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Short Communication

Uncorking the muse: Alcohol intoxication facilitates creative problem solving

Andrew F. Jarosz *, Gregory J.H. Colflesh, Jennifer Wiley

Department of Psychology, University of Illinois at Chicago, 1007 W. Harrison St. MC 285, Chicago, IL 60647, United States

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ABSTRACT

That alcohol provides a benefit to creative processes has long been assumed by popular culture, but to date has not been tested. The current experiment tested the effects of moderate alcohol intoxication on a common creative problem solving task, the Remote Associates Test (RAT). Individuals were brought to a blood alcohol content of approximately .075, and, after reaching peak intoxication, completed a battery of RAT items. Intoxicated individuals solved more RAT items, in less time, and were more likely to perceive their solutions as the result of a sudden insight. Results are interpreted from an attentional control perspective.

1. Introduction

The nature of creativity and its causes is a topic that has long been of interest. Creative thought drives both artistic products and scientific innovations, yet the mechanisms underlying great accomplishments have been notoriously difficult to study due to the rarity of these events. A popular belief is that altered cognitive processing, whether due to insanity, sleep state, mood, or substance use, may spark creativity among artists, composers, writers and problem solvers. The use of alcohol in particular (alone or in combination with other substances) has been linked to the accomplishments of many great individuals including Beethoven, Poe, Hemingway, Coleridge, Pollock, and Socrates. Despite this, most investigations of alcohol and creativity are case studies or correlational studies, with little work demonstrating the connection empirically (Norlander, 1999; Plucker, McNeely, & Morgan, 2009).

Why might intoxication lead to improved creative problem solving? One promising mechanism is the effect that alcohol has on executive functioning in combination with previous observations that sometimes a reduced ability to control one's attention can have positive implications for select cognitive tasks, including creative problem solving tasks (Kim, Hasher, & Zacks, 2007; Ricks, Turley-Ames, & Wiley, 2007; see Wiley & Jarosz, 2012, for a review). The role of individual differences in executive function and how they affect problem solving is a topic that has received a considerable amount of attention. Much of this work has used working memory capacity (WMC) as assessed by complex span tasks as a measure of executive function (see Engle, 2002) and has focused on the relation of WMC to analytical problem solving (see, for example, Kane et al., 2004) and mathematical problem solving (see Ashcraft & Guillaume, 2009, for a review). In these areas working memory capacity is often considered as the ability to control one's attention (Engle, 2002), and increased working memory capacity generally leads to superior problem solving performance. Recently, however, the role of executive function in creative problem solving has been receiving increasing attention. Creative problem solving, as opposed to analytical problem solving, does not involve computational algorithms or incremental analytic procedures. Instead creative problem solving tends to be characterized by more divergent, associational or discontinuous solution processes.

* Corresponding author. Fax: +1 312 413 4122.
E-mail addresses: ajaros5@uic.edu (A.F. Jarosz), colflesh@gmail.com (G.J.H. Colflesh), jwiley@uic.edu (J. Wiley).

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One interesting prediction is that superior executive functioning, such as increased attentional control, may in fact be detrimental to reaching creative solutions. Increased attentional control implies that one is better able to screen out peripheral information, which, while useful during analytical problem solving, would be disadvantageous in a situation where the assimilation of information outside of the perceived problem space may be useful (Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995). As such, it is reasonable to suggest that in the case of creative problem solving, less attentional control may in fact be beneficial to solution (Kim et al., 2007; Ricks et al., 2007; Wiley & Jarosz, 2012).

Turning now to the effects of alcohol on executive functioning, there are reasons to believe that intoxication will lead to changes in attentional control. While early work on alcohol intoxication suggested that alcohol may narrow one's focus of attention (Josephs & Steele, 1990; Steele & Josephs, 1990), recent work has suggested different accounts. For example, Saults, Cowan, Sher, and Moreno (2007) demonstrated that intoxicated individuals had particularly poor memory for sequentially presented items, while their memory for simultaneous lists was relatively unimpaired compared to sober participants. Based on this, they suggested that rather than narrowing one's focus of attention (which would presumably affect performance on the simultaneous lists), alcohol impairs strategy use and processes involved in encoding and retrieving sequences. Similarly, Kirchner and Sayette (2003) found that moderate intoxication in male social drinkers impaired controlled processing during a memory task for previously studied lists of words, while automatic processes were left unaffected. More recently, Sayette, Reichle, and Schooler (2009) found that moderate intoxication increased instances of mind wandering in a sample of male social drinkers (it is common for male samples to be examined in initial investigations of intoxication due to IRB complications of dealing with unknown pregnancies in females and differential dosage levels). In the Sayette et al. study, intoxicated participants were more likely to zone out (and not realize it) when they were supposed to be attending to a target cognitive task. This result suggests less attentional control and if anything a less focused attentional state due to intoxication. Finally, intoxication to .07 blood alcohol content (BAC) has been directly linked to decreases in WMC as measured by changes in pre-to-post intoxication performance on complex span tasks (Colflesh, Jarosz, & Wiley, 2010). These tasks require alternating between a processing task, such as judging the meaningfulness of sentences, and a memory task, such as remembering a list of letters. Performance on complex span tasks is thought to depend on attentional control and executive functioning (Engle, 2002). Taken together, these findings suggest that moderate alcohol intoxication may in fact lead to less attentional control or a more diffuse attentional state, which in turn could improve performance on creative problem solving tasks.

