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Drinking tea improves convergent creativity performance

Abstract

Tea consumption has been extensively shown to be closely related to physical health and cognitive abilities. However, there are no definite conclusions on the relationship between tea consumption and convergent thinking. Convergent thinking requires top-down cognitive processing, which focuses on searching for an appropriate idea based on well-defined criteria. It is a necessary part of the creative process and is inextricably linked to divergent thinking that requires people to search for many different ideas with less defined criteria within a wider search span. It has been found that tea consumption is beneficial to divergent thinking in creativity. Given that convergent thinking is related to divergent thinking, we hypothesized that drinking tea may also promote convergent thinking. This research was to investigate the enhancing effects of tea on convergent thinking and test its possible mediating mechanism (i.e., the role of positive emotions) and marginal conditions (e.g., the moderating roles of intelligence and tea preference). In Experiment 1, participants completed the Remote Association Test (RAT) which requires the solver to create a meaningful link (word association) that mediates three seemingly unrelated cues (e.g., Same–Tennis–Head is mediated by Match) after drinking tea or water. The results showed that the type of drinks and tea consumption habits had a significant interaction effect on RAT scores.

The participants who drank tea (v.s. water) and had the habit of drinking tea performed best in the RAT. A "split half effect" was found. That is, participants' performance in different groups was significantly different in the second half of the RAT, suggesting that drinking tea leads to persistent problem-solving convergent thinking. Experiment 2 aimed to replicate the findings in Experiment 1 using a different convergent thinking task, namely, riddle tasks, where participants needed to solve riddles with different levels of difficulty. The results revealed that performance in the tea group on the difficult tasks was significantly higher than that in the water group; after controlling for knowledge level and intelligence, the differences in the performance in the medium- and high-difficulty riddle tasks between the two groups were significant. Although no experiments found a mediating effect of positive emotions, Experiment 2 showed that the participants in the tea group were happier and more interested in the task than those in the water group. To conclude, the positive effects of tea drinking on convergent thinking was demonstrated, and the moderating effects of knowledge level, intelligence, and tea drinking habits were elaborated. The results have important practical significance for those who are engaged in creative work or those who are prone to fatigue.

Keywords: Tea Drinking; Convergent Thinking; Creativity Performance; Tea Consumption; "Split half effect"

1. Introduction

Tea consumption ranks second in the world, only to water consumption (Hodgson & Croft, 2010). Many studies have explored the functional effects of tea. It has been found that drinking tea is good for physical health (Ruxton, Phillips, & Bond, 2015; Shen & Chyu, 2016; Hayat, Iqbal, Malik, Bilal, & Mushtaq, 2015), cognition (Einöther & Martens, 2013; Dietz & Dekker, 2017; Kuriyama et al., 2006), and emotion (Einöther & Martens, 2013; Einöther, Rowson, Ramaekers, & Giesbrecht, 2016).

Recently, research on the cognitive impact of tea drinking has focused on creativity. Convergent creativity and divergent creativity involve different cognitive processes. Convergent creativity requires top-down cognitive processing, which focuses on searching for an appropriate idea based on well-defined criteria, while divergent creativity involves less top-down processing, so people can search for many different ideas with less defined criteria within a wider search span. It has been found that tea improves divergent thinking in creative tasks, e.g., the Remote Association Test (RAT, Huang et al., 2018). However, few empirical studies have investigated the effect of tea drinking on convergent thinking (Einöther et al., 2015). Since convergent thinking is an essential human activity (Abu-Akel, Webb, de Montpellier, Von Bentivegni, Luechinger, Ishii, & Mohr, 2020; Shettar & Tewari, 2020), it is worth discovering methods that could improve convergent thinking. The current research will address this issue. We will first review the literature and describe our research proposal.

1.1 Tea and primary cognitive processing

Empirical studies on tea consumption and cognition mainly focus on tea and low-level cognitive processes, namely, attention or alertness level. To date, some studies have specifically explored the effect of black tea on attention performance (Einother

and Martens, 2013). Hindmarch, Quinlan, Moore, and Parkin (1998) compared the effects of coffee, water, and tea with and without caffeine in the critical flicker fusion (CFF) task (an objective means of measuring subjects' ability to distinguish discrete sensory data) and the line analog rating scale (LARS). In the CFF task, subjects are required to discriminate flicker fusion in a set of four light-emitting diodes held in foveal fixation at 1 m. With LARS, subjective ratings of treatment effects are obtained from a series of 100-mm line analog rating scales, where attention is assessed by alertness items. The results showed that caffeinated beverages improved task performance and self-reported alertness, and cognitive performance decreased more slowly over time than performance did with noncaffeinated beverages. Moreover, the study found that tea's attention benefits could not be entirely attributed to caffeine and that other components (e.g., flavonoids, theanine) of tea could also contribute to cognitive benefits. The study showed that subjects who drank caffeinated tea had a significantly greater CFF threshold than those who drank caffeinated water (caffeine concentrations were equal). The study provided preliminary evidence for the beneficial effects of tea on attention-related performance. In their subsequent study, the main effects of 37.5 and 75 mg caffeine in the CFF and LARS tasks, respectively, were successfully replicated (Hindmarch et al., 2000).

A recent study (Bruin, Rowson, Buren, Rycroft, & Owen, 2011) used double-blind placebo-controlled crossover designs and more complex attention tasks to further investigate these effects. Again, accuracy in the attention-switching task was improved after drinking black tea, and the participants in the tea group reported higher levels of

alertness than those in the placebo group.

It can be concluded from the above studies that drinking tea can improve attention and self-reported alertness. Studies on caffeine and the combination of theanine and caffeine further support these conclusions (Giesbrecht, Rycroft, Rowson, & De Bruin, 2010; Kelly, Gomez-Ramirez, Montesi, & Foxe, 2008).

1.2 Tea and cognitive thinking in creativity

convergent thinking, as assumed by Einöther et al. (2015). Einöther et al. (2015) claimed that tea consumption will improve creative problem solving due to increased positive affect compared to a neutral control and to a similar extent as a positive control. Unfortunately, Einöther et al. (2015) did not find significant evidence to support their assumption.

