EFFECTS OF COGNITIVE DEMAND AND EMOTION

ON THE INCUBATION EFFECT IN DYADS

by

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ABSTRACT

The incubation effect describes the phenomenon of performance improvement after being away from a hard task for some time. Though much research has been done, the mechanism(s) underlying this effect was unclear yet, together with a lack of studies in groups. The current study examined the incubation effect in a group context using dyads and explored the effects of cognitive demand of interpolated task and emotions on the incubation effect, in hope of deepening understanding of possible mechanisms of the incubation effect. Four experiments were conducted: Experiments 1-3 manipulated cognitive demand of interpolated task and Experiment 4 manipulated emotions during incubation. Three divergent thinking tasks were employed: Experiments 1 and 4 employed alternative uses task, Experiment 2 employed instances task and Experiment 3 employed consequences task. Participants in each trial worked together with their partner on a creativity task, then worked on the designated interpolated task, then came back and worked on the same creativity task again, except in no-incubation condition where they worked on the creativity task continuously.

The results showed trends that fit the incubation effect in Experiments 2 and 3, but no significant effect of cognitive demand of interpolated task or emotions during incubation was found on the proposed group incubation effect. Possible reasons might come from the setup of cognitive demand levels and emotion conditions, or the relatively weak nature of the incubation effect. Future studies on the group incubation effect should carefully set conditions and explore more group sizes for the generalizability concern.

LIST OF ABBREVIATIONS AND SYMBOLS

df Degrees of freedom: number of values free to vary after certain restrictions have been placed on the data

F Fisher's F ratio: A ration of two variances

t T ratio: Measures the size of the difference relative to the variation of in your sample data

M Mean: the sum of a set of measurements divided by the number of measurements in the set

SD Standard deviation: the measure of how dispersed data is in relation to the mean

N Sample size: the number of samples

p Probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value

r Pearson product-moment correlation

t Computed value of t test

η_p^2 Effect size

$<$ Less than

$=$ Equal to

H1 Hypothesis one

H2 Hypothesis two

H3 Hypothesis three

RQ1 Research Question one

RQ2 Research Question two

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INTRODUCTION

Creativity has been viewed as one of the most important drives of individuals, organizations, and the society. In research, creativity is generally treated as the ability to generate both new (novelty, originality, unexpectedness, etc.) and useful (appropriateness, effectiveness) ideas or products (Runco & Jaeger, 2012; Sternberg & Lubart, 1996). Because of its importance, how to enhance creativity (or creative performance) has become a hot topic of research. One of the most widely accepted way to promote creative performance is to take a break from the task. There are many anecdotal examples from famous people of their problem-solving success after setting aside the task for some time (Csikszentmihalyi, 1997; Schooler & Melcher, 1995). This beneficial effect of taking a break was later proposed as the incubation effect by Wallas in his 4-stage creativity model (Wallas, 1926). Since then, this effect has been widely examined and is well established, at least with individuals, and with certain tasks (Gilhooly et al., 2012; Smith & Blankenship, 1991; Yaniv & Meyer, 1987). Experimentally, the incubation effect is established when creative performance is higher after taking a break compared to not taking a break.

The Incubation Effect

There is an interesting phenomenon in our daily life: when we get stuck by a difficult problem, leave it and do something else, then come back, the problem can usually be solved. This performance improvement after a break from the original task is called the incubation effect. Many famous anecdotal examples are said to be associated with the effect, such as Kekule and his Benzene ring, Archimedes and the buoyancy law, and many others (Csikszentmihalyi, 1997; Schooler & Melcher, 1995).

The concept of the incubation effect was first proposed by American psychologist Wallas (1926) in his 4-stage creativity model. In this model, the four stages are preparation, incubation, illumination and verification. (1) In the preparation period, problem solvers represent the problem, search a knowledge source and their memory for the solution, or use reasoning to solve the problem. In this period, if answers are found, then the problem-solving process ends. If problem solvers fail to find the answers, they get into a fixation or mindset, and then move on to the incubation period. (2) In the incubation period, problem solvers shift their attention away from the problem. (3) In the illumination period, problem solvers finally "know" the answer, or we can say answers suddenly "appear" in problem solvers' mind. (4) In the verification period, problem solvers verify whether the answer that "appeared" in their mind is correct. After finishing this step, the whole creative problem-solving process ends. Wallas (1926) provided relatively clear explanations of preparation, illumination, and verification periods; however, only for the incubation period, no satisfactory explanation was given. Thus, many researchers have worked on exploring the underlying mechanism of the incubation effect (Baird et al., 2012; Gilhooly et al., 2012; Gilhooly et al., 2007; Gilhooly et al., 2013; Hao et al., 2014; Mednick et al., 1964).

Although not all research results agree, it has been shown that 75% of creative problem-solving studies found the incubation effect in at least one of their experiments (Ellwood et al., 2009). A meta-analysis (Sio & Ormerod, 2009) included 117 studies of the incubation effect, and found that the average effect size is between low to medium (mean d = .32) when taking into account both insight problems and divergent thinking problems. However, if only divergent thinking problems are taken into account, the average effect size increases significantly (mean d = .65), which is between medium and high. So, the incubation effect has been well confirmed.

Study paradigms

There are two main paradigms when study the incubation effect: the delayed incubation and the immediate incubation. The delayed incubation paradigm is most widely used. In this paradigm, participants in the experimental group work on the target task (stage 1), an interpolated task (incubation period), and target task again (stage 2) successively. Participants in the control group work on the target task for two stages successively, without an incubation period. The total time working on the target task is the same for the control group and the experimental group. Then participants' creative performance in the two groups is compared. The creative performance can be whether they solve the problems, the number of ideas they generate, the rated creativity of their solutions, and so on. Many previous studies found that the creative performance of the experimental group on stage 2 is higher than that of their partners in the control group, thus providing evidence supporting the incubation effect (Mednick et al., 1964; Murray & Denny, 1969).

The immediate incubation paradigm is a relatively newer paradigm. In this paradigm, participants in the experimental group first get the target task question presented to them, then instead of working on the target task, they directly start the interpolated task (incubation period), and then work on the target task (stage 2), so there's not a stage 1 working on target task as in the delayed incubation paradigm. Therefore, this paradigm is called the "immediate" paradigm, as after being presented the target task question, participants immediately enter the incubation period. Participants in the control group directly work on the target task after the target task question presented, with no incubation period for them. The total time participants have on the target task is the same for the two groups. Then, participants' creative performance is compared. Similar results were obtained, showing that participants in the experimental group show higher creativity than those in the control group (Dijksterhuis & Meurs, 2006; Gilhooly et al., 2013). Some researchers also compared the delayed and immediate incubation paradigms, and the results showed that the incubation effect triggered by the immediate incubation paradigm is larger than that of the delayed paradigm (Gilhooly et al., 2013). However, given the relatively small number of studies in this area, it is still inconclusive which paradigm is better.

In their 2002 study, Dodds, Smith and Ward used a different paradigm. Participants worked on a certain number of problems successively. Under different conditions, there were or weren't other tasks, corresponding to the experimental condition and the control condition respectively. However, the results were not consistent with their hypotheses across all experiments within the study, and they failed to find the incubation effect in some conditions. As this is the only study that used this paradigm, whether this is an effective paradigm still needs to be verified in future research.

Frequently used tasks

Based on the different roles they play, there are 2 types of tasks in incubation effect studies: target tasks and interpolated tasks. Target tasks are tasks for which that participants need to find the solution and are mostly creative tasks. Interpolated tasks are tasks that participants work on during the incubation period, which draw participants' attention away from the target task. Interpolated tasks can be creative or non-creative tasks and are usually different from the target task in some aspect.

Most target tasks are either divergent or convergent thinking tasks. In convergent thinking (CT) tasks, a single answer is pursued, while, in divergent thinking (DT) tasks, various answers are required. Two of the most commonly used convergent thinking tasks are the remote association task (RAT) (Dijksterhuis & Meurs, 2006; Mednick, 1962) and insight problems. In the RAT, experimenters show participants several semantically unrelated words and ask them to think of one word that can be combined with each of the presented words and still make sense. For example, for cottage, blue, and mouse, the answer is cheese; and for Chinese characters 月(moon), 铁(iron) and 煎(fry), the answer is 饼(pancake) (Sio & Rudowicz, 2007).

In an insight problem, there's only one answer and the answer is relatively unusual, so it is hard for problem solvers to find. Participants need to re-represent or re-construct the problem to find the answer; this problem-solving process is usually characterized by the "Aha!" phenomenon, like riddles and rebuses (Smith & Blankenship, 1989). A famous insight problem is the "Duncker candle problem": participants are given several pins, a box of matches and a candle, and their task is to set the candle on the wall (Ritter & Ferguson, 2017). In this problem, participants need to jump out of the mindset that the match box is only a container to hold matches and realize that it can also be used as a platform. Thus, pinning the match box on the wall and putting the candle on it can solve the problem. The "farm problem" is another famous insight problem (Browne & Cruse, 1988; Olton & Johnson, 1976). Participants need to divide a polygon farm into 4 same-sized pieces. The task requires no professional knowledge, rather participants need to use a new angle of view which cannot be easily transferred from previous trainings. There are also other insight tasks such as the insightful mathematic puzzle (Segal, 2004), word puzzles/riddles (Hao et al., 2014) and verbal insight problems (Nielsen et al., 2008).

One of the most widely used divergent thinking tasks is the alternative uses task (AU). In this task, participants need to think of different unusual uses for common everyday items, such as "brick" and "pencil" (Gilhooly et al., 2012; Gilhooly et al., 2007). Another frequently used divergent thinking task is the instances task. Participants think of instances of an attribute; for example: list as many things that are blue as you can think of (Nielsen et al., 2008). The consequences task is also frequently used by researchers (Silvia, 2011). Participants are required to think of as many creative consequences as they can for a hypothetical event. For example: what would happen if people no longer needed to sleep?

Besides the tasks talked about above, some other tasks are also used in incubation effect studies. They include idea generation tasks, and creative writing task (Medd & Houtz, 2002), and the anagram task, improvisation task, and creative spatial mental synthesis task (Gilhooly et al., 2012).

Interpolated tasks are not necessarily creative tasks, as the main function of them is to draw participants' attention away from target tasks. Thus, given different study purposes and designs, various tasks have been employed, such as working memory tasks (e.g., n-back task, Stroop task, go/no-go task, etc.). Creative tasks different from target tasks of the same study are also used, such as the various divergent thinking and convergent thinking tasks introduced above. Other tasks include the anagram task (Gilhooly et al., 2013), arithmetic task, word stem completion task (Penney et al., 2004), cross-word puzzle task (Segal, 2004) and figure tracking task (Dijksterhuis & Meurs, 2006). Sometimes interpolated tasks can be really simple, such as listening to music, reading newspapers, resting quietly, and so on.

Influencing factors

Many factors have been found to have an effect on the incubation effect. Sio and Ormerod made a brief summary of these factors in their 2009 meta-analysis (Sio & Ormerod, 2009). However, results from different studies don't all agree with each other. Some main factors are introduced below.

Time-related factors. At the very beginning, researchers thought that the longer the incubation period was, the bigger the incubation effect would be. Those who held this view believed that, the longer the incubation period, the more time participants have for solving the problem or forgetting wrong information (mindset), generating more activation or being exposed to more external stimuli, and getting better rest. Some early results supported these ideas (Smith & Blankenship, 1989), showing that participants' performance after incubation was better when they incubated for 15 minutes compared to 5 minutes. However, in Segal's (2004) study, participants performed poorer when they incubated for longer times (3 hours or 24 hours) than when they incubated for shorter time (15 minutes). A possible explanation for the inconsistent results is that the relationship between the incubation effect and the duration of the incubation period might not be linear — there might be a relatively ideal duration for the incubation period. If it is shorter or longer than the ideal duration, it may jeopardize the effect; this ideal incubation duration might be different for different types of creative tasks.

Some researchers believe that the time duration of the preparation period (i.e., stage 1) and the incubation period should be taken into consideration together. That is, it is not the duration of the incubation period that matters, but the ratio of the preparation period and the duration of the incubation period; the bigger this ratio, the larger the incubation effect (Kaplan, 1993). However, in Sio and Ormerod's (2009) meta-analysis study, they failed to find a significant relationship between this ratio and the incubation effect. Instead, the results showed that the preparation duration significantly influenced the incubation effect: the longer the preparation period, the bigger the incubation effect.

Besides the durations of different periods and/or their ratio, affording choice as to when to start the incubation may also influence the incubation effect. Some researchers allowed their participants to decide how long stage 1 is themselves instead of giving them a fixed preparation duration and forcing them to start the incubation. In these studies, a significant incubation effect was obtained (Penney et al., 2004; Segal, 2004).

Task-related factors. Tasks can also influence the incubation effect; for example, the type of target tasks employed, and the cognitive demand of the interpolated task.

When working on insight problems, problem solvers need to jump out of their mindsets and reconstruct the problem; however, when working on verbal divergent thinking tasks, activating more various concepts is beneficial. In Sio and Ormerod's (2009) study, when working on verbal reasoning or visual insight tasks, participants looked for knowledge and strategies stored in memory and in the external environment. According to the authors, in this process, the task-related information may have already been activated, but represented in a wrong way, thus a reconstruction of the problem is needed. Under this situation, having an incubation period is not necessarily associated with whether the reconstruction happens — there's not a guarantee for the incubation effect. Similarly, there is not a clear association between the length of the incubation period and the incubation effect when working on these tasks. For verbal divergent thinking tasks, however, activating more various concepts helps improving the performance. Having an incubation period allows time for ideas to be activated; having a longer incubation period provides more time for this activation to happen compared to a shorter incubation period. Thus, a longer incubation period gives participants more time to activate vast ideas. Hence, the incubation effect can be expected when working on divergent thinking tasks.

