likert scale from 1 (*not original at all*) to 5 (*highly original*). They were blind to the purpose and experimental design (or condition) of the current study. Internal consistency of the ratings (Cronbach's alpha coefficient = .86) was satisfactory. The ratings of each idea by 6 raters were averaged to provide an originality rating for this idea. To correct for possible differences in fluency, the ratings across ideas were averaged to provide an originality score for solving the given instances problem. Finally, the mean originality scores of the 10 instances problems in each block were calculated for every participant.

Results

Manipulation Check for Clarity

First, it was necessary to check whether the 10 videos in each block induced similar valence and arousal levels. The internal consistency of the valence across the 10 trials was satisfactory for each of the positive, neutral, and negative blocks (Cronbach's alpha coefficient was .81, .80, and .85, respectively), as was internal consistency of the induced arousal levels (alpha was .82, .82, and .83, respectively). Furthermore, the valence levels across the 10 trials showed no difference respectively for positive, neutral, or negative blocks (three separate analyses of variance, ANOVAs, for repeated measures, p values $>.05$; post hoc Tukey's tests, p values $>.05$), as did the arousal levels across the 10 trials in each of three blocks (three ANOVAs, p values $>.05$; post hoc Tukey's tests, p values $>.05$). These results indicate that the 10 videos arranged in the 10 trials of each block did induce similar valence and arousal levels.

Second, it was important to check whether watching emotion-appropriate videos did induce the corresponding emotions. The valence levels for the 10 trials in each block were first averaged for every participant, and then an ANOVA for repeated measures was performed, with condition (positive, neutral, and negative) as the within-subject factor. The results revealed a significant effect of condition, $F(2, 86) = 285.89$, $p < .001$, $\eta_p^2 = .87$ (see Table 1). Post hoc Tukey's tests found that valence levels were significantly different between the three conditions, p values $< .001$. To further test whether the induced emotions were positive, neutral, or negative, the valence levels in the three conditions were respectively compared with the median (i.e., 5) of the valence range, from 1 (*very pleasant*) to 9 (*very unpleasant*). Three separate one-sample t tests (relative to the test value of 5) revealed that the valence levels induced by watching positive or negative videos were significantly lower or higher than the median, $t(43) = -15.14$, $p < .001$ and $t(43) = 13.98$, $p < .001$, while the valence levels induced by watching neutral videos were not different from the median, $t(43) = -.91$, $p > .05$. These results indicate that watching videos during the incubation intervals did actually induce positive, neutral, and negative emotions.

Another ANOVA for repeated measures on arousal levels also revealed a significant effect of condition, $F(2, 86) = 118.97$, $p < .001$, $\eta_p^2 = .74$ (see Table 1). The induced arousal levels differed significantly between the three conditions (post hoc Tukey's tests, p values $< .001$). These results indicate that the induced positive, neutral, and negative emotions were associated with different arousal levels.

Consistency of Task Performance Across Trials in Each Block

The internal consistency (Cronbach's alpha coefficient) of the fluency scores over 10 trials was .93, .91, .92, and .92, in the positive, neutral, negative, and control blocks, respectively. Similar levels of consistency were found for the uniqueness scores (i.e., .84, .82, .85, and .81, respectively) and the originality scores (i.e., .86, .84, .85, and .86, respectively). These results indicate that participants' performance showed consistency across trials in each block. To further test whether there was any carryover effect between blocks, the fluency, uniqueness, or originality scores for the 10 trials of each block were first averaged for every participant. Then three separate ANOVAs for repeated measures, with block order (1, 2, 3, and 4) as the within-subject factor, were performed on participants' mean fluency, uniqueness, or originality scores (three ANOVAs, p values $>.05$; post hoc Tukey's tests, p values $>.05$). The results indicate that the presented order of blocks did not influence any of these scores, and there was no carryover effect between blocks.