We argue that there are several reasons why no empirical evidence has been found. First, there are problems in the method of measuring creativity. Previous studies have used the classic RAT to measure creativity. This subjective test is very likely to be influenced by individuals' linguistic ability and vocabulary, which were not controlled for in the former studies. In addition, convergent thinking performance is closely related to the level of participants' knowledge and intelligence, which was not considered and controlled for in previous studies. In the current research, we will examine the effect of tea drinking on convergent thinking by addressing all the above methodological issues. Second, the tea-drinking scenes and the individuals tea-drinking habits were very different, which was not controlled for in previous studies. Huang et al. (2018) controlled for the influence of individual tea-drinking habits and tea-making scenario regarding the volume, concentration, and temperature of the tea by preparing the tea in the laboratory in advance, such that they found the effect of tea on divergent thinking. Therefore, we also used the same methods to exclude the influence of those factors.

Based on the above discussion, we propose the following hypothesis:

H1: Drinking tea improves performance in convergent thinking activities.

We will test our research hypothesis in two experiments. In particular, we will

control for the possible marginal conditions of language ability, intelligence, and tea preference and habit. Experiment 1 will test the main effect using the RAT to measure convergent thinking. Experiment 2 will try to replicate the findings in Experiment 1 using another type of convergent thinking task, namely, riddle tasks. In both experiments, we will measure possible, previously mentioned marginal conditions to control for their impacts on convergent thinking performance. In particular, we mainly focused on the acute effect of tea on creativity, and creativity was measured 15-20 minutes after tea drinking. In other words, we are mainly interested in the effects of psychological function related to creativity that may happen in a very short period of time after drinking.

Moreover, we will test the mediating role of emotion in this relationship since previous studies have found that tea drinking promotes positive emotion and mood, which may benefit cognitive thinking (Isen, Labroo, & Durlach, 2004; Desmet & Schifferstein, 2008; Yoto, Motoki, Murao, & Yokogoshi, 2012). Meta-analyses of mood and creativity research have shown that a positive mood leads to higher creativity than a neutral mood (Baas, De Dreu, & Nijstad, 2008; Davis, 2009). De Dreu, Baas, and Nijstad (2008) explained the relationship between mood and creativity through a dual pathway model. Creativity can be achieved through either cognitive flexibility or cognitive perseverance, both of which are mediated by mood. Fisher, Ashkanasy, and Rowe (2012) showed that activating a negative mood had a significant lagged effect on creative process engagement (CPE) whereas activating a positive mood did not, and that activating a positive mood had the strongest association with CPE when both proven goal orientation and supervisory support were high. Therefore, we will also test

another hypothesis:

H2: Positive emotions mediate the effect of drinking tea on convergent thinking.

2. Experiment 1

2.1 Method

manipulated implicitly by serving tea or water during the greeting stage of the experiment, so the participants did not realize that drinking was the crucial part of our study. The participants were randomly assigned to one of two conditions. In that sense, participants are blinded to their condition.

2.1.3 Procedure

In the warming-up stage, the participant arrived at room A as scheduled to wait for the start of the experiment. A receptionist (experimenter A) poured a cup of pre-prepared hot drink (water/tea) in front of the participant. The cups provided to the participants were disposable, which were picked out from a new package in front of every participant. The purpose of this manipulation was to ensure that participants wouldn't refuse the drink for hygienic reasons. To avoid the color, trademark and other factors of the cup affecting participants, the cup was pure white without any pattern or trademark.

Then, the receptionist returned to the seat and asked for participants' personal information, such as the department, major, grade, student ID number, and mobile phone number not only for the payment purpose but also for extending the duration of warming-up stage. To let the participants drink as much as possible, the receptionist also poured herself a cup of the same drink. The warming-up stage lasted for three to five minutes so that the participant had enough time to finish the drink. Then, the receptionist led the participant to room B to perform the experimental task. After the participant entered room B, the receptionist measured how many milliliters the participant drank with a measuring tube and recorded it.

In room B, the experiment was conducted by experimenter B who didn't know which drink the participant drank. The participant was asked to complete the tasks on a computer. The participant completed the Mood Inventory scale, RAT, Raven Advanced

Progressive Matrices Test, Mood Inventory scale, tea consumption habits and attitudes scale, and demographic statistics questionnaire (including Chinese and math scores on the college entrance examination) in order. Experimenter B checked whether the tasks were successfully submitted and then directed the participant to go to room A to ask the receptionist for the payment. The sessions lasted 35 minutes in total.

2.1.4 Measurements

Emotional state: The mood inventory (MI) scale was used to measure the participants' emotional state during the experiment. This scale was taken from Phillips, Bull, Adams, and Fraser (2002) and Oaksford, Morris, Grainger, and Williams (1996) and used to measure the participants' mood after drank the beverage and after they completed the convergent thinking task. In this study, the English version of Chermahini and Hommel (2012) was used for the translation into Chinese. All scale items underwent a back-translation process (Brislin, 1986) to ensure the internal validity of our translated scales. The scale has ten items: six measuring happiness (Cronbach's alpha = 0.89), two measuring physical arousal (Cronbach's alpha = 0.88), and two measuring anxiety (Cronbach's alpha = 0.93).

Remote Association Test (RAT): The Chinese version of RAT compiled by Xiao, Yao, and Qiu (2016) was adopted in this study and contained 30 items. In each item there are three words (e.g., Same–Tennis–Head"), and participants are asked to make association among the three words (e.g., "please give a meaningful link by figuring out a word (word association) that mediates the three words"). The scale has good criterion validity, with a correlation coefficient of 0.34 with the Raven test and coefficients of 0.18 and 0.28 with the Torrance Test of Creativity Test (TTCT) and RCAB, respectively. In our study, the participants had 10 minutes to complete the test.