What participants do during the incubation period also plays an important role. In the incubation effect, among the many properties of the interpolated task, its cognitive demand seems to be important. Some typically high demanding tasks include mental rotation, visual memory and various working memory tasks. While frequently used low demanding tasks include reading newspapers, watching videos, etc.

Some researchers found that working on high cognitive demanding tasks during the incubation period is more beneficial to the problem-solving process compared to low demanding tasks (Patrick, 1986; Segal, 2004). For example, Segal (2004) employed a visual insight puzzle as the target task and employed a crossword puzzle and scanning newspapers as interpolated tasks for demanding and nondemanding conditions respectively. The results showed that more participants solved the insight puzzle in demanding condition (i.e., crossword puzzle) than in nondemanding condition (i.e., scanning newspaper). However, other researchers found the opposite results — low demanding interpolated tasks improved later target task performance compared to high demanding tasks (Smith & Blankenship, 1989). Baird and his colleagues examined the incubation effect in four conditions: low demand (i.e., 0-back), high demand (i.e., 1-back), rest, and no break. They found the highest incubation effect in the low demand condition compared to other conditions (Baird et al., 2012). These authors argued that the higher incubation effect came from more mind wandering during the incubation period in the low demand condition. Mind wandering is associated with divergent thinking and thus is likely beneficial to creative problem solving. In the meta-analysis described earlier, Sio and Ormerod (2009) found an interaction between the target task type and the cognitive demand level of the interpolated tasks. For verbal target tasks, low demand interpolated tasks were more beneficial to the incubation effect. For visual-spatial target tasks, no difference between low demand and high demand conditions was found.

Other factors. Some other factors were also examined in previous studies. Task-related cues are one of these factors. They can be further divided into helpful cues and misleading cues.

Previous literature has shown that participants provided with helpful cues during the incubation period have a larger incubation effect. For example, participants who received primes (i.e., helpful cues) during the incubation period thought of more ideas in stage 2 compared to non-primed group (Penney et al., 2004). In addition, participants had more correct answers on primed RAT questions compared to nonprime questions (Mednick et al., 1964). Christensen and Schunn (2005) also found that participants' target task performance in stage 2 significantly improved after analogical clues were provided during the incubation period. They concluded that analogical clues during the incubation period were an effective way to trigger the incubation effect. However, Olton and Johnson (1976) failed to find the incubation effect under a clue condition in which visual analogies to the solution of the target task were presented. The inconsistent results bring up the necessity of further research.

Smith and Blankenship (1989) employed a modified RAT as their target task, in which a misleading word (printed in italic) was added into some problems to trigger participants' fixation on wrong answers. Their results showed that there was a bigger incubation effect on RAT questions with misleading words compared to those without misleading words (Smith & Blankenship, 1989). These researchers argued that the fixation (or mindset) triggered by these misleading words faded during the incubation period, thus improving the later performance. However, more research is still needed to explore the effect of misleading information on the incubation effect.

Some researchers are curious about the influence of participants' status (being awake or sleeping) on the incubation effect. In one study, participants were required to either think about a focal problem or simply relax either prior to sleep or after waking up, or do nothing. The results showed that participants who thought about the problem prior to sleep showed less stress when facing problems, a higher likelihood of solving problems, higher performance on focus problems, and less anxiety or depression after a 10-day period than those who did nothing (White & Taytroe, 2003). However, these researchers failed to obtain consistent results in their second experiment. In another study, participants who had rapid eye movements (REM) during dream incubation had higher RAT performance improvement than those without REM and those without sleep (quiet rest) (Cai et al., 2009). But these researchers thought that it was the REM, instead of the sleep itself, that benefited the incubation effect. Thus, further exploration is needed to examine whether participants' status effectively influenced the incubation effect.

Alcoholic use is another potential factor for the incubation effect. One study found that, compared with a control no-drink group and a placebo non-alcoholic drink group, the alcoholic use group showed a larger incubation effect, and higher creativity overall (Norlander & Gustafson, 1996).

Theoretical hypotheses

The underlying mechanism of the incubation effect is always a focus of various studies. However, given many inconsistent results, a general conclusion has not been achieved yet. Multiple theoretical hypotheses have been proposed by different researchers, among them several most popular ones are introduced here.

Selective forgetting theory. The selective forgetting theory is also called beneficial forgetting or forgetting-fixation theory (Smith & Blankenship, 1989, 1991). Opposite to the spreading activation theory, instead of increasing the activation, the selective forgetting theory claims that during the incubation, the activation of irrelevant concepts and wrong ideas attenuates. These irrelevant concepts and wrong ideas activated or generated in stage 1 blocks the problem-solving process. After the incubation, these unhelpful concepts and ideas get deactivated, and problem solvers can have a fresh view and reconsider the problem, thus increasing the likelihood of solving the problem.

A highly similar theory is the set breaking theory (Kaplan, 1993; Woodworth et al., 1954). It claims that during the incubation period, mindsets due to wrong strategies and unhelpful information break up. Thus, after incubation, problem solvers have the opportunity to reconstruct the problem.

Unconscious processing theory. In Wallas's (1926) description of the incubation effect, he described the incubation process as a process without individual active thinking. He believed that the incubation effect comes from unconscious processing. The unconscious processing theory claims that, during the incubation period, working on the target task does not stop, but continues unconsciously. In this case, the target task performance after incubation would get more promoted when the interpolated task is totally different from the target task, as the 2 tasks use different cognitive sources. Supporting evidence were obtained in various studies (Dijksterhuis & Meurs, 2006; Gilhooly et al., 2013). More detail will be discussed in later sections.

Attention withdrawal/shifting theory. Researchers who support this theory believe that, during incubation, individual's attention doesn't focus on the target task, so the activation of target-task-related information fades, including wrong assumptions generated during the preparation period. Then after incubation, when participants return to the original problem, the problem-related information in their minds are in a status that they can be perceived but not perceived yet. Then participants can reuse them to reconstruct the problem, form correct assumptions, and finally solve the problem (Segal, 2004).

Fatigue dissipation theory. Although the fatigue dissipation theory was explained in detail in 1995 (Seifert et al., 1995), its origin can be tracked back to scientist Helmholz in 19th century, who believed that the break only gave participants an opportunity to rest. Following researchers further explain that the incubation period gives problem solvers an opportunity to accumulate energy and recover from the fatigue, so they can spend more effort on the target task after incubation. However, some researchers pointed out a problem of the theory, stating that the supposed neural activation during the incubation period may also lead to neurons' fatigue (Ellwood et al., 2009).

Intermittent conscious working theory. Although the incubation process has been viewed as an unconscious process, the intermittent conscious working theory assumes that there is still some intermittent conscious working (Seifert et al., 1995). It is this conscious working that leads to the improvement of target task performance on stage 2. Based on this theory, the conscious working on the target task during the incubation period will use some cognitive resources, thus cognitive resources available to the interpolated task processing become less, so the performance of the interpolated task during the incubation period would be poorer compared to simply working on the interpolated task itself.

However, previous studies failed to obtain supporting evidence. Participants' performance on 2 interpolated tasks, anagram and mental rotation, was no worse than their performance on these 2 tasks without being in an incubation condition (Gilhooly et al., 2013). In another study, the researchers asked participants to work on AU trials; they were probed while they worked to indicate what they were thinking about. The results showed that participants did have conscious thoughts related to the target task, but these thoughts were irrelevant to the target task performance (Baird et al., 2012).

Spreading activation theory. According to the spreading activation theory (Yaniv & Meyer, 1987), the incubation effect is due to spreading activation. During incubation, semantic activation spreads within a concept network; the more the activation spreads, the more concepts get activated. These activated concepts become more accessible to problem solvers and finally benefits creative problem solving. The spreading activation happens unconsciously (Anderson, 1983; Gilhooly, 2016).

Various studies have provided evidence for this theory. For example, Sio and Rudowicz (2007) had participants attempt to solve RAT items. The results showed that even though participants failed to solve some items, those in incubation condition recognized the solutions to these items quicker than those in no-incubation condition. The authors believed that this increased sensitivity came from spreading activation during the incubation period. However, inconsistent results were also obtained. In Dodds et al. (2002), a bigger incubation effect was found only when participants were reminded to pay attention to clues. When there was no specific instruction, the incubation effect was not boosted (Dodds et al., 2002). The authors believed that these results undermined the spreading activation theory. If spreading activation happens automatically (unconsciously), no matter there’s specific instruction on clues or not, the spreading activation should happen and thus the incubation effect should have benefited.

The Incubation Effect in a Group Context

With the rise of globalization and collaboration among different organizations, there is a rising need for productive working groups in both education and industry, for which high creativity is one of the expectations. Thus, it is logical to wonder whether the same techniques employed to enhance individual creativity could also be applied in a group creativity context. If the incubation effect applies with groups, it would be one of the easiest enhancements to adopt for problem solving. However, the research in this area is very little. The few studies that employed the incubation paradigm with groups are not informative enough. For example, in Coskun (2005), although incubation was induced for dyads, the study lacked a control condition (no incubation), so there is no way to tell whether an incubation effect happened. The same problem applies to the study conducted by Smith and her colleagues, in which 3-person groups were used (Smith et al., 2010). Some other studies did include a control condition, but one study only measured the influence of expert and group satisfaction and did not provide performance data (Ziller & Behringer, 1959). Another study only compared performance after the incubation period (Kirkwood, 1984; Ziller & Behringer, 1959), but did not report whether performance was the same for the incubation vs. no-incubation conditions before the incubation period. So, these results again make it impossible to verify the incubation effect.

Given the inconsistency of previous research, we do not know for sure whether an incubation effect happens in a group context. However, we think there is a good possibility that an incubation effect could be found in a group context. Though we mentioned earlier that some previous studies did not include a control condition while employing the incubation paradigm in groups, creativity performance increase from before to after incubation was found. This builds up the foundation of a possible incubation effect. Also, when groups go through the incubation paradigm, each individual member in groups also experience the incubation paradigm. Given the stable incubation effect found in individual participants, each member in groups should manifest an incubation effect. Thus, the incubation effect from each group member could converge into an overall incubation effect, which is the incubation effect in group context that we propose. However, an incubation effect might not be found in a group context. Possible reasons come from 2 aspects. First, in a group setting, many more factors may come into effect and impede the incubation effect from happening. For example, evaluation apprehension (Camacho & Paulus, 1995), social loafing (Diehl & Stroebe, 1987), or tending to converge on similar answers (Paul & Brown; Larey & Paulus, 1999). Second, given the lack of sufficient research, we do not know what a proper group setting is within which an incubation effect would happen. For example, size of groups, the group member diversity, the time frame of incubation paradigm and so on. With both the promising side and the uncertainty, we are interested in examining the incubation effect in a group context.

Cognitive Demand and Unconscious Processing

Consciousness refers to a state of being aware of our thoughts, feelings, and sensations, and of our environment and objects in it. In contrast, unconsciousness refers to a state of not being aware of our thoughts, sensations, or feelings; however, one cannot say that they do not affect us. In other words, unconscious thoughts may influence our conscious perceptions or behaviors. According to the unconscious thought theory (UTT), it is possible for unconscious thoughts about the creativity task to continue even though they are not relevant to the current task (i.e., the interpolated task), and therefore an incubation period enhances creativity compared to not having an incubation period.

Early research on conscious vs. unconscious thought assumed that conscious thought was part of a limited-capacity cognitive system, whereas unconscious thought was not (Dijksterhuis & Nordgren, 2006). More recently, research has shown that conscious and unconscious thinking are both constrained by similar factors, including limited cognitive resources (Dijksterhuis & Strick, 2016). Actually, there are findings showing that conscious and unconscious thinking processes are not fully independent of each other. On the contrary, are interactive (Evans, 2006; Kahneman & Frederick, 2002; Reber, 1993). Recent research has shown that conscious perception and unconscious processing are not different in terms of their time course (Peremen & Lamy, 2014). Hence, taken together the limited capacity and the non-independent relationship of the two thinking types, it is reasonable to presume that both types of processes rely on the same pool of basic cognitive resources.

On this premise, attending to different processes (e.g., tasks) simultaneously may cause information overload and hamper one or both of the processes (Kahneman, 1973). That is, working on two different tasks may lead to decreased performance on one or both tasks. Further, this capacity overload will happen whether we are consciously aware or unaware of these processes. In other words, unconscious thinking processes can be hindered if conscious thinking processes at the same time take up too much cognitive resources.

There is very little creativity research that tests conscious vs. unconscious process, there is some research on decision making. In the decision-making literature, a typical procedure is to present participants with a complex set of information about different products (e.g., cars), about which they need to make the best choice. Participants either report their choice immediately after the instruction, or first work on a different task then report their choice, or first deliberately think about the options then report their choice (Abadie, Villejoubert, et al., 2013; Bos et al., 2008; Dijksterhuis, 2004; McMahon et al., 2011). Results of these studies found that participants in the distraction-task condition chose the best option more frequently than in other conditions. The authors assumed that any condition with a distraction task involved only unconscious thinking about the decision, without further explanation. In contrast, the deliberate thinking condition involved conscious thinking (only) without further explanation.

However, this is not exactly the case in research on the incubation effect. From the definition of incubation, we know that the incubation period is the duration of time where we are away from the original target task (and usually do something else). Based on UTT researchers' standard, it should be called the unconscious thinking period. But incubation effect researchers have different opinions about what happens during the incubation period and they do not fully exclude conscious processes. Though it's hard to decide what specific processing, conscious, unconscious, or both, is responsible for the incubation effect, given the shared cognitive resources pool of consciousness and unconsciousness, the leftover cognitive resources available for the target task is easy to manipulate. The easier the interpolated task is (i.e., the lower cognitive demand the interpolated task requires), the more leftover cognitive resources there will be, vice versa. Thus, instead of trying to distinguish between conscious and unconscious processing during incubation, the leftover cognitive resources could be manipulated through varying the cognitive demand level of the interpolated task.