Table 1
Levels of Valence and Arousal of Emotional States, Levels of Mental Effort, Accuracy of Answers to the Content Questions in Three Blocks (M ± SD), and the Results of ANOVAs

	Positive	Neutral	Negative	F	η_p^2
Valence	3.04 ± .86	4.92 ± .59	6.95 ± .92	285.89***	.87
Arousal	5.32 ± 1.65	8.27 ± .73	4.43 ± 1.98	118.97***	.74
Mental effort	2.57 ± 1.04	2.43 ± .93	2.45 ± 1.04	.37	.01
Accuracy	.76 ± .11	.75 ± .10	.75 ± .13	.25	.01

*** $p < .001$.

Task Performance in the Incubation and Control Conditions

The uniqueness scores showed significantly positive correlation with the originality scores, $r = .39$, $p < .001$, which indicates that the objective and subjective scoring methods yielded relatively consistent results in assessing the creativity of DT performance. Yet, the fluency scores had no correlation with the uniqueness scores, $r = .07$, $p > .05$, or the originality scores, $r = .09$, $p > .05$. These may be because a comparatively short response period (i.e., 10 s) limited the number of reported ideas, which resulted in similar fluency scores across conditions. Thus, three separate ANOVAs for repeated measures, with condition (positive, neutral, negative, and control) as the within-subject factor, were conducted on the fluency, uniqueness, and originality scores.

The results revealed no significant effect of condition on the fluency scores, $F(3, 129) = 2.46$, $p > .05$, $\eta_p^2 = .05$ (see Table 2). However, there showed a significant effect of condition on the uniqueness scores, $F(3, 129) = 30.05$, $p < .001$, $\eta_p^2 = .41$ (see Table 2). Post hoc Tukey's tests revealed that the uniqueness scores in the positive condition were significantly higher than those in the neutral, negative, and control conditions, $p < .01$, $p < .001$, $p < .001$, respectively. Also, the uniqueness scores in the control condition were significantly lower than those in the neutral and negative conditions, $p < .01$ and $p < .05$. However, the uniqueness scores in the neutral and negative conditions did not differ significantly, $p > .05$.

Moreover, condition significantly affected the originality scores, $F(3, 129) = 30.93$, $p < .001$, $\eta_p^2 = .42$ (see Table 2). Post hoc Turkey tests revealed that the originality scores in the positive condition were significantly higher than those in the neutral, negative, and control conditions, $p < .01$, $p < .01$, $p < .001$, respectively. Moreover, the originality scores in the control condition were lower than those in the neutral and negative condition, p values $< .01$, while originality scores in the neutral and negative conditions did not differ significantly, $p > .05$.

Mental Efforts During the Incubation Intervals

An ANOVA for repeated measures revealed that the self-rated effortfulness of engagement in interpolated tasks showed no difference among the positive, neutral, and negative conditions, $F(2, 86) = .37$, $p > .05$, $\eta_p^2 = .01$ (see Table 1). This result provides evidence that the incubation effects observed in the current study were not confounded by the effects of mental effort during the incubation interval.

Table 2
Fluency, Uniqueness, Originality Scores on the Instances Task Under the Four Conditions (M ± SD), and the Results of ANOVAs

	Positive	Neutral	Negative	Control	F	η_p^2
Fluency	4.01 ± .57	3.98 ± .65	3.87 ± .69	3.80 ± .57	2.46	.05
Uniqueness	1.66 ± .22	1.52 ± .18	1.50 ± .18	1.39 ± .13	30.05***	.41
Originality	2.76 ± .48	2.42 ± .48	2.37 ± .53	1.98 ± .49	30.93***	.42

*** $p < .001$.

Intermittent Conscious Work During the Incubation Intervals

The accuracy of answers to the video contents in each block was first calculated for every participant. An ANOVA for repeated measures revealed no difference in accuracy among the positive, neutral, and negative conditions, $F(2, 86) = .25$, $p > .05$, $\eta_p^2 = .01$ (see Table 1). Moreover, participants' average accuracy to the content questions ($M = .76$, $SD = .08$) across the three conditions was not different from that ($M = .78$, $SD = .09$) of the comparison group, $t(82) = 1.63$, $p = .11$. These results indicate that participants in the current experiment were engaged in the interpolated tasks, and the observed incubation effects could not result from intermittent conscious work on the target problems during the incubation intervals.