Level of knowledge and intelligence: Previous studies have shown that convergent

thinking is related to knowledge and intelligence (Lee & Therriault, 2013; Ritter, Abbing & Van Schie, 2018), so these factors needed to be controlled for. Xiao, Yao, and Qiu’s (2016) Chinese version of the RAT also found that the participants' RAT scores were moderately correlated with their intelligence (Raven's test) and significantly correlated with their Chinese and math scores. Therefore, in this study, the Chinese and mathematics scores of the participants on the national standardized college entrance examination were selected as one index of the level of knowledge and intelligence of the participants, and the scores of the participants in the Raven’s Advanced Progressive Matrices (APM) were selected as another index. In consideration of the total duration, only half of the questions on the APM were used in this study (18 odd-numbered items were selected). Since the Spearman-Brown split-half reliability of the parity score on the APM in Barrow's (1990) study was 0.82, we believed that it was reasonable to select half of the questions. The participants were given 10 minutes to complete the questions.

The participants were also asked to report their past Chinese and math scores on the national standardized college entrance examination. The two questions were as follows: "What is your past Chinese score in the college entrance examination? " and "What is your past math score in the college entrance examination?"

Tea consumption habits and attitudes scale: Due to the influence of tea drinking behavior on participants' physical health and psychological aspects, the study conducted by Einöther et al. (2015) only recruited participants who were habitual tea drinkers (those who drank more than 5 cups of tea a week). They believed that positive emotions would be generated when people who were regular tea drinkers drank their favorite drink in the lab, so we also asked the subjects whether they drank tea and used this as a control variable in this study. In addition, studies on caffeine conducted by Cook, Beaven, Kilduff, and Drawer (2012) showed that even when taking a placebo,

participants could show the same stimulatory effect as when consuming actual caffeine, suggesting that participants' beliefs about drinks may also affect the effects of drinks on them. Thus, we also measured one's attitude towards the role of tea because if people believe that drinking tea makes them happier, calmer and more alert, it may also affect whether it actually works for them. We asked three questions that were rated on a 9-point Likert scale (*1* = "totally disagree", *9* = "totally disagree"): "Do you believe in tea as a pick-me-up?" "Do you believe that drinking tea makes people happier? ", " Do you think tea makes you calmer?"

2.2 Results

2.2.1 Statistical analysis

We used SPSS 22.0 to analyze our data. ANCOVA was used to determine the main effect of tea on performance in the RAT and the moderating effects of beverage type and tea-drinking habit.

2.2.2 Main effect

Descriptive statistics showed that RAT scores were significantly correlated with gender, and the scores of males were lower than those of females, which were also significantly correlated with age and educational background (see Table 1).

[insert Table 1 about here]

Using ANCOVA controlled for gender, APM scores, education, Chinese and math scores on the college entrance examination, age, and drink volume, we found that, consistent with our hypothesis, the participants in the tea group had significantly higher RAT scores (M = 13.89, SD = 6.00) than those in the water group (M = 12.94, SD = 6.00) [$F(1, 34) = 5.09$, $p = 0.035$, $\eta^2_p = 0.195$, *observed power* = 0.576].

2.2.3 Moderating effects

Further analysis showed that there was a marginally significant interaction between

the type of drink (drinking water/drinking tea) and whether or not the participants usually drank tea [$F(1, 34) = 4.23$, $p = 0.052$, $\eta^2_p = 0.168$, *observed power* = 0.501]. Specifically, in the tea group, 14 participants who drank tea at ordinary times had the highest convergent thinking creativity scores ($M = 23.20$, $SD = 3.01$), which was much higher than those who did not usually drink tea ($M = 13.11$, $SD = 1.52$). The difference between the tea group ($M = 11.91$, $SD = 3.24$) and the water group ($M = 10.84$, $SD = 1.84$) was relatively small for participants who did not usually drink tea (see Figure 1).

[insert Figure 1 about here]

The main effect of participants' Raven test scores on RAT scores was significant [$F(1, 34) = 6.24$, $p = 0.021$, $\eta^2_p = 0.229$, *observed power* = 0.664]. The Pearson correlation coefficient between the participants' Raven test scores and RAT scores was 0.300 ($p = 0.060$). This is similar to the results of Xiao, Yao, and Qiu's (2016) research, showing that scores on the Chinese version of the RAT were correlated with the intelligence levels of the participants.

After controlling for gender, drink volume, attitude towards tea, age, and educational background, MANOVA revealed no significant differences between emotional states reported by the participants in the tea group and in the water group, both immediately after drinking tea and after completing the RAT and Raven tasks.

Finally, similar to previous studies (Huang et al., 2018), this study found the "split half effect". The scores on the first half (15 questions) and the second half of the RAT were separately scored and then added to the MANOVA model. After controlling for the same variables, we found no significant differences [$F(1, 34) = 3.30$, $p = 0.084$, $\eta^2_p = 0.136$, *observed power* = 0.410] in the RAT scores from the first half between the tea group and the water group. However, with the RAT scores from the second half, the scores of participants in the tea group ($M = 8.00$, $SD = 2.83$) were significantly higher

than those in the water group (M= 7.35, SD = 2.85) [$F(1, 34) = 5.90$, $p = 0.024$, η^2_p = 0.219, *observed power* = 0.639], suggesting that tea leads to persistent problem-solving convergent thinking. We call this phenomenon the "split half effect".