Emotional Valence and Cognitive Processes

As mentioned earlier, spreading activation is one of the most prevalent explanations of the cognitive processes that occur during incubation (e.g., Yaniv & Meyer, 1987). Spreading activation theory provides both a structural basis for memory and a mechanism for accessing information in memory (Anderson, 1983; Collins & Loftus, 1975; Yaniv & Meyer, 1987). As summarized by Roskos-Ewoldsen & Roskos-Ewoldsen (2009), the theory posits that (1) information is stored in memory as nodes; each node represents a unique concept; (2) nodes are connected by associative pathways; nodes of related concepts are more strongly connected--metaphorically, closer together--than nodes of weakly related or unrelated concepts; (3) each node has an activation threshold; if energy from outside the memory system (the environment) or inside the memory system (from other nodes) exceeds the threshold, the node is activated (available to consciousness) and its energy spreads to other nearby nodes; (4) in turn, when these nearby nodes activate, their energy spreads to other nearby nodes, and so on; and (5) spreading activation takes time, such that spreading activation between strongly related nodes takes less time than between weakly related nodes.

Unfortunately, researchers have not directly tested whether spreading activation is the process underlying the incubation effect for divergent thinking tasks. Instead, researchers have tested the spreading activation hypothesis using a convergent thinking task, or they tested the effects of emotion on other types of tasks that may be related to divergent thinking. Most of these studies did not use an incubation paradigm. One study that specifically tested the spreading activation hypothesis during incubation used a creativity task, the Remote Associates Task (RAT), which measures convergent thinking (Sio & Rudowicz, 2007). As a reminder, a RAT item includes three words that are unrelated to one another (e.g., cream, skate, water), but each one is related to a fourth word (ice). The researchers used a lexical decision task (LDT) as a measure of spreading activation. The LDT task is simple: participants see a word (the prime), which they can ignore, then see a string of letters (the target); their task is to decide whether the string of letters is a word or not. When the prime and target are related (e.g., nurse, doctor), the distance between nodes is short (i.e., the association is strong), whereas when the prime and target are not related (e.g., butter, doctor), the distance between nodes is longer (i.e., the association is weak). As a result, responses to the target are faster when the prime is related to the target compared to when it is not.

In Sio and Rudowicz's (2007) study, the solution is only weakly related to the prime words and activation would take more time compared to when they were strongly related. On each trial, participants first attempted to complete a RAT item, then they completed the LDT either immediately after the RAT (no incubation) or after an incubation period. The LDT had six items comprising the solution to the RAT item, irrelevant words, and nonwords. The results showed that, for unsolved RATs, participants in the incubation condition reacted faster to the solution in the LDT compared to participants in the immediate condition. The authors concluded that this increased sensitivity to solutions after incubation came from spreading activation during the incubation period.

Using a lexical decision task is not useful as a measure of spreading activation when using divergent thinking tasks, however. This is because there are no fixed solutions for a divergent thinking task, as there are in a convergent thinking task (e.g., RAT). Thus, in current study, we present a different way to test whether spreading activation occurs during incubation: we manipulated emotional valence during incubation to enhance or inhibit spreading activation.

Emotional valence and cognitive tasks

Previous research using cognitive judgments has provided evidence that emotion affects the quality of a person's judgment. Bolte and her colleagues examined the influence of emotion on implicit judgments of semantic coherence (Bolte et al., 2003). Positive or negative emotions were induced by asking participants to recall either happy (positive-emotion) or sad (negative-emotion) episodes in their life (Experiment 2); a neutral-emotion group received no manipulation (Experiment 1). Two types of stimulus triads were presented: coherent triads, which had three words all weakly associated with a common fourth word (i.e., the solution), and incoherent triads, which had three words not associated with a common solution word. Participants were asked to make a judgment on semantic coherence for each triad. The comprehensive results (Experiments 1 & 2) showed that participants with positive emotions were significantly better at discriminating coherent and incoherent triads than participants with neutral emotions, while participants with negative emotions were significantly worse than participants with neutral emotion. These researchers interpreted their results in term of spreading activation: positive emotions promoted the activation of widespread associative networks, thus facilitating intuitive coherence judgments, whereas negative emotions restricted the spread of activation, thus remote associates were not activated sufficiently to make correct coherence judgments.

Research using other cognitive tasks found similar results. In one study, participants were asked to rate the extent to which an exemplar belonged to a given category. There were three excellent exemplars, three moderately good exemplars and three poor exemplars for each category. Results showed that positive-mood participants (induced either by a free gift or by watching a comedy film clip) rated more poor exemplars as category members compared to either the no-manipulation control group or the neutral-mood group (Isen & Daubman, 1984). In another experiment of the same study, participants were asked to divide 14 color chips into as many or as few categories as they wanted. Results showed that the positive mood group generated fewer but broader categories than the other two groups. These authors concluded that their results indicated that people in positive moods see more relatedness and interconnections among concepts.

In another study, participants were asked to report the first associated word in their mind to each stimulus word after different emotions were induced by using a list of words with different emotional valences (positive, neutral, negative) (Isen et al., 1985). The results showed that positive-mood participants reported more unusual associates to stimulus words than neutral-mood participants. In the second experiment of the same study, they found similar results: participants in whom a positive mood was induced reported more unusual associates than those in whom a neutral mood was induced. In addition, they found that neutral-mood participants made more unusual and diverse associates to positive stimulus words than to neutral stimulus words. The authors concluded that positive emotion resulted in an increased breadth of concepts, increased perception of relatedness, and a broader range of associates.

Emotional valence and creativity tasks

Research about the influence of emotion on creativity adds more evidence that emotion affects cognitive performance and is more relevant to the current study. Vosburg examined the influence of participants' emotions upon arrival on performance of divergent thinking tasks (i.e., problem finding and problem solving) (Vosburg, 1998). Vosberg categorized participants into positive and negative groups. For the positive emotion group, the results revealed a positive relationship between extent of positive emotion and divergent thinking performance. For the negative emotion group, the results showed a negative relationship between extent of negative emotion and divergent thinking performance. Overall, participants with positive emotions produced more answers to the divergent thinking tasks than those with negative emotions. However, given the correlational nature of the study, no cause-effect conclusion can be made about the relationship between emotions and divergent thinking task performance.

Yamada and Nagai's (2015) study examined the influence of positive emotion on creative thinking. Participants were induced with either positive or neutral emotions by listening to different materials: happy music or a reading of the Japanese constitution. Next, participants were presented with five examples of different names for rice, all ending with the same suffix, and then given one minute to generate other names for rice. Their answers were categorized as either divergent answers (i.e., names not ending with the same suffix as in example answers) or convergent answers (i.e., names ending with the suffix of example answers). The authors found that the positive group generated more divergent answers than the neutral group, but there was no difference between two groups on the number of convergent answers. Though this research is encouraging for our study, it does not include a negative emotion group, nor does it have an incubation period.

Ritter and Ferguson (2017) also employed music as their emotion induction and tested divergent and convergent thinking. Participants either listened to calm (positive valence, low arousal), happy (positive valence, high arousal), sad (negative valence, low arousal), or anxious (negative valence, high arousal) music or no music (control) while working on one divergent thinking task (i.e., AUT) and three convergent thinking tasks (e.g., Creative Insight Task). The results revealed a significant difference in performance on the divergent thinking task between the happy and control conditions, with a higher score for participants listening to happy music. No other significant differences were obtained. The authors concluded that valence had a larger effect on performance than arousal. However, the data analysis was a one-way ANOVA, making it impossible to look for possible main effects. In any case, positive emotion was linked to better performance than both neutral emotion (control) and negative emotion, with no difference in performance between the control and negative emotion conditions. Like Yamada and Nagai's (2015) study, this study did not use an incubation paradigm.

Emotional valence and group creativity

Though there are a limited number of studies on group creativity, previous studies have revealed similar effects of emotions on creativity. In one study, participants working in triads were instructed to imagine either a positive or a neutral scenario, inducing emotional valence, and then to think of ways to improve student life quality in their university (Grawitch et al., 2003). The positive emotion participants generated more unique answers compared to the neutral emotion participants. Similarly, another study also employed triads and imagery tasks as the positive, negative, and neutral emotion inductions (Grawitch et al., 2003). Participants were required to design a hotel on the surface of the moon and their performance was assessed based on four criteria (aesthetic appeal, number of airholes, durability, and height), which were combined to form an overall measure of creative performance. Results revealed that the positive emotion groups had significantly higher creative performance than the neutral or negative emotion groups. There were no significant performance differences between the neutral and negative emotion groups. However, as this study employed unconventional creativity indices, it requires caution when interpreting the results.

Incubation and Divergent Thinking Tasks

Various tasks have been employed as creativity tasks in previous studies. These tasks can be divided into 2 broad categories: divergent thinking tasks (e.g., alternative uses task, AUT) (Gilhooly et al., 2012) and convergent thinking tasks (e.g., remote association task, RAT) (Dijksterhuis & Meurs, 2006). Some researchers may further divide convergent thinking tasks into 2 sub-categories, as verbal tasks (e.g., rebuses) (Smith & Blankenship, 1989) and visual tasks (e.g., farm problem) (Browne & Cruse, 1988), but this further division is beyond the scope of current study. Incubation effects have been found in studies employing both categories of tasks (Medd & Houtz, 2002; Mednick, 1962; Olton & Johnson, 1976; Segal, 2004). However, research has shown that there is a higher likelihood for divergent thinking (DT) tasks to benefit from an incubation period relative to other tasks (Sio & Ormerod, 2009).

There are various divergent thinking tasks used in creativity research, such as the titles task, the similarities task, and the alternative uses task. These tasks are similar in that they all involve generating as many different answers as possible within a given amount of time. In the titles task, participants are required to think of titles for different things such as a paragraph story, a movie, and a book (Runco et al., 2016). In the similarities task, participants are required to think of similarities between different objects, such as a pair of words or two everyday objects (Runco et al., 2016). In the alternative uses task, participants are required to think of new uses for common everyday items, such as a brick or a knife (Silvia, 2011).

However, divergent thinking tasks are not fully equivalent. One study examined the reliability of subjective creativity ratings across three divergent thinking tasks (Silvia, 2011). Three trained, independent coders rated participants' responses from the alternate uses task, instances task, and consequences task, using a scale ranging from 1 (not at all creative) to 5 (very creative). The results revealed a substantial difference in interrater reliability across tasks, with the alternate uses task having the highest reliability among the raters. The instances task had intermediate reliability and the consequences task had the lowest reliability.

Another study that included seven divergent thinking tasks found that some tasks (i.e., titles, realistic problem generation) were better at eliciting unique responses than others (e.g., instances task, realistic presented problems) (Runco et al., 2016). In addition, the alternative uses task had lower inter-item reliability compared to the other tasks.

These findings inform us that different divergent thinking tasks may capture different facets or dynamics of creativity. For example, executive processes might be more important for the alternate uses task, while the instances task may rely more on semantic fluency (Silvia, 2011). Further, the best scoring method for different tasks may also vary, which may be another reason for the discrepant results. As a result, Runco et al. (2016) concluded that the results from a single creativity task may not be indicative of overall creativity. They suggested instead that multiple tasks should be used to achieve more generalization, which is also consistent with psychometric theory that the most reliable assessments are based on multiple indicators (Anastasi, 1988; Cronbach, 1989). Given this consideration, three different verbal divergent thinking tasks will be employed in the current study (i.e., alternative uses task, instances task, and consequences task).

Overview and Hypotheses

There are aspects that have not been explored about the incubation effect; the incubation effect in a group context is one of them. Thus, the first purpose of the current study is to confirm the incubation effect in a group context. We decided to focus our investigation of group creativity to the simplest case—interactive dyads. Compared to groups of more than two people, using dyads may minimize the effects of some of the possible confounding factors of group dynamics and avoid effects from unwanted group-dynamic factors. While at the same time, using interactive dyads will allow us to simulate working groups that are most common in real life. Hence, the choice of interactive dyads will help us examine a relatively pure incubation effect in a group context similar to real-life groups.

To test the group incubation effect, we included both a control condition (no-incubation) and an incubation condition. Given the reliable effect in individuals, we expect to find an incubation effect with dyads. During an incubation period, the processes responsible for the incubation effect in individuals, should also happen for each member in a group. Collectively, the effect of these processes on each individual group member will sum to an effect for the whole group. There could be an alternative though, as the effect of some processes in the group interactions after the incubation may counteract the effect of the incubation period, such as evaluation apprehension (Camacho & Paulus, 1995), social loafing (Diehl & Stroebe, 1987), or tending to converge on similar answers (El Paul & Brown; Larey & Paulus, 1999). As a result, we may not find an incubation effect.

We also manipulated the cognitive demand of the interpolated task to test its effect on the possible group incubation effect. From the introduction earlier, we have limited cognitive resources. When there are two tasks being processed simultaneously, the more cognitive resources used by one task, the less cognitive resources left for the other task. An interpolated task with a high cognitive demand requires more resources, and thus should lead to fewer resources available for processing of the target task, and vice versa. During the incubation period, participants work on the interpolated task, while at the same time, there's some processing of the target task happening. Thus, considering the relative amount of leftover cognitive resources, a high-demand interpolated task should lead to a smaller incubation effect, while a low-demand interpolated task should lead to a bigger incubation effect. This was the case confirmed by previous research on individual participants (Baird et al., 2012). For a group, we expect that this will also apply to each of the participants. And collectively, this effect from each participant would sum to an effect for the whole group. In other words, we expect a larger incubation effect in groups after they work on a low-demand interpolated task during incubation, and a smaller incubation effect after they work on a high-demand interpolated task. We might also not find a difference between high- and low-demand interpolated tasks. Production blocking may happen in the interaction and hinder participants' creativity performance. Or, due to an increased group memory capacity, the difference between cognitive demands of high- and low-demand tasks may not be sufficient to influence groups' performance.