Effects of Covariates on Task Performance

Three separate analyses of covariance (ANCOVAs) for repeated measures, with condition as the within-subject factor, and mood and enjoyment of the experimental task as covariates, were conducted on the fluency, uniqueness, and originality scores. The results revealed that neither of these two factors diminished the effects of condition on the fluency, uniqueness, or originality scores.

Effects of Emotional Valence and Arousal on Task Performance

As shown in Table 1, the emotional valence levels were different in three incubation intervals, as were the arousal levels. To examine the relationship of valence and task performance when arousal was statistically controlled, linear regressions were conducted with valence and arousal levels as predictors and task performance as the independent variable. The regression with uniqueness score as the independent variable, $R^2_{adj} = .1$, $F = 8.13$, $p < .001$, revealed that valence was a significant predictor, $\beta = -.34$, $p < .001$, but arousal was not, $\beta = -.09$, $p = .29$ (see Table 3). Another regression with originality score as the independent variable, $R^2_{adj} = .07$, $F = 5.57$, $p < .01$, also found that valence was a significant predictor, $\beta = -.29$, $p < .01$, unlike arousal level, $\beta = -.06$, $p = .53$ (see Table 3). These results indicate that it was the valence rather than arousal of the induced emotions during the incubation interval that influenced the originality of instances performance.

Discussion

The present study explored the effects of different emotions (i.e., positive, neutral, and negative) during the incubation interval on verbal DT performance. The results revealed that positive emotion in the incubation interval was associated with higher originality of instances performance, relative to neutral or negative emotion. Also, an incubation interval (no matter what emotions were induced) helped people be more original in solving instances problems than when continuously working. This study demonstrated, for the first time, that emotional state during the incubation interval could be an effective influencing factor of the incubation effect.

These findings provide evidence in favor of the unconscious work theory of incubation. Positive emotion is often interpreted as a cue, signaling safety that elicits an exploratory orientation (Schwarz, 1990, 2002), thereby stimulating activation in semantic networks to automatically spread to remote but relevant nodes (Ashby et al., 1999; Friedman & Förster, 2010; Rotteveel & Phaf, 2007; Storbeck & Clore, 2008). The findings of the current study could be interpreted to mean that an induced positive emotion during the incubation interval may facilitate remote associative processes, which in turn, on the basis of the unconscious work theory, have a positive impact on subsequent creative performance. Such an explanation was supported by a recent empirical study (Topolinski & Deutsch, 2012), which showed that very brief variations in emotion, lasting for only a few seconds and even

Table 3
Predictions of Valance and Arousal Levels to the Uniqueness and Originality Scores

	Uniqueness score				Originality score			
Predictors	R^2_{adj}	B	β	T	R^2_{adj}	B	β	T
Valance level		−.04	−.34	−4.01***		−.08	−.29	−3.37**
Arousal level		−.01	−.09	−1.07		−.01	−.06	−.64
	.10				.07			

** $p < .01$. *** $p < .001$.

changing from trial to trial within a participant, are sufficient to influence the breadth of semantic spread.

The beneficial forgetting theory of incubation suggests that old ideas or sets weaken during the incubation interval because of forgetting, and then a fresh start is facilitated. Conceivably, when people work on the instances problem, they may become set on some particular categories of examples and generate less unusual ideas. Thus people need an incubation to "forget" those sets. In this case, an incubation interval with negative emotions would have a more beneficial influence, given that negative emotions were found to be associated with more difficulties in recalling old information (Ellis & Ashbrook, 1988; Hasher & Zacks, 1979; Hertel & Rude, 1991; Roy-Byrne et al., 1986). Yet, the results deviated from this prediction (see Table 2). Furthermore, the current results were not in line with the alternative prediction for the effects of negative emotion. That is, the dual pathway to creativity model (De Dreu et al., 2008; Nijstad et al., 2010) suggests negative emotion enhance participants' persistence in working on DT problems, thus participants may be less likely to forget the sets during the negative interval, which, based on the beneficial forgetting theory, would impair subsequent DT performance. However, the originality of DT performance in the negative condition was not found to be different from that in the neutral condition (see Table 2). Taken together, our findings do not lend support to the beneficial forgetting theory of incubation.