2.3 Discussion

The results provide preliminary support for our hypothesis that drinking tea can enhance performance in convergent thinking tasks, and the effect was stronger for people who usually drink tea. This study first demonstrated the role of tea in enhancing convergent thinking. It is worth noting that in both cases, the participants did not drink much tea. Moreover, the participants did not spend much time on the task. That is, even if you drink a limited amount of tea (89.57 ml on average, which is not significantly different from 89.74 ml of water in the water group), tea may still enhance performance in convergent thinking tasks. This result indicated that the tea-drinking event itself (rather than the biological components of tea) played an enhancing

needs to be further evaluated.

was the mechanism for explaining how drinking tea significantly improved convergent thinking. There are several possible explanations. First, our experiment did not include the tea preparation process that affects emotion (Dohle, Rail, & Siegrist, 2014). Second, unlike previous studies (Einöther et al., 2015, 2016), we did not purposely recruit tea drinkers as participants. We were interested in a more generalized effect of tea consumption on convergent thinking for common people. However, tea was not liked by everyone. Only a few of our participants had tea drinking habits. The four most frequently consumed beverages reported by participants were water, juice, carbonated beverages, and milk tea, all of which were sweet drinks except for water. It has been shown that emotion is related to food and beverage consumption, especially to their sensory properties, e.g., sweet taste

is related to happiness and surprise, while bitter taste is related to anger and disgust (Rousmans, Robin, Dittmar, & Vernet-Maury, 2000). Hence, participants who did not have tea-drinking habits and were accustomed to sweet drinks might experience negative emotions caused by a bitter taste and unfamiliar beverage, which may offset any positive emotions elicited by the tea.

We attempted to determine the psychological mechanisms that mediated the performance difference shown by the two groups of participants within such a short period of time. Therefore, in Experiment 2, we explored other possible mediating mechanisms. In addition, we wanted to confirm whether the result regarding the effects of tea on convergent thinking task performance in Experiment 1 using the RAT to measure convergent thinking creativity could be replicated through other types of creative tasks. Hence, in Experiment 2, we used riddle tasks to measure convergent thinking. With this design, we tested whether the influence of tea on different convergent thinking tasks could be universal.

3. Experiment 2

The research intends to systematically replicate the research in Experiment 1 and determine whether tea can promote performance in other types of convergent thinking tasks. Therefore, we replaced the RAT with riddle tasks in this experiment.

Additionally, we measured participants' motivation and involvement to control for the impact of these factors on convergent thinking performance.

3.1 Method

3.1.1 Participants

A total of 60 (19 males) participants were recruited through the Internet and WeChat. After controlling for the intelligence level of the participants, 59 valid data points were obtained. The participants were full-time undergraduate or graduate

students at Peking University, with an average age of 21.82 (*SD* = 2.47). Each participant received $6 as a reward for participating in the experiment.

3.1.2 Design

This experiment included two drink conditions: a cup of black tea (the brand was Lipton, but the participant was unaware of the brand) and a cup of water, both of which were approximately 260 ml, and the temperature was 42°C. Under both conditions, the amount drank (ml) by the participants was recorded. The participants were randomly assigned to one of two conditions.

3.1.3 Procedure

The reception process and precautions were the same as in Experiment 1. Then, the participants entered another designated room and were guided by another experimenter to complete the experimental task on a computer. The participants completed the emotional mood inventory (MI) scale, riddle task 1, motivation and involvement scale 1, riddle task 2, motivation and involvement scale 2, Raven Advanced Progressive Matrices Test, motivation and involvement scale 2, mood inventory (MI) scale, tea consumption habits and attitude scale, and the final demographic questionnaire (including Chinese and math scores in the college entrance examination). The session lasted 40 minutes in total.

3.1.4 Measurements

The measurements of demographic variables, knowledge level, and intelligence level of the participants were consistent with the materials used in Experiment 1. The remaining materials were as follows:

***Chinese riddle tasks*:** There are two riddle tasks used in this study, taken from Chen Li's (2008) research. Riddle task 1 consisted of 10 pairs of medium difficulty riddles (average prototype heuristic rate was 0.58). Riddle task 2 consisted of 10 pairs of high

difficulty riddles (average prototype heuristic rate was 0.14). In this experiment, the participants learned the prototype riddles first. The participants were presented with both the question and the answer of the prototype riddles at the same time (“ ”, meaning that "you couldn't remember with a heart and couldn’t see with eyes," and the answer is “ ”(lost something) (see the Appendix for details). They needed to solve riddle tasks 1 and 2 based on the corresponding method they learned from the prototype riddles. The participants were given 3 minutes to complete each task, and two riddle tasks together took 6 minutes.

***Tea consumption habits and attitude scale*:** In addition to the items used in Experiment 1, we also added a scale about the participant's impression of the experimenter. It contained 2 additional items: "What do you think of the receptionist's enthusiasm level?" and "What do you think of the receptionist happiness level?" (rated on a 9-point Likert scale: 1 was “the lowest” and 9 was “the highest”). We added this scale as an operational test to confirm that the way the participants were treated would not affect the experimental results.

Motivation and involvement scale: Based on Einöther et al.'s (2016) research, we adapted the motivation and involvement scale. Whenever a participant completed a task, we asked the participant questions about motivation and involvement. There were 5 items in total: "What is your concentration level in the past X minutes?", "What is your involvement level with the task in the past X minutes?", "How much happiness did you feel in the past X minutes?", "How happy have you felt in the past X minutes?", and "How much stress have you experienced in the past 10 minutes?" The ratings were scored on a 9-point Likert scale (1 was “the lowest” and 9 was “the highest”).

3.2 Results

3.2.1 Data checks

The results of the operation test showed that there were no significant differences between the impressions of the experimenters reported by the tea group participants and the water group participants. The descriptive statistics of the main variables are shown in Table 2.

3.2.2 Main effect

The participants' scores on the two riddle tasks were summed to obtain a total score, which represented the convergent thinking score (see Figure 2). We found that after controlling for the participants' Chinese scores, math scores, intelligence levels and tea-drinking habits, the scores of the tea group participants on the riddle task (M = 10.94, SD = 2.86) were significantly higher than those of the water group (M = 9.00, SD = 3.01) [$F(1, 58) = 6.27$, $p = 0.015$, $\eta^2_p = 0.106$, *observed power* = 0.691].

[Insert Figure 2 about here]

The results (see Table 2) showed that there was a significant positive correlation between the first and second riddle tasks. The Raven scores were significantly positively related to the scores of the two riddle tasks; The type of the drinks influenced the performance of the second part of the riddle task: Participants who drank tea had higher scores in the second riddle task than those who drank water. The math scores on the college entrance examination were significantly positively related to the Raven scores and the Chinese scores on the college entrance examination.