The effect of another variable, the emotional valence induced during the incubation period, was also tested in current study. Emotional valence has not been examined in an incubation effect in group context previously. However, its effect on various creativity tasks has been widely researched in both individuals and groups. Positive emotions are found to be associated with increased breadth of concepts, increased perception of relatedness, broader range of associates, and more divergent answers. During incubation, there is processing of the target creativity task, based on previous research then, a positive emotion should benefit this processing, thus lead to an enhanced incubation effect. Oppositely, negative emotions have been found to be associated with narrower range of associates, less divergent answers, more local focus, etc. Hence, a negative emotion during incubation would impede processing of divergent thinking tasks, and then lead to a discounted incubation effect. Though previous research was on individuals, parallel to participants working individually, each member in a dyad should be impacted in the way discussed above, and these effects on individuals should manifest as an overall effect. The above proposed results in positive- and negative-emotion conditions compared to neutral-emotion condition may not be found though, due to possible effect of other aspects of emotions. For example, different emotions may influence behaviors differently, such as activating or inhibiting behaviors. Thus, a negative activating emotion may enhance creativity performance while a positive inhibiting emotion may harm creativity.

In the current study, a delayed incubation paradigm is employed, where participants work on a divergent thinking task, complete interpolated tasks (or not) during an incubation period, and then continue the same divergent thinking task. The study includes two sets of experiments, three experiments in each set, resulting in six experiments in total. However, in current dissertation document, we only present the first four experiments. So, only contents of Experiments 1 to 4 will be presented in following sections. In first set of experiments (Experiments 1-3), three verbal divergent thinking tasks are used as target tasks, one per experiment: the alternative uses task, the instances task and the consequences task. In Experiments 1 to 3, the cognitive demand of the interpolated task during the incubation period is varied, including four conditions: low demand, high demand, rest, and no incubation (control). In Experiments 4, the alternative uses task is used and the emotional status of participants during the incubation period is manipulated, including four conditions: negative, positive, neutral and no incubation (control). Surveys will be administered to collect participants' demographic information, arrival and leaving emotions, tendency towards cooperation, openness in personality, and cooperation experience in the study.

Our hypotheses are:

H1: There will be an incubation effect in a dyad creativity setting, which will be indicated by higher creativity performance in incubation conditions compared to no-incubation conditions.

H2: For Experiments 1-3, there will be a larger incubation effect in the low cognitive demand condition compared to the high demand.

H3: For Experiments 4, there will be a larger incubation effect in the positive emotion condition compared to the neutral condition, and a smaller effect in the negative condition compared to the neutral condition.

We also have two research questions.

RQ1: Is the incubation effect consistent across types of creativity tasks?

RQ2: Is openness to new experiences, group preferences, and satisfaction with the cooperation experience related to the incubation effect?

METHOD

As the methods for each experiment are the same, they are combined here.

Participants

All participants were students taking an introduction to psychology class at The University of Alabama. They received research credits as part of a class requirement. The demographic information of participants in each experiment is in Table 1.

Table 1.

Demographic Information of Participants in Each Experiment

	Exp 1	Exp 2	Exp 3	Exp 4
N of participants	50	120	110	78
Gender % (n)				
Male	18% (9)	40.83% (49)	28.18% (31)	29.49% (23)
Female	82% (41)	59.17% (71)	71.82% (79)	70.21% (55)
Age				
Range	17-23	18-33	18-24	18-27
Average	18.64	19.43	18.45	18.91
Familiarity % (n)				
Stranger	86% (43)	93.99% (112)	93.64% (103)	92.31% (72)
Acquaintance	4% (2)	1.67% (2)	1% (1)	1.28% (1)
Good friends	10% (5)	5% (6)	5.45% (6)	6.41% (5)
Race % (n)				
White/Caucasian	78% (39)	70.83% (85)	68.18% (75)	76.92% (60)
Black/African American	6% (3)	23.33% (28)	20.91% (23)	20.51% (16)
Asian	6% (3)	2.5% (3)	1.82% (2)	1.28% (1)
Native American	2% (1)	0% (0)	2.73% (3)	1.28% (1)
Mixed-race	2% (1)	0.83% (1)	3.64% (4)	0% (0)
Unspecified	6% (3)	2.5% (3)	2.73% (3)	0% (0)
Hispanic/Latinx % (n)	12% (6)	5% (6)	1.82% (2)	3.85% (3)

The number of participants varied from N = 50 to N = 120 across the experiments. The sample sizes were based on prior research that used similar methods (赵琪琛, 2015). Any differences in the number of dyads across experiments was due to concerns about possible order effects.

A power analysis for a repeated-measures ANOVA with 4 repeated measurements indicated that the minimum sample size to yield a statistical power of at least .8 with an alpha level of .05, a correlation of .5 between the repeated measurements, and a medium effect size (f = .25) is N = 24 (Intellectus Statistics, 2022). Therefore, we believe we have enough power to detect a medium effect. This sample size also corresponds with that in the author's thesis.

Due to experimenter and technical errors, and other unexpected events (e.g., fire alarm went off), 5 dyads (10 participants) in Experiment 1, 7 dyads (14 participants) in Experiment 2, 1 dyad (2 participants) in Experiment 3 and 1 dyad (2 participants) in Experiment 4 were excluded from all data analyses.

Procedure

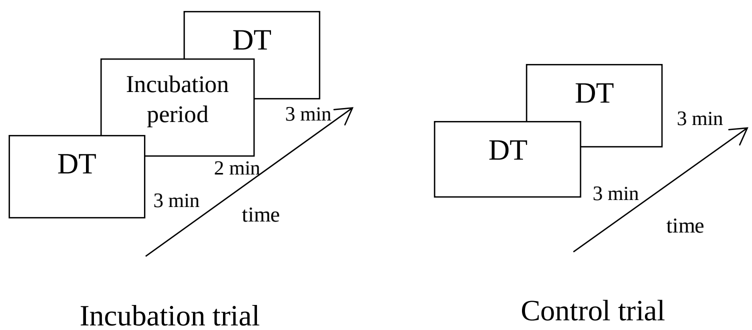
In each experiment, after reading and signing the consent form, participants completed four surveys individually. Then they practiced the creativity task individually, after which they worked on four experimental incubation trials together with their partner. After finishing all the incubation trials, participants answered two more surveys individually and were released. In Experiment 4, before being released, dyads watched a video with cheerful music and various cute dogs to eliminate any residual negative feelings at the end of the experiment. The total time for each experiment was approximately 60 minutes.

Study Paradigm

We used a delayed incubation paradigm, so named because participants worked on the target task before the incubation period. There were two general types of trials, incubation trials and a no-incubation control trial (Figure 1). In the incubation trials, dyads were given a divergent thinking target task (described later), which they worked on for 3 minutes (Stage 1). Then they had an incubation period for 2 minutes, during which they completed a task or rested (described later), and then they continued working on the same target task for another 3 minutes (Stage 2). In the no-incubation trial, participants worked on the target task for two 3-minute periods consecutively.

Figure 1.

Experiment paradigm for the incubation trials and the control trial.



Note. DT = divergent thinking task.

Tasks

Divergent thinking target tasks

As introduced previously, three widely used divergent thinking tasks were employed in this study. In Experiments 1 and 4, the alternative uses task was used. In the alternative uses task, participants are asked to think of as many new uses as they can for an everyday item. In Experiment 2, the instances task was used. In the instances task, participants are asked to think of as many unique instances as they can for a specific feature. In Experiment 3, the consequences task was used. In the consequences task, participants are asked to think of as many creative consequences as they can for a hypothetical situation. In all experiments, one or both participants in the dyad wrote down the responses on a sheet of paper. When the end of Stage 1 was announced, they turned the sheet of paper over, then completed the incubation task (or not), and then continued writing down new responses on the back side of the sheet.

Five different items or questions were selected for each divergent thinking task—one for each of the four experimental trials and another for the practice trial. The five different items/questions were assigned to each condition randomly for each dyad. For the alternative uses task, the five items were bucket, hand fans, eyeglasses, cellphone, and candle. For the instances task, the five attributes selected were dark, round, hot, can fly, and can get bigger. For the consequences task, the five hypothetical situations selected were: people do not need food anymore; people lose the ability to read and write; people do not need to sleep anymore; everybody is 12 in tall; and our life becomes two times longer than the current one.

Our dependent variable was performance on the divergent thinking tasks. Four widely employed creativity performance indices are fluency, flexibility, uniqueness, and originality. The fluency score captures the number of unique answers generated by dyads, excluding irrelevant answers. Flexibility is the number of different categories a dyad generated. All responses for each item/question in a creativity task for all dyads are combined and sorted into broader categories (e.g., for bucket: holds liquids, used as weapon, used as furniture). The uniqueness score (i.e., objective creativity) is the number of relatively unique answers the dyads generated, which involves the quantitative uncommonness or infrequency of answers. Here, a frequency distribution is created for all responses, and those responses that occur less than 5% of the sample are awarded 1 point, all other answers receive no points. The number of uncommon responses generated by a dyad represents objective creativity. The originality score (i.e., subjective creativity) refers to the rated creativity level of answers by independent raters. All unique responses for a task are listed and each one is rated for creativity on a 1 (not at all creative) to 5 (very creative) scale. The average rating is calculated for each response. Then, the ratings for each response generated by a dyad are summed to produce the subjective creativity score. For this dissertation, only the fluency score will be calculated and analyzed.

Interpolated (incubation) tasks

In Experiments 1-3, the cognitive demand level of the interpolated task was manipulated, and four conditions were employed: high cognitive demand, low cognitive demand, rest, and no incubation (control). Dyads completed all four conditions in random order. In the high demand condition participants in a dyad take turns counting backward by 3 from 699, and in the low demand condition participants in a dyad take turns counting forward by 2 from 5. In the rest condition, participants rested quietly during the incubation period and were not allowed to work on the creativity task, and in the no incubation control condition, participants started Stage 2 immediately after Stage 1.

In Experiment 4, the emotional status during the incubation period was manipulated and four conditions were employed: positive emotion, negative emotion, neutral emotion, and no incubation (control). Dyads completed all four conditions in a randomly determined order. In each of the emotion conditions, a 2-min video clip was played to the participants on a lab computer during the incubation period. The final three video clips were chosen based on a pilot study prior to the formal experiments. In the pilot study, undergraduate students watched videos and rated their emotional valence and arousal using the Self-Assessment Manikin (introduced later in Survey section) after watching each one. The emotional valence scale ranges from -4 to 4, and the emotional arousal scale ranges from 1 to 9. The positive emotion video clip was a cut from America's Got Talent show. Participants' average valence rating on it was 2.47 (*SD* = 1.61) and significantly higher than 0, and their average arousal rating was 5.32 (*SD* = 2.24). The negative emotion video clip was a cut from a movie on World War II. Participants' average valence rating on it was -3.13 (*SD* = 1.02) and significantly lower than 0, and their average arousal rating was 6.75 (*SD* = 2.44). The neutral movie clip showed 24 pictures of different walls, with each picture shown for 5 seconds, with a background white noise. Participants' average valence rating on it was -0.02 (*SD* = 1.27) and not significantly different from 0, and their average arousal rating on it was 1.96 (*SD* = 1.46).

In each experiment there was an individual practice trial before the four experimental trials, where each participant worked on the creativity task alone and rested quietly during the incubation period.

Surveys

Surveys were included to investigate in an exploratory way the possible relations between creativity and openness to new experiences, group preferences, and cooperation experiences (see Appendices). All surveys were answered by each participant individually. Besides demographic questions (gender, age, race/ethnicity, city/country grew up), three surveys were employed before participants started the experiment. These surveys assessed participants' emotional state, openness, and group preferences. After the creativity trials, participants completed two more surveys. One was the same emotional state questionnaire again, and the other was about cooperation experiences during the study.

Emotional state questionnaire. This is a 9-point Likert scale made up of 9 questions asking about participants' emotional feelings at arrival, from 1 ("extremely bad" or "not at all") to 9 ("very good" or "extremely") (赵琪琛, 2015) (See Appendix). For example, how worried do you feel right now?

The openness subscale of NEO-PI-R. This is a 5-point Likert scale consisting of 48 questions assessing the openness level of participants (Costa & MacCrae, 1992) (See Appendix). Participants select the extent of their agreement to each statement, from 0 ("totally disagree") to 4 ("absolutely agree"). For example, I rarely experience strong emotions; I often try new and foreign foods; I have a wide range of intellectual interests.

Group preference scale (GPS). This is a 5-point Likert scale with 10 questions assessing participants' willingness to cooperate with others (Larey & Paulus, 1999) (See Appendix). Participants select the extent of their agreement to each statement, from 1 ("totally disagree") to 5 ("absolutely agree"). For example, I find it hard to generate novel ideas in group situations.

Cooperation experience survey. This is a 9-point Likert scale composed of 8 questions asking about participants' opinions of their cooperation experience in the study (赵琪琛, 2015) (See Appendix). Participants choose the extent of their agreement to each statement, from 1 ("not at all/absolutely no") to 9 ("extremely/very much"). For example, are you satisfied with the process of the cooperation task?

Emotion manipulation check. To confirm that the wanted emotional states were successfully induced in Experiments 4-6, we included a manipulation check using the Self-Assessment Manikin (SAM) (Bradley & Lang, 1994) (See Appendix). SAM is a non-verbal pictorial assessment that directly measures a person's affective reactions. In our study, we included two questions measuring emotional valence and arousal respectively. Both questions use a 9-point Likert scale, from -4 to 4 in the emotional valence question and 1-9 in the emotional arousal question. Participants complete the assessment two times: (1) immediately after watching each video and (2) after watching all the videos (i.e., after finishing all the trials). The immediate manipulation check asks participants to choose their current emotional valence and arousal right after watching each video, and the second check asks participants to recall their emotions after watching each video and reevaluate those feelings.