The intermittent conscious work theory of incubation predicts no difference of DT performance between the three conditions. Obviously, the current results differ from this prediction. Moreover, it must be kept in mind that any conscious work on the target problem during the incubation interval could impair performance on the interpolated task (Gilhooly et al., 2012). The results revealed that participants' performance on the interpolated task (i.e., accuracy of answers to the content questions) showed no difference between three blocks (see Table 1). Also, participants' average accuracy to the content questions was not different from that of the comparison group. These findings indicate that the better DT performance in the positive condition cannot be attributed to intermittent conscious work on the target problems during the incubation intervals.

The findings refute the fatigue recovery theory of incubation, given that this theory suggests no difference of DT performance between the three conditions. In addition, the incubation intervals in three blocks were self-rated by participants as equally effortful (see Table 1). This indicates that the larger incubation effects observed in the positive condition cannot be interpreted by a better fatigue recovery during the incubation interval.

The originality of DT performance was higher after an incubation interval (regardless of the emotions induced) than when continuously working (see Table 2). This result was consistent with previous findings (see Sio & Ormerod, 2009). A possible explanation is that spread of activation through the semantic network happens during the incubation interval (Baird et al., 2012; Hao, Ku et al., 2014). As a result, an incubation interval benefited originality of DT performance, with a larger incubation effect emerging in the positive condition, for more remote spread activation is promoted by the induced positive emotion (Friedman & Förster, 2010; Topolinski & Deutsch, 2012). Therefore, these findings are also in accord with the unconscious work theory of incubation.

A noteworthy finding is that emotions during the incubation interval had no impact on the fluency scores (see Table 2). This appears to be inconsistent with previous findings that participants in a positive emotion are more fluent with ideas and generate more responses than those in a neutral or negative emotion (Hirt, Melton, McDonald, & Harackiewicz, 1996; Vosburg, 1998). However, this may be because participants were asked to report ideas in a comparatively short time period (i.e., 10 s), which limited the number of ideas being reported, and resulted in similar fluency scores in four conditions. This explanation is consistent with previous research on the impact of time on DT (Mednick, 1962; Runco, 1999b). In addition, the results revealed that neither the mood nor enjoyment of the experiment task diminished the effects of condition on DT performance. These results indicate that people's emotions in the incubation interval may influence DT performance irrespective of their mood or enjoyment of the experimental task.

There are four limitations to this study. First, a comparatively short period of oral reporting (i.e., 10 s) might limit the number of ideas reported, which may obscure the possible effects of emotions during the incubation interval on fluency of DT performance. Similarly, only about four ideas were generated when solving an instances problem (see Table 2), so it is impossible to assess flexibility of DT performance. In further research, participants could be given more time to report ideas, thus enabling an opportunity to test the effects of emotions during the incubation interval on fluency and flexibility scores. Second, the forgetting mechanism of incubation was indirectly investigated based on experimental manipulation, as in previous studies (Kohn & Smith, 2009; Penaloza & Calvillo, 2012; Segal, 2004; Sio & Rudowicz, 2007; Vul & Pashler, 2007). We propose that a direct way to test the "forgetting theory" of incubation could be to measure the "sets" in preincubation session, and then check whether incubations release the sets. However, it is difficult to empirically measure sets when solving DT tasks. Perhaps the "flexibility"—the number and/or uniqueness of categories of responses to a given stimuli—could be used as an indicator of sets, but this claim has not be clearly stated in previous studies. Further research is necessary to address this issue. Third, the emotion induced via watching a video has somewhat limited generalizability. The emotions induced by real-life events may have longer-term and different effects than those induced by videos. Further research could adopt various ways (e.g., olfactory stimuli, music, imagination, computer game, casual game, etc.) to induce emotions in the incubation interval. Fourth, the results on verbal DT performance (i.e., the instances problem) cannot be generalized to the domain of visual creativity (e.g., the nine-dot problem), since any difference between visual and verbal problems may arise from a greater reliance on strategic search rather than activation of knowledge in visual problems (see Sio & Ormerod, 2009).

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