MANOVA showed that participants in the tea group had significantly higher scores (M = 3.41, SD = 1.52) in the second riddle task than those in the water group [F (1, 58) = 5.29, p = 0.025, η^2_p=0.091, *observed power* = 0.617]. The difference between the scores for the tea group participants (M = 7.53, SD = 2.01) and the water group participants (M = 6.59, SD = 2.31) on the medium difficulty riddle task was not significant [$F(1, 58) = 2.95$, p =0.092, η^2_p= 0.053, *observed power* = 0.392].

[Insert Table 2 about here]

3.2.3 Moderating effects

Furthermore, the influence of participants' level of interest and involvement in the task was analyzed through ANCOVA. After controlling for factors such as gender, age, education, milliliters consumed, Raven test scores, Chinese scores, and math scores, it was found that there were no significant differences in the participants' motivation and involvement in riddle tasks 1 [F (1, 58) = 0.104, p = 0.748] and 2 [F (1, 58) = 0.003, p = 0.956] between the two groups.

Similar to Experiment 1, we did not find a main effect of drinks on emotion either before or after cognitive tasks.

3.3 Discussion

Experiment 2 replicated the results of Experiment 1, suggesting that drinking tea can significantly contribute to convergent thinking. We observed the same effect of drinking tea in two different convergent thinking tasks, including the RAT and riddle task, providing substantial evidence of the consistent positive effect of drinking tea on convergent thinking, especially convergent thinking in semantics.

The results of the research by Einöther et al. (2015) showed that the response time in the tea group was faster than that in the water group (marginally significant), while there were no significant differences in the simple and difficult RAT scores between the

have been due to a ceiling effect, which means that both groups could do well because the task was relatively easy, and any differences are not likely to be significant. This means that the role of tea drinking was mainly reflected in improved performance in the high difficulty creative tasks. Our research showed that participants' intelligence level and task difficulty should be taken into more consideration in the design of experiments.

4. General Discussion

The purpose of our study was to test whether tea drinking improved convergent thinking and whether emotions mediated this effect. Experiments with two different tasks produced similar findings. Experiment 1 showed that drinking tea resulted in better performance on the RAT than drinking water. Experiment 2 repeated the results of Experiment 1 with a different convergent thinking task (solving riddles) and showed that those who drank tea performed better than those who drank water on difficult riddle tasks. Experiment 2 also found that participants' knowledge level, intelligence level, and task difficulty had moderating effects on the impact of tea drinking on convergent thinking task performance.

Our study was the first to demonstrate a main effect of tea drinking on convergent thinking, which is consistent with Einöther et al.'s (2016) hypothesis. Although the study by Einöther et al. (2016) did not find a significant effect, the direction of their results was consistent with the hypothesis. Our results may have been due to various reasons, such as consideration of the moderating effects of intelligence level and knowledge level and controlling for variables such as beverage temperature and concentration. Our study used more rigorous experimental methods and procedures to demonstrate that tea enhanced convergent thinking, which could be a summary of previous research and

biological composition of the tea. The results of Einöther and Martens (2013) showed that two biological components, caffeine and theanine, are beneficial to attention, and attention is an essential part of cognitive function. A cup of tea (250 ml) typically contains 35-61 mg (average: 48 mg) of caffeine and 4.5-22.5 mg (average: 13.5 mg) of theanine. In most previous experiments examining tea's effects on cognitive performance, the tea contained more than 50 mg of caffeine or 10 mg theanine (Bryan, 2008). In the present experiment, our participants absorbed relatively small amounts of tea ingredients (most of our participants drank approximately 180 ml of tea, which may contain less than the amount of caffeine and theanine consumed in a typical study.)

Second, there are limitations in our samples. On the one hand, the sample sizes in our studies were relatively small. The sample size was determined by referring to the classical research paradigm in this field. With reference to previous classic studies (Einöther et al., 2015, 2016; Huang et al., 2018), the sample sizes of the two studies in this paper were set at 40 and 60. Further study could enlarge the sample size to replicate the result. On the other hand, knowledge level and intelligence level were important control variables in our research, but our participants' knowledge level and intelligence level were high. Most participants were undergraduate students at Peking University, a leading university in China, and their intelligence level and knowledge level far exceed the average level. It is worth considering whether our experimental results can be replicated if our participants had more diverse levels of intelligence and knowledge. However, we assume that the effect may be more significant for people with common levels of knowledge and intelligence because knowledgeable people may not need to drink much tea to solve difficult intellectual tasks.

Third, time between tea intake and testing is short. But after tea intake, participants had to answer some questions about their information, such as the department, major,

grade, student number, and mobile number while drinking tea, which took 3-5 minutes. Then, the receptionist would lead the participant to room B where the Experimenter directed the participant to perform the experimental tasks. In room B the participant would complete MI scale first and then, complete the testing of dependent variable. All of the activities will cost 15-20 minutes which is enough for tea to take effect (Einöther et al., 2015).

In short, drinking tea can enhance performance in creative thinking tasks. Future research should focus on specific mechanisms and clarify which variables moderate the impact of tea consumption on convergent thinking. There are several important research directions for the future.

First, the expansion of ecological validity needs to extend laboratory experiments to actual tea drinking environments as well as to different cultural environments.

The second is the exploration of mediating mechanisms. Previous research has found that people tend to associate tea drinking with a specific set of personality traits, such as smart, creative, elegant, confident, and stable (Lara et al., 2011). It may be that when participants are stimulated by tea, the mental representation of a tea drinker is also activated, and they unconsciously think that they should be smarter and more creative. Another factor worth considering is the level of attention. Previous studies have shown that caffeine and theanine in tea can improve attention (e.g., Hindmarch et al., 2000) and performance in attention tasks and attention plays a very important role in other advanced cognitive processes, especially the creative process (Einöther et al., 2015; Huang et al., 2018).

The third is to explore at what stage of creativity tea takes effect. The American psychologist Runco (2004) suggested that the creative process includes six basic stages. We approximated that the effect of tea on creativity is most likely to occur in the

inspiration stage when creative ideas transferred from the preconscious processing into conscious awareness (Kounios & Beeman, 2009). This is a time when ideas explode and require rich attention resources (Burton, 1999). In the future, we can explore the differential impacts of tea consumption at each stage.