RESULTS

The descriptive statistics for the fluency scores in all experiments are found in Table 2. Skewness and kurtosis measures for each variable are presented in the appendix. The skewness and kurtosis values indicated that there were no serious violations of normality in the data, so no corrections were made.

Table 2.

Means (± Standard Deviations) for Fluency Scores in Each Experiment

	Exp 1			
	High	Low	Rest	No Incu
Fluency				
Stage 1	12.7 (± 5.74)	12.10 (± 3.40)	10.15 (± 4.50)	10.15 (± 3.39)
Stage 2	9.05 (± 3.68)	9.30 (± 4.01)	6.95 (± 3.52)	6.50 (± 2.95)
	Exp 2			
	High	Low	Rest	No Incu
Fluency				
Stage 1	19.81 (± 7.08)	19.66 (± 6.07)	20.30 (± 7.65)	20.00 (± 6.84)
Stage 2	15.81 (± 5.77)	16.06 (± 6.19)	15.43 (± 6.33)	14.17 (± 6.34)
	Exp 3			
	High	Low	Rest	No Incu
Fluency				
Stage 1	9.41 (± 3.31)	9.30 (± 3.84)	9.06 (± 3.68)	9.07 (± 3.73)
Stage 2	7.67 (± 3.15)	7.93 (± 3.43)	7.46 (± 3.44)	7.26 (± 3.60)
	Exp 4			
	Pos	Neg	Neu	No Incu
Fluency				
Stage 1	8.79 (± 3.88)	9.08 (± 4.05)	9.03 (± 4.79)	8.89 (± 3.83)
Stage 2	7.08 (± 4.00)	6.84 (± 3.43)	7.11 (± 3.55)	7.13 (± 3.57)

Note. High and Low refer to high cognitive-demand condition and low cognitive-demand condition. Pos, Neg, and Neu refer to positive emotion condition, negative emotion condition and neutral emotion condition. No Incu refer to No incubation control condition.

Experiment 1 Results: AU Task

An overall 4 (Conditions) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA was conducted first. A main effect of Condition (F (3, 57) = 4.13, p = .01, η_p^2 = .18) and a main effect of Stage (F (1, 19) = 50.92, p < .001, η_p^2 = .73) were obtained. Post hoc tests using LSD correction revealed that fluency scores in the high-demand condition (*M* = 10.88, *SD* = 4.28) were significantly higher than in the rest condition (*M* = 8.55, *SD* = 3.70; *p* = .02) and no-incubation control conditions (*M* = 8.33, *SD* = 2.76; *p* = .04). Also, fluency scores in the low-demand condition (*M* = 10.70, *SD* = 3.39) were significantly higher than in the rest condition (*M* = 8.55, *SD* = 3.70; *p* = .03) and no-incubation control conditions (*M* = 8.33, *SD* = 2.76; *p* = .02). Fluency scores in the high- and low-demand conditions were not significantly different from each other (*p* = .84). Neither were the fluency scores in the rest and no-incubation conditions (*p* = .82). Fluency scores in Stage 1 (*M* = 11.28, *SD* = 2.91) were significantly higher than that in Stage 2 (*M* = 7.95, *SD* = 2.41). The interaction between Condition and Stage was not significant, F (3, 57) = .31, p = .82, η_p^2 = .02. Further analyses were conducted to test specific hypotheses.

Hypothesis 1 was an anticipated incubation effect in a group setting, which would be indicated by an interaction between Stage and Incubation/No Incubation conditions. We tested this hypothesis in two ways, one in which all incubation conditions were combined and compared with the no-incubation condition, and another with only the cognitive conditions combined. We first calculated averaged incubation fluency scores by averaging fluency scores in three incubation conditions (rest, low, high) for Stage 1 and Stage 2 respectively. Then we conducted a 2 (Condition: averaged incubation vs. no-incubation) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA. A significant main effect of Stage was obtained (F (1, 19) = 55.02, p < .001, η_p^2 = .74) with Stage 1 fluency score (M = 10.90, SD = 2.61) significantly higher than Stage 2 (M = 7.47, SD = 2.16). A near-significant main effect of Condition was obtained (F (1, 19) = 3.88, p = .064, η_p^2 = .17), with a trend of higher fluency score in averaged incubation condition (M = 10.04, SD = 3.05) than in no-incubation control condition (M = 8.33, SD = 2.76). The interaction between Condition and Stage was not significant, F (1, 19) = .25, p = .62, η_p^2 = .013. To keep parallel with other experiments, a one-way repeated measures ANOVA on Stage 2 fluency was conducted between averaged incubation condition and no-incubation control condition. A significant difference was obtained (F (1, 19) = 4.54, p = .046, η_p^2 = .19), with the averaged incubation condition (M = 8.43, SD = 2.99) higher than the no-incubation control condition (M = 6.50, SD = 2.95). Same analysis on Stage 1 fluency scores didn't find a difference, F (1, 19) = 2.10, p = .16, η_p^2 = .10.

We further examined the incubation effect for the cognitive incubation tasks only, compared to the no-incubation control condition. We calculated a averaged cognitive incubation condition where fluency scores were averaged across the high- and low-cognitive demand incubation conditions for each stage separately. We then conducted another 2 (Condition: averaged cognitive incubation vs. no-incubation) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA. Results from this analysis revealed a significant main effect of Condition (F (1, 19) =7.05, p =.016, η_p^2 = .27) with fluency score in averaged cognitive incubation condition (M = 10.79, SD = 3.33) higher than in no-incubation control condition (M = 8.33, SD = 2.76; p = .02). A significant main effect of Stage was also obtained (F (1, 19) =49.56, p < .001, η_p^2 = .72), with fluency score in Stage 1 (M = 11.28, SD = 2.67) higher than in Stage 2 (M = 7.84, SD = 2.31).

The interaction between Condition and Stage was not significant, F (1, 19) =.24, p = .63, η_p^2 = .012. Again, to parallel other experiments, a one-way repeated measures ANOVA was conducted to compare Stage 2 fluency between the averaged cognitive incubation condition and the no-incubation control condition. A significant difference was obtained, F (1, 19) = 7.46, p = .01, η_p^2 = .28, with cognitive incubation condition (M = 9.18, SD = 3.40) higher than no-incubation control condition (M = 6.50, SD = 2.95). However, this result needs to be treated with caution because there was also a significant difference in Stage 1, F (1, 19) = 4.44, p = .049, η_p^2 = .19.

Hypothesis 2 stated that there would be a larger incubation effect in low-demand condition compared to high-demand condition, which would be indicated by an interaction between Stage and Conditions. We conducted a 2 (Conditions: high-demand vs. low-demand) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA. Only the main effect of Stage was significant (F (1, 19) =28.49, p < .001, η_p^2 = .60), with Stage 1 (M = 12.40, SD = 3.77) fluency scores higher than Stage 2 (M = 9.18, SD = 3.40). Neither the main effect of Condition (F (1, 19) =.04, p = .84, η_p^2 = .002) nor the interaction between Condition and Stage (F (1, 19) =.49, p = .49, η_p^2 = .025) was significant.

Research question 2 asked whether some individual characteristics (i.e., openness to new experience, preference for working in groups) and group factor (i.e., quality of cooperation experience) were related to the incubation effect in a group setting. To explore it, we conducted the following analysis. We first calculated a difference score for each incubation condition by subtracting Stage 2 fluency score from Stage 1 fluency score; this difference score represents participants' performance decline from Stage 1 to Stage 2. A composite quality-of-cooperation-experience score was calculated for each participant by averaging their answers in each question about cooperation experience. Then we calculated openness to new experience, preference to work in groups and quality of cooperation experience for each group by averaging scores on these measures from the two participants. A Pearson correlation was then conducted between these 3 measures and fluency difference scores for 4 conditions, for a total of 12 tests. Results from this analysis revealed a negative moderate correlation between openness to new experience and high-demand condition fluency difference score, r (20) = -.45, $p < .05$, a positive moderate correlation was also found between high-demand and rest condition fluency difference scores, r (20) = .51, $p < .05$. No other significant results were found.

Short discussion

In Experiment 1, we required participants to think of as many creative uses as they could for different everyday items. Hypothesis 1 stated that creativity performance in Stage 2 relative to Stage 1 would be higher in the incubation conditions compared to the no-incubation control condition. Hypothesis 2 stated that the level of creativity performance in Stage 2 relative to Stage 1 would be higher in the low-demand condition compared to in the high-demand condition. However, we failed to find evidence supporting either hypothesis.

Despite not finding an incubation effect, we found a stable and strong effect of Stage: participants consistently reported more answers in the first stage than in the second stage. Besides this, we also found a stable condition difference: participants who completed cognitive tasks (i.e., high- & low-demand) during the incubation period reported more answers than participants who rested during incubation or had no break.

The negative correlation between participants' openness to new experience and their fluency difference in high-demand condition indicates that when participants are more open to new experience, their creativity performance decline less compared to those who are less open. However, this correlation was only found in the high-demand condition. Neither preference for working in groups nor quality of cooperation experience was related to fluency difference in any condition.

A discussion of the possible reasons for the null results will be reserved for the general discussion.

Experiment 2 Results: Instances Task

An overall 4 (Conditions) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA was conducted first. The main effect of Condition was not significant, F (3, 156) = .404, p = .75, η_p^2 = .008. However, the main effect of Stage was significant, F (1, 52) = 119.75, p < .001, η_p^2 = .70, with fluency scores in Stage 1 (M = 19.94, SD = 4.79) significantly higher than those in Stage 2 (M = 15.37, SD = 4.37). The interaction between Condition and Stage was not significant, F (3, 156) = 1.27, p = .29, η_p^2 = .024. Although one might have expected an interaction overall, the hypotheses were more specific and so they were tested separately.

Hypothesis 1 was that there would be an incubation effect in a group setting, which would be indicated by an interaction between Stage and Incubation/No Incubation conditions. We tested this hypothesis in two ways (see Experiment 1). First, using an average score with all three incubation conditions (rest, low, high) we conducted a 2 (Condition: averaged incubation vs. no-incubation) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA. We did not find a main effect of Condition, F (1, 52) = 1.12, p = .30, η_p^2 = .021, but we found a significant main effect of Stage, F (1, 52) = 118.64, p < .001, η_p^2 = .70. As expected, fluency scores were higher in Stage 1 (M = 19.96, SD = 5.02) than in Stage 2 (M = 14.97, SD = 4.68). Further, we found an interaction between Condition and Stage that was nearly significant, F (1, 52) = 3.03, p = .088, η_p^2 = .055.

To explore the nature of the near-significant interaction, a follow-up repeated measures one-way ANOVA for Stage 2 only was conducted. The results again showed a nearly significant difference, with the fluency scores in the averaged incubation condition (M = 15.77, SD = 4.53) higher than the no-incubation control condition (M = 14.17, SD = 6.34), F (1, 52) = 3.99, p = .051, η_p^2 = .07. Same analysis on Stage 1 fluency scores did not find a difference, F (1, 52) = 0.01, p = .94, η_p^2 = .0001.

Second, we further explored the data with an average score for cognitive incubation tasks (high and low) only. We conducted a 2 (Conditions: averaged cognitive incubation vs. no-incubation) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA. The results revealed a significant main effect of Stage, F (1, 52) = 90.83, p < .001, η_p^2 = .64, with higher fluency scores in Stage 1 (M = 19.87, SD = 4.87) compared to Stage 2 (M = 15.05, SD = 4.84). A marginally significant interaction between Condition and Stage was also obtained, F (1, 52) = 3.76, p = .058, η_p^2 = .07. The main effect of Condition remained non-significant, F (1, 52) = .96, p = .33, η_p^2 = .02.

A follow-up analysis was conducted to examine the nature of the marginally significant interaction. We used a repeated measures one-way ANOVA of fluency scores for the averaged cognitive condition and the no-incubation control condition on Stage 2 only. A significant difference between the conditions was obtained, F (1, 52) = 4.48, p = .039, η_p^2 = .08, with fluency scores of the averaged cognitive condition (M = 15.93, SD = 5.01) significantly higher than the no-incubation control condition (M = 14.17, SD = 6.34). Same analysis on Stage 1 fluency scores didn't find a difference, F (1, 52) = .07, p = .78, η_p^2 = .001.

Hypothesis 2 stated that creativity performance in Stage 2 relative to Stage 1 would be higher in the low-demand condition compared to the high-demand condition. To test this hypothesis, a 2 (Condition: high- vs. low-demand) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA was conducted only between the high- and low-demand conditions. The results revealed a significant main effect of Stage, F (1, 52) = 33.56, p < .001, η_p^2 = .39. Neither the main effect of Condition (F (1, 52) = .004, p = .95, η_p^2 = .0001), nor the interaction between Condition and Stage (F (1, 52) = .089, p = .77, η_p^2 = .002) was significant.

As in Experiment 1, we also explored whether openness to new experience, preference for working in groups and quality of cooperation experience were related to the incubation effect. The calculations were the same as Experiment 1: a fluency difference score between 2 stages for each condition, and average scores in each dyad for all three measures. A Pearson correlation between fluency difference scores in 4 conditions and these 3 measures were calculated. A small to moderate positive correlation was found between quality of cooperation experience and openness to new experience, r (53) = .40, p < .01. None of the measures was found to be related to fluency difference scores in any condition.

Short discussion

This experiment used the instances task as the target task, with fluency as the main measure. We found some support for the first hypothesis (incubation vs. no-incubation), but our second hypothesis (high vs. low cognitive load) was not supported. For Hypothesis 1, we expected creativity performance in Stage 2 relative to Stage 1 would be higher in the incubation conditions compared to the no-incubation control condition. We found an incubation effect, but only when comparing cognitive incubation conditions (i.e., high- and low-demand conditions) and no-incubation control conditions. When including the rest condition, the results were non-significant. Possible reasons for results found here will be discussed in more detail in general discussion.

For Hypothesis 2, we expected a higher creativity performance in Stage 2 relative to Stage 1 in the low-demand condition compared to the high-demand condition. However, we failed to obtain the anticipated difference. Given that we found an incubation effect in both high- and low-demand incubation conditions, we know that cognitive tasks are an effective way to elicit the incubation effect at least with the Instances task.

Experiment 3 Results: Consequences Task

As in Experiments 1 and 2, an overall 4 (Conditions) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA was conducted first. Neither the main effect of Condition (F (2.79, 147.97) = .88, p = .45, η_p^2 = .016) nor the interaction between Condition and Stage (F (3, 159) = .33, p = .81, η_p^2 = .006) were significant. The main effect of Stage was significant, F (1, 53) = 67.51, p < .001, η_p^2 = .56, with fluency scores in Stage 1 (*M* = 9.21, *SD* = 3.09) significantly higher than those in Stage 2 (*M* = 7.58, *SD* = 2.96). To test the hypotheses, more specific analyses were conducted, and the results are reported below.

Hypothesis 1 stated that there would be an incubation effect in a group setting, which would be indicated by an interaction between Stage and Incubation/No incubation conditions. We tested this in two ways (see Experiments 1 and 2). First, using the average of the three incubation conditions (rest, low & high) we ran a 2 (Condition: averaged incubation vs. no-incubation) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA. Neither the main effect of Condition (F (1, 53) = 1.13, p = .29, η_p^2 = .021) nor the interaction between Condition and Stage (F (1, 53) = .34, p = .56, η_p^2 = .006) were significant. The main effect of Stage was significant, F (1, 53) = 63.10, p < .001, η_p^2 = .54, with higher fluency score in Stage 1 (*M* = 9.16, *SD* = 3.15) compared to Stage 2 (*M* = 7.47, *SD* = 3.09).

To parallel with other experiments, a one-way repeated measures ANOVA of fluency scores in average incubation condition and the no-incubation control condition was conducted for both Stage 1 and Stage 2. No difference was found between conditions in either Stage 1 (F (1, 53) = .20, p = .66, η_p^2 = .004) or Stage 2 (F (1, 53) = 2.02, p = .16, η_p^2 = .037).

Second, using an average with only the two cognitive demand conditions, we conducted another 2 (Conditions: averaged cognitive incubation vs. no-incubation) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA. Only the main effect of Stage was significant, F (1, 53) = 54.13, p < .001, η_p^2 = .51. Fluency scores in Stage 1 (M = 9.21, SD = 3.14) were higher than in Stage 2 (M = 7.53, SD = 3.14). Neither main effect of Condition (F (1, 53) = 1.6, p = .21, η_p^2 = .029) nor the Condition-Stage interaction (F (1, 53) = 0.37, p = .56, η_p^2 = .007) was significant.

To parallel the analyses of previous experiments, a follow-up analysis was conducted using a one-way ANOVA of fluency scores for the averaged cognitive condition and the no-incubation control condition on Stage 2 only. A near-significant difference was obtained, F (1,53) = 2.89, p = .095, η_p^2 = .052, with the Stage 2 fluency score in the averaged cognitive condition (M = 7.80, SD = 3.08) higher than that in the no-incubation control condition (M = 7.26, SD = 3.60). Same analysis on Stage 1 fluency scores didn't find any difference, F (1,53) = 0.39, p = .54, η_p^2 = .007.

Hypothesis 2 stated that the level of creativity performance in Stage 2 relative to Stage 1 would be higher in the low-demand condition compared to in the high-demand condition. To test this, we conducted a 2 (Condition: high- vs. low-demand) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA. The results revealed only a significant main effect of Stage, F (1, 52) = 34.23, p < .001, η_p^2 = .39, with Stage 1 fluency scores (M = 9.35, SD = 3.34) higher than Stage 2 scores (M = 7.8, SD = 3.08). Neither the main effect of Condition (F (1, 53) = .09, p = .77, η_p^2 =

.002), nor the interaction between Condition and Stage (F (1, 53) = .69, p = .41, η_p^2 = .013) was significant.

As in previous experiments, to explore Research Question 2, we calculated Pearson correlations between the 3 individual (dyad) differences measures and the fluency difference scores in each condition. As one of participants did not answer the post-survey, the dyad was excluded from this analysis. A positive small correlation was obtained between quality of cooperation experience and openness to new experience, r (53) = .29, p < .05. No other significant correlations were obtained.

Short discussion

In Experiment 3, we required participants to think of as many creative consequences as they could for different hypothetical situations. Hypothesis 1 stated that creativity performance in Stage 2 relative to Stage 1 would be higher in the incubation conditions compared to the no-incubation control condition. Hypothesis 2 stated that the level of creativity performance in Stage 2 relative to Stage 1 would be higher in the low-demand condition compared to in the high-demand condition. However, we failed to find evidence supporting either hypothesis. Despite not finding an incubation effect, we found a stable and strong effect of Stage: participants consistently reported more answers in the first stage than in the second stage. We didn't find any individual characteristics or group dynamic factor related to creativity performance decline.

Experiments 1-3 Comprehensive Short Discussion

Research Question 1 asked whether there was some extent of consistency across different divergent thinking tasks regarding the incubation effect in a group setting. As per our data analysis plan, we conducted a qualitative analysis to compare results obtained in Experiments 1 to 3 and give a comprehensive short discussion here.

We failed to find a significant incubation effect in any experiment. We only found a near-significant incubation effect in Experiment 2, when we compared the average of incubation conditions and the average of cognitive incubation conditions to the no-incubation control condition. However, we found a similar pattern of results across the experiments. Though an interaction between incubation conditions and working periods was hypothesized as an indicator of an incubation effect, it usually comes from two parts of results: a non-significant difference on creativity performance across different conditions before an incubation period (i.e., Stage 1), and a significant difference across conditions after an incubation period (i.e., Stage 2). In both Experiment 2 and 3, we found fluency scores not different from each other in Stage 1 but different in Stage 2 while comparing averaged cognitive incubation condition and no-incubation control condition. Differently, in Experiment 2 we also found the same results pattern while comparing averaged incubation condition and no-incubation control condition. But in Experiment 3, we found fluency scores not different in Stage 1 but different in Stage 2 between low-demand condition and no-incubation control condition.

In Experiment 1, we found a different pattern. There was a difference of fluency scores in Stage 1, that the high- and low-demand conditions were higher than the rest and no-incubation control conditions. So, though we also found a difference of fluency scores between conditions in Stage 2, they were confounded by difference from Stage 1. Thus, these results in Experiment 1 do not fit an incubation effect result pattern.

Regarding the effect of cognitive demand level on the creativity task, we failed to find any significant results. In all experiments, fluency scores in the high-demand condition and low-demand condition were not different from each other in either stage. Though not one of our hypotheses, we happened to find similar results between rest condition and no-incubation control condition: fluency scores in these conditions were not different from each other in either stage. In conclusion, in Experiments 1 to 3, it seems that high- and low-demand conditions were somehow homogeneous and comparable to the rest and no-incubation control conditions.

We also found a stable and strong effect of incubation stage in all experiments. Participants consistently reported less answers in second stage than in first stage. We believe this indicates a trend of idea exhaustion along with the passage of time.

Experiment 4 Results: AU Task

In Experiment 4 the emotional status of participants during the incubation period is manipulated to test the effect of emotion on the incubation effect in a group context. Four conditions were included: positive-, negative-, neutral-emotion conditions and no-incubation control condition. The data analysis of this experiment includes a manipulation check of emotion induction and the testing of each hypothesis.

Manipulation check – emotion induction.

We first conducted a manipulation check to make sure the intended emotions were successfully induced in each condition. A one-way repeated measures ANOVA across the three incubation conditions (i.e., positive, negative, neutral) was conducted on the emotional valence tested immediately after watching each video clip. The results revealed that participants' emotions after watching each video clip were significantly different, F (2, 150) = 342.54, $p < .001$, $\eta_p^2 = .82$. Post hoc analysis with an LSD adjustment revealed that participants' emotional valence was significantly higher after watching the positive video clip (M = 2.89, SD = 1.29) compared to watching the neutral video clip (M = 0.17, SD = 1.27; $p < .001$), and significantly lower after watching the negative video clip (M = -3.01, SD = 1.43) compared to after watching the neutral video clip ($p < .001$). Participants' recalled emotional valence at the end of the experiment revealed similar results. Their emotional valence varied significantly after watching the different video clips, F (1.49, 114.59) = 421.14, $p < .001$, $\eta_p^2 = .85$. Post hoc analysis with an LSD adjustment revealed that the participants' recalled emotional valence was significantly higher in the positive emotion condition (M = 3.08, SD = 1.21) compared to the neutral emotion condition (M = -0.10, SD = 0.86; $p < .001$), and significantly lower in the negative emotion condition (M = -2.97, SD = 1.41) compared to the neutral emotion condition ($p < .001$).

We also examined participants' level of emotional arousal after watching each video clip. A repeated measures one-way ANOVA on emotional arousal was conducted for arousal immediately after watching each video across the three incubation conditions. Participants' arousal was significantly different after watching the different video clips, F (1.78, 136.95) = 99.39, $p < .001$, $\eta_p^2 = .56$. Post hoc analysis with an LSD adjustment revealed that emotional arousal was significantly higher in both the positive condition (M = 6.45, SD = 1.89) and the negative condition (M = 6.90, SD = 1.88) compared to the neutral condition (M = 3.12, SD = 2.24) (positive vs. neutral: $p < .001$; negative vs. neutral: $p < .001$). Similar results were obtained with the participants' recalled emotional arousal at the end of the experiment, F (1.84, 140.08) = 144.31, $p < .001$, $\eta_p^2 = .66$. Results of the post hoc analysis with an LSD adjustment showed that participants' recalled arousal was significantly higher in both the positive condition (M = 6.43, SD = 2.00) and the negative condition (M = 6.69, SD = 2.28) compared to the neutral condition (M = 2.31, SD = 2.09) (positive vs. neutral: $p < .001$; negative vs. neutral: $p < .001$).

Creativity performance – fluency.

As in the previous experiments, an overall 4 (Conditions) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA was conducted first. Neither the main effect of Condition (F (3, 111) = .024, p = .96, $\eta_p^2 = .001$) nor the interaction between Condition and Stage (F (3, 111) = .24, p

= .87, η_p^2 = .006) was significant. The main effect of Stage was significant, F (1, 37) = 43.40, p < .001, η_p^2 = .54, with fluency scores in Stage 1 (M = 8.95, SD = 3.32) significantly higher than those in Stage 2 (M = 7.04, SD = 2.87). To test the hypotheses, more specific analyses were conducted, and the results are listed below.

Hypothesis 1 stated that there would be an incubation effect in a group setting, which would be indicated by an interaction between Stage and Conditions. As in previous experiments, a composite incubation condition was first calculated by averaging the three emotion incubation conditions (positive, negative, neutral). A 2 (Condition: averaged incubation vs. no-incubation) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA was then conducted. Neither the main effect of Condition (F (1, 37) = .004, p = .95, η_p^2 = .0001) nor the interaction between Condition and Stage (F (1, 37) = .103, p = .75, η_p^2 = .003) was significant. The main effect of Stage was significant, F (1, 37) = 29.91, p < .001, η_p^2 = .45, with higher fluency score in Stage 1 (M = 8.93, SD = 3.33) compared to Stage 2 (M = 7.07, SD = 2.92). To parallel the analyses of previous experiments, a follow-up analysis was conducted using a one-way ANOVA of fluency scores for the averaged condition and the no-incubation control condition on Stage 2 only. No difference was found for this analysis, F (1, 37) = .06, p = .81, η_p^2 = .002. Same analysis on fluency scores in Stage 1 didn’t find a difference either, F (1, 37) = .02, p = .89, η_p^2 = .001.

Hypothesis 3 stated that the level of creativity performance in Stage 2 relative to Stage 1 would be higher in the positive-emotion condition and lower in the negative-emotion condition compared to in the neutral-emotion condition. We conducted two 2 (Condition: positive/negative vs. neutral) × 2 (Stage: Stage 1, Stage 2) repeated measures ANOVA. A significant main effect of Stage was found in both analyses, positive vs. neutral: F (1, 37) = 22.0, p < .001, η_p^2 = .37, with Stage 1 (M = 8.91, SD = 3.79) fluency scores higher than Stage 2 scores (M = 7.10, SD =

3.37); negative vs. neutral: F (1, 37) = 32.80, p < .001, η_p^2 = .47, with Stage 1 (M = 9.05, SD = 3.85) fluency scores higher than Stage 2 scores (M = 6.97, SD = 3.11). Neither the main effect of Condition nor the interaction between Stage and incubation Condition was significant in either analysis. For positive vs. neutral, the main effect of Condition was F (1, 37) = .06, p = .81, η_p^2 = .002, and the interaction between Stage and Condition was F (1, 37) = .11, p = .75, η_p^2 = .003. For negative vs. neutral, the main effect of Condition was not significant, F (1, 37) = .04, p = .84, η_p^2 = .001, nor was the interaction between Stage and Condition F (1, 37) = .24, p = .63, η_p^2 = .006.

Research Question 2 asked whether participants' openness to new experience, preference for working in groups, and quality of cooperation experience were related to the incubation effect. Results revealed that a preference for working in groups was negatively and moderately correlated with the fluency difference score in the positive-emotion condition (r (38) = -.41, p = .01) and the no-incubation control condition (r (38) = -.46, p = .004), but not in the negative-emotion or neutral-emotion conditions. No other significant correlation between these measures and fluency score difference was found.

Though not related to any hypothesis, we found a positive weak correlation between quality of cooperation and openness to new experience, r (38) = .33, p = .05.