Finally, we can explore the long-term and short-term effects. At present, research on tea and creativity has mainly focused on the immediate effects of tea. Engagement with these creativity tasks begins after a few minutes of drinking tea (Einöther et al., 2015; Huang et al., 2018). At this time, the pharmacological effects of the tea chemicals have not started to fully work, which shows that it is the psychological effects of tea that is active. Over long periods, will long-term tea drinking also improve performance in creative activities? This notion needs further verification.

Ethic Statement

The research was conducted in compliance with all APA Ethical Guidelines for the treatment of human participants. Neither the manuscript nor the data have been published previously, nor are they under consideration for publication elsewhere, and its publication is approved by all authors.

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Author Contributions

L.W. conceived the main research idea. L.W. and Y.H. made the research design. Y.H. ran the experiments. Y.H., J.Y., and L.W. performed the statistics. Y.J. and L.W. were responsible for making the first English draft of the manuscript. All authors were involved in the manuscript preparation.

References

Abu-Akel, A., Webb, M. E., de Montpellier, E., Von Bentivegni, S., Luechinger, L., Ishii, A., & Mohr, C. (2020). Autistic and positive schizotypal traits respectively predict better convergent and divergent thinking performance. *Thinking Skills and Creativity*, 36, 100656. https://doi.org/10.1016/j.tsc.2020.100656

Baas, M., De Dreu, C. K. W., & Nijstad, B. A. (2008). A meta-analysis of 25 years of mood-creativity research: Hedonic tone, activation, or regulatory focus? *Psychological Bulletin, 134*(6), 779-806. doi:10.1037/a0012815

Barrow, R. (1990). Achieving extraordinary ends - An essay on creativity. *Interchange, 21*(4), 81-82. doi:10.1007/bf01810096

Bryan, J. (2008). Psychological effects of dietary components of tea: Caffeine and L-theanine. *Nutrition Reviews, 66*(2), 82-90. doi:10.1111/j.1753-4887.2007.00011.x

Burton, L. (1999). Why is intuition so important to mathematicians but missing from mathematics education? *For the Learning of Mathematics, 19*(3), 27-32. doi: www.jstor.org/stable/40248307

Canli, T., Omura, K., Haas, B. W., Fallgatter, A., Constable, R. T., & Lesch, K. P.

(2005). Beyond affect: A role for genetic variation of the serotonin transporter in neural activation during a cognitive attention task. *Proceedings of the National Academy of Sciences, 102*(34), 12224-12229. doi:10.1073/pnas.0503880102

Canli, T., Qiu, M., Omura, K., Congdon, E., Haas, B. W., Amin, Z., . . . Lesch, K. P. (2006). Neural correlates of epigenesis. *Proceedings of the National Academy of Sciences, 103*(43), 16033-16038. doi:10.1073/pnas.0601674103

Chermahini, S. A., & Hommel, B. (2012). Creative mood swings: Divergent and convergent thinking affect mood in opposite ways. *Psychological Research-Psychologische Forschung, 76*(5), 634-640. doi:10.1007/s00426-011-0358-z

Cook, C., Beaven, C. M., Kilduff, L. P., & Drawer, S. (2012). Acute caffeine ingestion's increase of voluntarily chosen resistance-training load after limited sleep. *International Journal of Sport Nutrition and Exercise Metabolism, 22*(3), 157-164. doi:10.1123/ijsnem.22.3.157

Davis, M. A. (2009). Understanding the relationship between mood and creativity: A meta-analysis. *Organizational Behavior and Human Decision Processes, 108*(1), 25-38. doi:10.1016/j.obhdp.2008.04.001

De Bruin, E. A., Rowson, M. J., Van Buren, L., Rycroft, J. A., & Owen, G. N. (2011). Black tea improves attention and self-reported alertness. *Appetite, 56*(2), 235-240. doi:10.1016/j.appet.2010.12.011

De Dreu, C. K. W., Baas, M., & Nijstad, B. A. (2008). Hedonic tone and activation level in the mood-creativity link: Toward a dual pathway to creativity model. *Journal of Personality and Social Psychology, 94*(5), 739-756. doi:10.1037/0022-3514.94.5.739

Desmet, P. M. A., & Schifferstein, H. N. J. (2008). Sources of positive and negative emotions in food experience. *Appetite,* 50(2-3), 290-301.

doi:10.1016/j.appet.2007.08.003

De Dreu, C. K., Baas, M., & Nijstad, B. A. (2008). Hedonic tone and activation level in the mood–creativity link: Toward a dual pathway to creativity model. *Journal of Personality and Social Psychology*, *94*(5), 739–756. doi:10.1037/0022-3514.94.5.739

Dietz, C., & Dekker, M. (2017). Effect of green tea phytochemicals on mood and cognition. *Current Pharmaceutical Design, 23*(19), 2876-2905. doi:10.2174/1381612823666170105151800

Dohle, S., Rail, S., & Siegrist, M. (2014). I cooked it myself: Preparing food increases liking and consumption. *Food Quality and Preference, 33*, 14-16. doi:10.1016/j.foodqual.2013.11.001

Einöther, S. J., & Martens, V. E. (2013). Acute effects of tea consumption on attention and mood. *American Journal of Clinical Nutrition, 98*(6), 1700S-1708S. doi:10.3945/ajcn.113.058248

Einöther, S. J. L., Baas, M., Rowson, M., & Giesbrecht, T. (2015). Investigating the effects of tea, water and a positive affect induction on mood and creativity. *Food Quality and Preference, 39*, 56-61. doi:10.1016/j.foodqual.2014.06.016

Einöther, S. J. L., Rowson, M., Ramaekers, J. G., & Giesbrecht, T. (2016). Infusing pleasure: Mood effects of the consumption of a single cup of tea. *Appetite, 103*, 302-308. doi:10.1016/j.appet.2016.04.003

Giesbrecht, T., Rycroft, J. A., Rowson, M. J., & De Bruin, E. A. (2010). The combination of L-theanine and caffeine improves cognitive performance and increases subjective alertness. *Nutritional Neuroscience, 13*(6), 283-

and other beverages on aspects of cognition and psychomotor performance. *Psychopharmacology, 139*(3), 230-238. doi:10.1007/s002130050709

Hindmarch, I., Rigney, U., Stanley, N., Quinlan, P., Rycroft, J., & Lane, J. (2000). A naturalistic investigation of the effects of day-long consumption of tea, coffee and water on alertness, sleep onset and sleep quality. *Psychopharmacology, 149*(3), 203-216. doi:10.1007/s002130000383

Hodgson, J. M., & Croft, K. D. (2010). Tea flavonoids and cardiovascular health. *Molecular Aspects of Medicine, 31*(6), 495-502. doi:10.1016/j.mam.2010.09.004

Hong, Y.-y., Morris, M. W., Chiu, C.-y., & Benet-Martinez, V. (2000). Multicultural minds: A dynamic constructivist approach to culture and cognition. *American Psychologist, 55*(7), 709-720. doi:10.1037/0003-066X.55.7.709

Huang, Y., Choe, Y., Lee, S., Wang, E., Wu, Y., & Wang, L. (2018). Drinking tea improves the performance of divergent creativity. *Food Quality and Preference, 66*, 29-35. doi:10.1016/j.foodqual.2017.12.014

Isen, A. M., Labroo, A. A., & Durlach, P. (2004). An influence of product and brand name on positive affect: Implicit and explicit measures. *Motivation and Emotion, 28*(1),43–63. doi:10.1023/B:MOEM.0000027277.98917.9a

Kelly, S. P., Gomez-Ramirez, M., Montesi, J. L., & Foxe, J. J. (2008). L-theanine and caffeine in combination affect human cognition as evidenced by oscillatory alpha-band activity and attention task performance. *The Journal of Nutrition, 138*(8), 1572S-1577S.

Kounios, J., & Beeman, M. (2009). The Aha! Moment The Cognitive Neuroscience of Insight. *Current Directions in Psychological Science*, *18*(4), 210–216. doi: 10.1111/J.1467-8721.2009.01638.X

Kuriyama, S., Hozawa, A., Ohmori, K., Shimazu, T., Matsui, T., Ebihara, S., . . . Tsuji, I.

(2006). Green tea consumption and cognitive function: a cross-sectional study from the Tsurugaya Project. *American Journal of Clinical Nutrition, 83*(2), 355-361. doi:10.2307/40064471

Lee, C. S., & Therriault, D. J. (2013). The cognitive underpinnings of creative thought: A latent variable analysis exploring the roles of intelligence and working memory in three creative thinking processes. *Intelligence (Norwood), 41*(5), 306-320. https://doi.org/10.1016/j.intell.2013.04.008

Li, C., Qing, L, Z., Xia, Y., Ying. Z., Xianghui, L., & Yi, C. (2008). The Emotion Promoting Effect in the Logogriph Activation of Chinese Characters. *Acta Psychologica Sinica, 40*(02), 127-135. doi:10.7666/d.y1263408

Oaksford, M., Morris, F., Grainger, B., & Williams, J. M. G. (1996). Mood, reasoning, and central executive processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*(2), 476-492. doi:10.1037/0278-7393.22.2.476

Phillips, L. H., Bull, R., Adams, E., & Fraser, L. (2002). Positive Mood and Executive Function: Evidence From Stroop and Fluency Tasks. *Emotion, 2*(1), 12-22. doi:10.1037/1528-3542.2.1.12

Ritter, S.M., Abbing, J., & Van Schie, H.T. (2018). Eye-closure enhances creative performance on divergent and convergent creativity tasks. *Frontiers in Psychology 9*(13). doi:10.3389/fpsyg.2018.01315.1

Rousmans, S., Robin, O., Dittmar, A., & Vernet-Maury, E. (2000). Autonomic nervous system responses associated with primary tastes. *Chemical Senses, 25*(6), 709-718. doi:10.1093/chemse/25.6.709

Runco, M. (2004). Creativity. *Annual Review of Psychology, 55*, 657-687. doi:10.1146/annurev.psych.55.090902.141502.

Ruxton, C., Phillips, F., & Bond, T. (2015). Is tea a healthy source of hydration? *Nutrition Bulletin, 40*(3), 166-176. doi:10.1111/nbu.12150

Shen, C.-L., & Chyu, M.-C. (2016). Tea flavonoids for bone health: from animals to humans. *Journal of Investigative Medicine, 64*(7), 1151-1157. doi:10.1136/jim-2016-000190

Shettar, A., M, V., & Tewari, P. (2020). Categorizing student as a convergent and divergent thinker in problem-solving using learning analytics framework. *Procedia Computer Science,* 172, 3-8. https://doi.org/10.1016/j.procs.2020.05.001

To, M. L., Fisher, C. D., Ashkanasy, N. M., & Rowe, P. A. (2012). Within-person relationships between mood and creativity. *Journal of Applied Psychology, 97*(3), 599-612. https://doi.org/10.1037/a0026097

Yoto, A., Motoki, M., Murao, S., & Yokogoshi, H. (2012). Effects of L-theanine or caffeine intake on changes in blood pressure under physical and psychological stresses. *Journal of Physiological Anthropology, 31*(1), 28-36. doi:10.1186/1880-6805-31-28.

Table 1. *Descriptive Statistical Results of The Main Variables (Experiment 1)*

		Mean	*SD*	1	2	3	4	5	6	7	8	9
1	Gender	-	-									
2	Education	2.43	.50	-.10								
3	Age	22.93	2.47	-.13	.32*							
4	Tea / water	.48	.51	-.04	-.09	.04						
5	Whether to drink tea	1.65	.48	-.22	-.09	-.07	-.14					
6	Drinking amount(ml)	89.65	53.15	-.26	.16	-.01	.00	-.25				
7	RAT score	12.48	6.32	.34*	-.11	-.02						

Note. $N = 40$. * $p < .05$.