Short discussion

In Experiment 4, we asked participants to think of as many creative uses as they could for everyday items. Hypothesis 1 stated that the level of creativity performance in Stage 2 relative to Stage 1 would be higher in incubation conditions compared to no-incubation control condition. Hypothesis 3 stated that the level of creativity performance in Stage 2 relative to Stage 1 would be higher in the positive-emotion condition and lower in the negative-emotion condition compared to in the neutral-emotion condition. Results from the manipulation check indicated that the induction of emotions was successful: Participants' emotional valences were different after watching the different videos, and participants' emotional arousals were as expected in the different conditions. However, we failed to find evidence supporting either hypothesis. As with previous experiments, we found a stable and strong effect of Stage: Participants consistently reported more answers in the first stage than in the second stage.

Regarding the effects of openness to new experience, preference for working in groups and quality of cooperation experience, dyads with a higher preference for working in groups had less of a creativity performance decline in the positive-emotion condition and the no-incubation control condition. This indicates that preference for working in groups may have an effect of maintaining creativity performance and resisting idea exhaustion along with time goes. However, as these results were only found in 2 out of 4 conditions, caution needs to be exercised when drawing any firm conclusion.

DISCUSSION

In all experiments, we examined whether there was an incubation effect. An incubation effect describes the phenomenon in which there is an enhanced performance after taking a break from a task relative to continuously working on the task. In Experiments 1 to 3, we also examined whether the cognitive demand of the interpolated task impacted the incubation effect, and the generalizability of the incubation effect across different divergent thinking tasks. In Experiment 4, we also examined the effect of emotion on the incubation effect.

Regarding the incubation effect (Hypothesis 1), only minimal evidence was found that supported the hypothesis. There was a near-significant Condition×Stage interaction between incubation conditions and the no-incubation control condition in Experiment 2. In addition, there was a significant difference of fluency scores in Stage 2 between averaged cognitive incubation condition and no-incubation control condition in Experiments 2 and 3 when there's no difference in Stage 1. These results indicate that when working on the Instances task or the Consequences task, participants had higher creativity performance after completing a cognitive task during a break compared to having no break. The Alternative Uses task did not produce an incubation effect in the current study (Experiments 1 and 4).

Regarding the effect of the cognitive demand of the interpolated task on the incubation effect (Hypothesis 2), no significant results were found in any experiment. Fluency scores did not differ between the high-demand and low-demand conditions in either Stage 1 or Stage 2, nor was there a difference in the decline in performance from Stage 1 to Stage 2.

Regarding the impact of one's emotion during incubation on the incubation effect (Hypothesis 3), no significant results were found. Fluency scores in positive-, negative- and neutral-emotion conditions were not different from each other in either Stage 1 or Stage 2, and there was no difference for the decline in performance from Stage 1 to Stage 2.

Regarding the consistency of the incubation effect across divergent thinking tasks (Research Question 1), minimal evidence for an incubation effect was found only for the Instances task and the Consequences tasks (Experiments 2 and 3). When comparing the averaged cognitive incubation with the no-incubation control condition, fluency scores in Stage 1 were not different whereas fluency scores in Stage 2 were significantly higher on the Instances task but only near significance in the Consequences task.

Regarding the possible role of openness to new experiences, preference for working in groups and quality of cooperation experience in the incubation effect (Research Question 2), the results were found only in some conditions. In Experiment 1, only in high-demand condition was openness to new experiences correlated with the creativity performance decline. The higher the openness to new experience, the lower the decline in performance from Stage 1 to Stage 2. In Experiment 4, in the positive-emotion condition and the no-incubation control condition, there was a negative relationship with level of preference for working in groups and the amount of decline in creativity performance. The higher the preference for working in groups the smaller the decline in performance from Stage 1 to 2. These results indicate that openness to new experiences and a preference for working in groups are both related to higher group creativity performance. However, given the minimal evidence we found for the incubation effect, and the fact that we only found these correlations in 3 out of 16 tests(i.e., they may be false positives), it is hard to discern their true role in the incubation effect.

We also had two exploratory findings. First, a small to moderate positive correlation was found between quality of cooperation experience and openness to new experience in Experiments 2 to 4. Participants who were more open to new experiences reported a better cooperation experiences. The correlations in Experiments 1 and 4 were also positive but nonsignificant. Second, a strong and stable time effect was also found: participants reported fewer answers in the second stage compared with the first. This indicates an idea exhaustion as time passes.

Some possibilities that might be the reasons why we were not successful at finding expected results are discussed below. First, the creativity tasks employed in the current study may not have been the best for producing an incubation effect. Different tasks have been employed to examine the incubation effect; however, different tasks may not be equally likely to elicit an incubation effect. Though the tasks employed in the current study are all frequently used divergent thinking tasks, there is a possibility that they may not be ideal for a group setting.

Second, the creativity performance index employed (fluency) may not have captured creativity performance fully. Fluency is the number of answers reported. Though it is a frequently used creativity index, it only captures one aspect of performance, the ability to generate a large amount of ideas. Other indices, on the contrary, capture other aspects of creativity performance. For example, uniqueness, the number of answers reported by less than a specific percentage of participants (e.g., 5%) -- captures the ability to generate a good amount of uncommon answers. Participants may report many answers but none of them are unique; thus, though they may have a high fluency score, they may also have a low uniqueness score. Hence, the null results obtained here may be due to the creativity index we employed, and the results may be different when using other indices.

Third, some factors from groups may have influenced the results. In the current study, we employed interactive face-to-face dyads. In groups, there could be aspects that hinder creativity performance, such as evaluation apprehension and production blocking. For example, being afraid of what others will think of their ideas may harm participants' creativity performance.

Fourth, the rest condition may have not been well controlled and fully fulfilled. Though we explicitly required participants to rest quietly, not all participants followed the instructions well. For example, some participants talked with each other and some participants checked their phones,. Also, even when participants sat quietly as the experimenter instructed, we cannot tell whether their brain/mind really rested or not. They may have been thinking of the target task, or mentally engage in other things that prevented them from resting. Hence, the uncertainty of control condition may have also impeded us from finding an incubation effect.

Fifth, regarding the effect of the cognitive demand of the interpolated task, the cognitive demand levels we employed may not be ideal. Groups have higher memory capacity to process information, and the high-demand cognitive task employed in current study may not have been cognitively demanding enough for groups. Thus, our high-demand task may have had a similar level of demand as the low-demand cognitive task.

Sixth, regarding the impact of emotional status induced during incubation on the incubation effect, the emotion inductions may not have had their intended full effect. Participants may not have had the emotions during the whole incubation period. The videos likely did not induce emotions immediately, but instead gradually. Participants may have started to experience the intended emotions at different points within the incubation period, thus leading to participants having intended emotions for different lengths of time. In addition, there might have been lingering effects of the induced emotions that interfered with the incubation effect. The induced emotions may have lingered to the next trial (Stage 1).

Another aspect related to emotional status is the type of emotions induced. We only manipulated emotional valences but did not control emotion type. Participants may have had multiple emotions with similar valences at the same time (e.g., anger, fear, sorrow, etc.) Previous research has found that different emotions of the same valence may influence behavior in different ways. For example, anger is associated with approaching while fear is associated with avoiding; some emotions may activate behaviors while some may inhibit behaviors. Thus, though different emotions induced at the same time have similar valences, they may have different effects on participants' creativity performance.

Lastly, it may be that the incubation effect is less robust than researchers previously thought. Though previous research confirmed that the incubation effect is real, in many previous studies it was not observed. This is important because the incubation effect has been treated as "truth" by researchers and non-researchers alike. It is time to investigate different aspects of incubation, including when it is more (or less) likely to occur.

Conscious and Unconscious Processing in the Incubation Effect

One aspect of incubation involves the cognitive mechanisms underlying the effect when it does occur. One of the most popular hypothesized mechanisms is that the mind unconsciously works on the problem when a person turns their attention to something other than the problem. The real difficulty of testing this mechanism is the lack of direct measurements of unconscious processing. Further, there is not a clear distinction between consciousness and unconsciousness in the groups' shared cognitive resources pool or even in individuals. It is likely that the relationship between consciousness and unconsciousness is that they have partially overlapping resource pools with no fixed cutoff point between conscious and unconscious processing. The best way to think about the role of conscious and unconscious processing during incubation is to look for the relative contribution of each. In other words, we are open to the idea that in any condition, there might be both conscious and unconscious processing and that both may contribute to the incubation effect.

However, tasks of different difficulty levels require different amounts of resources, so that some requiring more conscious resources than others. Rather than figuring out which processing is working during incubation, it is more pertinent to look at the amount of cognitive resources that are available for each type of processing in tasks of different difficulty levels. In a dual-task scenario, working on an extremely easy primary task that requires little conscious resources leaves almost all cognitive resources, both conscious and unconscious, remaining for the other task. In this case, there are enough conscious resources available to process the secondary task effectively. When the primary task gets harder, more conscious resources are occupied, leading to fewer total available cognitive resources for the secondary task, but more unconscious than conscious resources. At the extreme, when the task is extremely hard, all conscious cognitive resources are occupied and any processing of the secondary task is completed with an even further reduced pool of unconscious resources.

Regarding the incubation effect, an empty incubation period (i.e., rest) is associated with the largest amount of conscious processing resources available that can be devoted to the creativity task. An easy interpolated task (e.g., reading newspaper) would lead to fewer conscious processing resources available if any and intact unconscious processing on the creativity task. An incubation period filled with a difficult task (e.g., mental rotation) would result in even fewer processing resources on the creativity task both consciously and unconsciously. Thus, the difficulty level, or to be more precise, the cognitive demand of the interpolated task determines the processing availability during the incubation period.

Though limited, previous research provided some evidence favoring unconscious processing. In a meta-analysis, Sio and Ormerod (2009) coded interpolated tasks employed by various incubation studies as either high- or low-demand tasks. They found that when solving verbal insight problems (e.g., Remote Association Task), a low demand task was associated with larger incubation effects than a rest period. When solving divergent thinking problems (e.g., Consequences task), rest and low demand tasks generated larger incubation effects than did high demand tasks. Baird and his colleagues employed systematically varying demands and found a larger incubation effect under low demand task condition compared to high demand task, rest or no incubation conditions (Baird et al., 2012). Unfortunately, our results provide minimal support for this explanation.

Emotional Valence, Spreading Activation, and the Incubation Effect

Another commonly cited cognitive mechanism underlying the incubation effect is through spreading activation, a mechanism that may be responsible for reading effects. Based on the spreading activation theory, different concepts in memory are located in different distances from each other, either closer or farther. When a core concept is activated, it spreads activation to nearby concepts, making them more accessible to the mind. Concepts located farther from the core concept are less accessible due to insufficient activation. This activation occurs in milliseconds, not minutes, but the theory is useful as a metaphor for understanding the incubation effect. For example, the concepts that are farther away from the core concept in a creativity task would be rare answers. However, under certain situations, when the activation from the core concept spreads far enough to reach these concepts, their accessibility to us is increased.

At least one of such situations, demonstrated by studies listed in previous sections, is when people are in positive moods. In these studies, people in positive moods included more "poorer" exemplars, generated more unusual associates of a concept, and more divergent names for "rice" (i.e., higher divergent thinking performance) We believe that the increased relatedness and interconnections among concepts, the enlarged breadth of concepts, and the broader range of associates obtained by previous research all come from enhanced spreading activation while having positive emotions. On the other hand, negative emotions may have a reversed effect in that they inhibit the spreading activation process. Thus, only limited, close concepts are activated, which results in less overall answers and less divergent answers (i.e., lower divergent thinking performance). However, more caution may be needed on negative emotion influence compared to positive emotion influence due to less consistent results.

Based on the association between emotion and spreading activation, we speculate about the role of spreading activation in the incubation effect. If spreading activation is the mechanism (or one of the mechanisms) that underlies the incubation effect, we should see an impact of emotion on the incubation effect. A condition that benefits the spreading activation process (i.e., positive emotion) may increase the incubation effect compared to a neutral emotion condition. In contrast, a condition which inhibits the spreading activation process (i.e., negative emotion) may result in a smaller incubation effect compared to a neutral emotion condition. Thus, we could expect the magnitude of the incubation effect to be in an orderly pattern across different conditions: positive emotion > neutral emotion > negative emotion > no incubation. Of course, this was not the case in the current studies because there was no effect of emotional state on the incubation effect.

Limitations and Future Directions

We fully understand that no research is perfect, the current study has its own limitations. First, the current study only employed fluency scores as the creativity performance index. As mentioned earlier, this might have impeded us from finding an incubation effect. Thus, multiple indices should be employed in the future to examine an incubation effect in a group setting.

Second, we only employed interactive face-to-face groups in current study. With concerns about aspects of interactive groups that may impede creativity performance, other types of groups may be worth a try, for example, nominal groups where answers are generated by the individuals in the group first and then the group decides as a whole, or electronic brainstorming groups who used technology to share ideas both temporally and simultaneously.

Third, the emotional induction leaves some space for improvement. How to guarantee that participants have the induced emotions for the whole incubation period, as well as how to make participants' emotional status return to baseline before the next trial, both need to be tackled. In addition, instead of only controlling for emotional valence, other types of emotions could also be induced. Inducing a single emotion in each condition instead of multiple emotions may also help detect emotions' effect on the incubation effect.

Fourth, we didn't include a manipulation check for the cognitive demand levels of the interpolated tasks. This made it impossible for us to tell whether the difficulties of cognitive tasks in current study were proper. Further, this makes it impossible for us to tell whether the null results we found were due to improper cognitive demand level settings or that there was not an incubation effect in this scenario. Considering the possibility of not having different enough cognitive tasks in the high- and low-demand conditions in Experiments 1 to 3, a manipulation check of interpolated task cognitive demand should be included in future studies. In the same vein, a pilot study could also be conducted to select adequate cognitive demand levels of interpolated tasks.

Lastly, the current study only employed dyads as participants. Though this was for simplifying the group setting, groups with three or more members should be examined in future research. With more complexity, the influences of more features of group dynamics on the incubation effect could be examined.