Table 2. *Descriptive Statistical Results of The Main Variables (Experiment 2)*

		Mean	*Var*	1	2	3	4	5	6	7	8	9	10
1	Gender	-	-										
2	Education	21.82	2.47	-.05									
3	Age	2.33	.51	-.30*	.76**								
4	Tea / water	.47	.50	-.08	.11	.07							
5	Whether to drink tea	1.62	.49	-.24	-.16	-.14	.19						
6	Drinking amount(ml)	76.78	56.80	**-.28***	.08	.03	.00	.00					
7	Riddle1 score	7.07	2.19	-.01	-.25	-.21	-.23	-.07	-.21				
8	Riddle2 score	2.95	1.55	.19	-.17	-.11	**-.32***	-.20	.03	**.32***			
9	Raven score	12.25	2.90	-.13	-.11	-.04	.02	.04	.02	**.34****	**.27***		
10	Chinese score	120.03	10.08	.20	-.21	-.26	-.13	-.17	.04	.10	**.32***	.17	
11	Math score	132.69	14.19	-.19	-.31	-.19	-.01	.05	.04	.22	.17	**.44****	**.29***

Note. $N = 59$. * $p < .05$. ** $p < .01$.

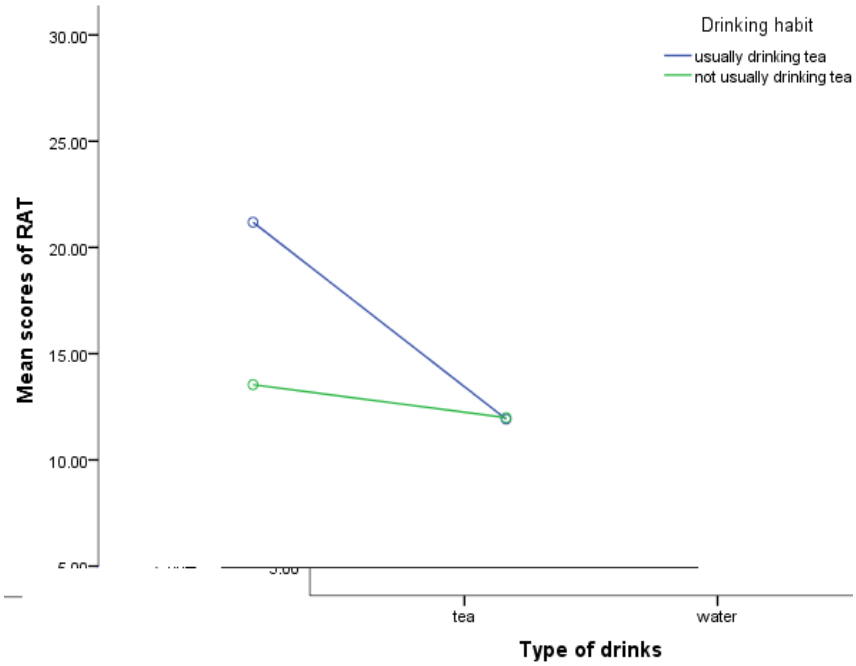

Figure 1. Moderating effect of drinking habit on RAT scores (Experiment 1).

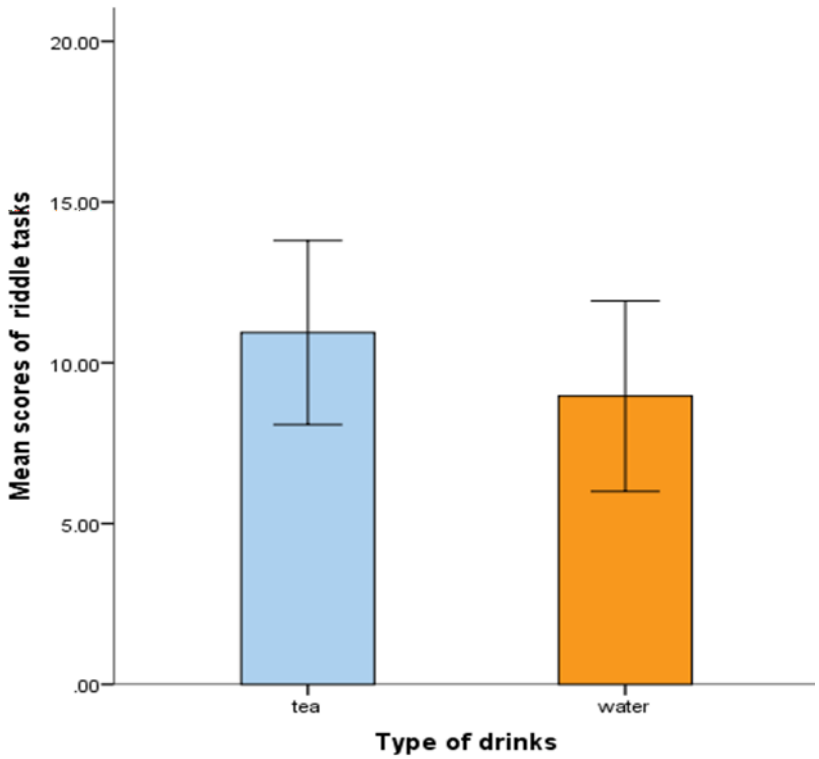

Figure 2. Main effect of drinking on the total scores of the two riddle tasks (Experiment 2).

Appendix: The description of Chinese riddle task

The riddles are based on the fact that Chinese characters are hieroglyphics. For example, in the prototype riddle, the Chinese character "　" means "can't remember" and "　" means "blind", respectively. As you can see, the top half of these two characters is the same character "　", which means "lost something". As to the bottom halves, "　" means "heart" and "　" means "eyes". That is, "　" means "lost the heart so you can't remember" while "　" means "lost eyes so you can't see." So when the riddle is asking, "you couldn't remember with a heart and couldn't see with eyes, what character is it?" the answer is the character "　" ("lost something").