Implications and Conclusions

As a widely researched topic, the incubation effect has received surprisingly little research in group context. The current study examined it using dyads, as a small step towards explore a possible group incubation effect. As mentioned earlier, taking a break in the middle of a task is an easy way to improve creativity performance. If a steady group incubation effect could be confirmed, the incubation effect might benefit scenarios as wide-ranging as school and family education, policy making, enterprise training, and therapeutic practice.

Research on the incubation effect in group context could also help further our understanding of the incubation effect. With the working unit changing from individuals to groups, many more possible variations are introduced. For example, group dynamic factors and some individual characteristics, as explored in the current study. By having such knowledge, "perfect" groups might be formed, for example, selecting group members that are likely to boost the incubation effect, which in turn could boost working performance. Future research may also help distinguish between the incubation effect in individuals and in groups. The small to null results obtained in current study may hint that the incubation effect is less likely to happen in groups.

As a summary, the current study was a systematic examination of the incubation effect in a group setting for the first time. Though not robust nor fully consistent across different divergent thinking tasks, an incubation effect might have occurred in the current group setting, but only for two of the three divergent thinking tasks. No effect of the cognitive demand of interpolated tasks or emotional status during the incubation period was found for this group incubation effect. Future research should be designed to address the limitations in current study.

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APPENDIX

Pre-surveys

Surveys 1 – 4 (participant ID: _____)

Welcome to this study, we'd like you first to answer some questions. The first survey asks about your demographic information. The second survey asks about your emotions, and the third survey asks some questions about your personality. The final survey asks about your preferences toward cooperation. There are no "right" or "wrong" answers. Please answer the surveys carefully. Thank you.

Survey 1

DEMOGRAPHIC INFORMATION

Gender: ______ Age: ______

Race(s)/Ethnicity: __________________________

(for describing the pool of participants only)

If you grew up in the U.S., what is the city and state?

City: ___________________________ State: _____________________________

If you grew up outside the U.S., what is the country?

Country: __________________________

Familiarity with the other participant: □Stranger or □Acquaintance or □Good friend

Survey 2

The questions below ask about your current emotional state. Please circle the corresponding number based on your current state.

#	Question	1————————————9								
		Very bad/not at all								very good/extremely
1	How do you feel right now?	1	2	3	4	5	6	7	8	9
2	How worried do you feel right now?	1	2	3	4	5	6	7	8	9
3	How disappointed do you feel right now?	1	2	3	4	5	6	7	8	9
4	How calm do you feel right now?	1	2	3	4	5	6	7	8	9
5	How happy do you feel right now?	1	2	3	4	5	6	7	8	9
6	How content do you feel right now?	1	2	3	4	5	6	7	8	9
7	How tense do you feel right now?	1	2	3	4	5	6	7	8	9
8	How discouraged do you feel right now?	1	2	3	4	5	6	7	8	9
9	How relaxed do you feel right now?	1	2	3	4	5	6	7	8	9

Survey 3

There are 5 choices for each question below, ranging from 0 (totally disagree) to 4 (absolutely agree). Please circle the number according to your actual situation.

0-totally disagree 1-not agree 2-have no idea 3-agree 4-absolutely agree

#	Question	0---------------4				
		Totally disagree------absolutely agree				
1	I have a very active imagination.	0	1	2	3	4
2	Aesthetic and artistic concerns aren't very important to me.	0	1	2	3	4
3	Without strong emotions, life would be uninteresting to me.	0	1	2	3	4
4	I'm pretty set in my ways.	0	1	2	3	4
5	I often enjoy playing with theories or abstract ideas.	0	1	2	3	4
6	I believe letting students hear controversial speakers can only confuse and mislead them.	0	1	2	3	4
7	I try to keep all my thoughts directed along realistic lines and avoid flights of fancy.	0	1	2	3	4
8	I am sometimes completely absorbed in music I am listening to.	0	1	2	3	4
9	I rarely experience strong emotions.	0	1	2	3	4
10	I think it's interesting to learn and develop new hobbies.	0	1	2	3	4
11	I find philosophical arguments boring.	0	1	2	3	4
12	I believe that laws and social policies should change to reflect the needs of a changing world.	0	1	2	3	4
13	I have an active fantasy life.	0	1	2	3	4
14	Watching ballet or modern dance bores me.	0	1	2	3	4
15	How I feel about things is important to me.	0	1	2	3	4
16	Once I find the right way to do something, I stick to it.	0	1	2	3	4
17	I enjoy solving problems or puzzles.	0	1	2	3	4
18	I believe we should look to our religious authorities for decisions on moral issues.	0	1	2	3	4
19	I don't like to waste my time daydreaming.	0	1	2	3	4

20	I am intrigued by the patterns I find in art and nature.	0	1	2	3	4
21	I seldom pay much attention to my feelings of the moment.	0	1	2	3	4
22	I often try new and foreign foods.	0	1	2	3	4
23	I sometimes lose interest when people talk about very abstract, theoretical matters.	0	1	2	3	4
24	I believe that the different ideas of right and wrong that people in other societies have may be valid for them.	0	1	2	3	4
25	I enjoy concentrating on a fantasy or daydream and exploring all its possibilities, letting it grow and develop.	0	1	2	3	4
26	Poetry has little or no effect on me.	0	1	2	3	4
27	I experience a wide range of emotions or feelings.	0	1	2	3	4
28	I prefer to spend my time in familiar surroundings.	0	1	2	3	4
29	I enjoy working on "mind-twister"-type puzzles.	0	1	2	3	4
30	I believe that loyalty to one's ideals and principles is more important than "open-mindedness".	0	1	2	3	4
31	If I feel my mind starting to drift off into daydreams, I usually get busy and start concentrating on some work or activity instead.	0	1	2	3	4
32	Certain kinds of music have an endless fascination for me.	0	1	2	3	4
33	I seldom notice the moods or feelings that different environments produce.	0	1	2	3	4
34	Sometimes I make changes around the house just to try something different.	0	1	2	3	4
35	I have little interest in speculating on the nature of the universe or the human condition.	0	1	2	3	4
36	I consider myself broad-minded and tolerant of other people's lifestyles.	0	1	2	3	4
37	As a child I rarely enjoyed games of make believe.	0	1	2	3	4
38	Sometimes when I am reading poetry or looking at a work of art, I feel a chill or wave of excitement.	0	1	2	3	4
39	I find it easy to empathize-to feel myself what others are feeling.	0	1	2	3	4
40	On a vacation, I prefer going back to a tried and true spot.	0	1	2	3	4

41	I have a lot of intellectual curiosity.	0	1	2	3	4
42	I think that if people don't know what they believe in by the time they're 25, there's something wrong with them.	0	1	2	3	4
43	I would have difficulty just letting my mind wander without control or guidance.	0	1	2	3	4
44	I enjoy reading poetry that emphasizes feelings and images more than story lines.	0	1	2	3	4
45	Odd things-like certain scents or the names of distant places-can evoke strong moods in me.	0	1	2	3	4
46	I follow the same route when I go someplace.	0	1	2	3	4
47	I have a wide range of intellectual interests.	0	1	2	3	4
48	I believe that the "new morality" of permissiveness is no morality at all.	0	1	2	3	4

Survey 4

There are 5 choices for each question below from 1 (totally disagree) to 5 (absolutely agree).

Please circle the number according to your actual situation.

1-totally disagree 2-not agree 3-have no idea 4-agree 5-absolutely agree

#	**question**	**1---------------------------------5** **Totally disagree -----absolutely agree**				
1	I enjoy working in groups.	1	2	3	4	5
2	I would rather study alone than in a group.	1	2	3	4	5
3	I believe people work more effectively in groups than alone.	1	2	3	4	5
4	My creativity is stimulated most when I am in a group.	1	2	3	4	5
5	I find it hard to generate novel ideas in group situations.	1	2	3	4	5
6	Working on a task with others makes me work harder.	1	2	3	4	5
7	I find it easy to work with others.	1	2	3	4	5
8	I would rather do a project by myself than seek the help of others.	1	2	3	4	5
9	I enjoy combining others' ideas with my own.	1	2	3	4	5
10	I would rather do a task that can be completed by myself than one that requires involvement of other individuals.	1	2	3	4	5

Post-surveys

Surveys 5 -6 (participant ID: _____)

Thank you for your work. Now please answer these questions. Some of the questions ask about your emotions and some ask about your cooperation experience. There are no “right” or “wrong” answers. Thank you.

Survey 5

Questions below ask about your current emotional state, please check the corresponding number based on your current state.

#	**Question**	**1——————————————9**								
		Very bad/not at all					**very good/extremely**			
1	How do you feel right now?	1	2	3	4	5	6	7	8	9
2	How worried do you feel right now?	1	2	3	4	5	6	7	8	9
3	How disappointed do you feel right now?	1	2	3	4	5	6	7	8	9
4	How calm do you feel right now?	1	2	3	4	5	6	7	8	9
5	How happy do you feel right now?	1	2	3	4	5	6	7	8	9
6	How content do you feel right now?	1	2	3	4	5	6	7	8	9
7	How tense do you feel right now?	1	2	3	4	5	6	7	8	9
8	How discouraged do you feel right now?	1	2	3	4	5	6	7	8	9
9	How relaxed do you feel right now?	1	2	3	4	5	6	7	8	9

Survey 6

The questions below ask about your attitudes and feelings about the cooperative process during the creativity task. The scale is from 1 (not at all / absolutely no) to 9 (extremely/ very much). Please circle the number based on your actual feeling.

#	Question	1								9
		Not at all/absolutely no				extremely/very much				
1	Are you satisfied with the process of the cooperation task?	1	2	3	4	5	6	7	8	9
2	Are you satisfied with the products of the cooperation task?	1	2	3	4	5	6	7	8	9
3	Are you satisfied with your own performance in the cooperation task?	1	2	3	4	5	6	7	8	9
4	How much contribution do you think you had in the cooperation task?	1	2	3	4	5	6	7	8	9
5	How much contribution do you think your partner had in the cooperation task?	1	2	3	4	5	6	7	8	9
6	How involved in the cooperative task do you think you were?	1	2	3	4	5	6	7	8	9
7	How involved in the cooperative task do you think your partner were?	1	2	3	4	5	6	7	8	9
8	How much effort do you think you put in the cooperative task?	1	2	3	4	5	6	7	8	9

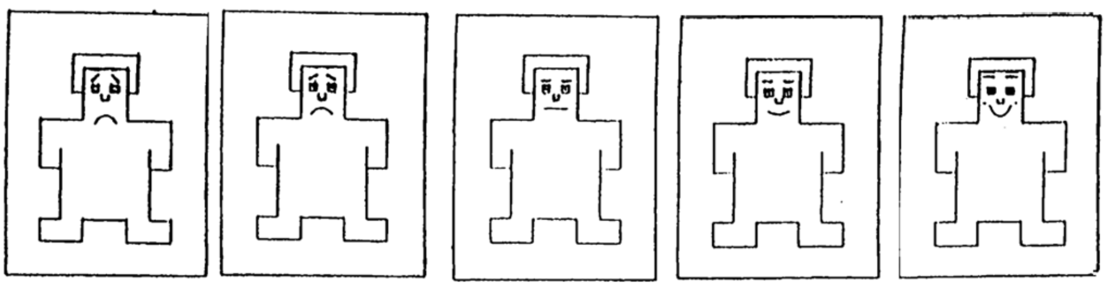
Self-Assessment Manikin (SAM)

Group number: ____________ Condition number: _____________

(@) For the following two questions, please circle the number that best fits your current emotional status.

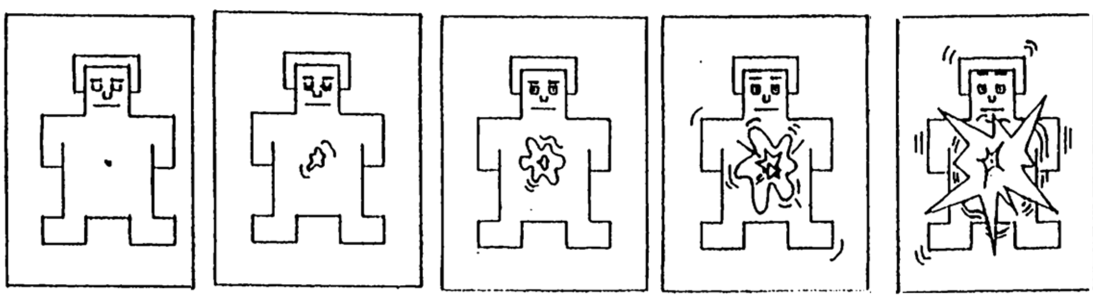
1. Please rate your current emotional valence (how positive/neutral/negative your emotional feelings are):

-4 -3 -2 -1 0 1 2 3 4



2. Please rate your current emotional arousal (the strength of your emotional feelings):

1 2 3 4 5 6 7 8 9



THE UNIVERSITY OF ALABAMA | Research & Economic Development
Office for Research Compliance

November 10, 2021

Qichen Zhao
Department of Psychology
College of Arts & Sciences
The University of Alabama
Box 870348

Re: IRB # 17-OR-219-R3-C "Group Creativity and the Incubation Effect"

Dear Ms. Zhao:

The University of Alabama Institutional Review Board has granted approval for your renewal application. You have also been granted the requested waiver of documentation of informed consent. Your renewal application has been given expedited approval according to 45 CFR part 46. Approval has been given under expedited review category 7 as outlined below:

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The approval for your application will lapse on November 9, 2022. If your research will continue beyond this date, please submit a continuing review to the IRB as required by University policy before the lapse. Please note, any modifications made in research design, methodology, or procedures must be submitted to and approved by the IRB before implementation. Please submit a final report form when the study is complete.

Good luck with your research.

Sincerel[redacted]

Carpantato T. Myles, MSM, CIM, CIP
Director & Research Compliance Officer