To test this hypothesis, the present study examined the effects of moderate alcohol intoxication (.07 BAC) on a creative problem solving task, the Remote Associates Test (RAT; originally developed by Mednick, 1962). The RAT is a commonly used creative problem solving task that has become popular due to its relatively short presentation time allowing for multiple trials during the course of a single session. For each item, participants are given three target words such as PEACH, ARM, and TAR, and are tasked with finding a fourth word, such as PIT, that forms a good two-word phrase with each of the target words. The RAT is thought to involve creative problem solving because the most salient potential responses to the problem are often incorrect, and one must retrieve more remote associates in order to reach solution (Bowden & Jung-Beeman, 2003b; Smith & Blankenship, 1991; Wiley, 1998). For those problems where initial associates are incorrect or the solver reaches an impasse, successful solution is thought to require divergent thinking and the ability to overcome fixation from earlier guesses (Zhong, Dijksterhuis, & Galinsky, 2008). If reduced executive control does in fact aid in creative problem solving, then participants in the intoxication condition should solve more RAT items than those in the sober control condition, or they may solve them more quickly.

Additionally, intoxication could change the perception of the "insightfulness" of RAT solutions. One common way to test for differences in the perception of solution methods is through feeling-of-insight ratings (Bowden, Jung-Beeman, Fleck, & Kounios, 2005), in which participants assess whether they felt the solution came suddenly to mind (an Aha! moment) or if they felt they reached solution through step-by-step, analytic processes. Reduced executive function may reduce participants' reliance on analytical strategies, which could make them more likely to report the use of intuitive processes during solution in the intoxicated condition.

2. Method

2.1. Participants

A target sample of 40 male social drinkers aged 21–30 was recruited by Craigslist and from the university community. Twenty participated in the alcohol intoxication condition and twenty in the sober comparison condition. Following standard procedures (Kirchner & Sayette, 2003), potential participants completed a telephone screening to establish that they met age, health and drinking pattern criteria for the intoxicated condition. Individuals were excluded from participating if they showed signs of problem drinking behaviors (scoring above a 3 on the Short Michigan Alcoholism Screening Test) or medical contraindications (e.g., heart or liver disease, psychiatric disorders). Participant eligibility was based on typical consumption of at least four alcoholic beverages for any day of the week on average over the previous 3-month period. Sober comparison condition participants were matched with participants in the intoxication condition on a measure of working memory capacity (Operation Span) that was administered while both samples were sober (sober sample: $M = .63$, $SD = .16$; intoxicated sample: $M = .63$, $SD = .18$; $t(38) = -.04$, *ns*). This matching process consisted of oversampling participants in sober comparison condition to obtain one participant who had an OSpan score within 1 point of each participant in the intoxication condition. Three extra participants were run in the sober comparison condition to meet this goal. Only the matched participants were used for analysis.

2.2. Measures

2.2.1. Operation Span Task (OSpan)

OSpan was used as a measure of WMC in this study, administered using standard procedures (Conway et al., 2005). The measure was presented via computer and involved a processing task interleaved with a memory task. Specifically, individuals were required to verify mathematical equations while remembering words. An equation was presented on the screen followed by the to-be-remembered word. Participants read the equation out loud, said ''Yes'' if the equation had the correct solution and ''No'' if it had the incorrect solution, then read the word out loud. As soon as the participants read the word, the experimenter advanced the program to the next equation, where the process was repeated. Trials contained between 2 and 5 equation-word pairs. At the end of each trial, participants were asked to write down the words they remembered in the correct serial position. Scores on the task were calculated by taking the average of the proportion of correctly remembered words on each trial.

Two forms of the Ospan were used in this experiment, with one administered before the drinking procedure and one after for the alcohol intoxication condition, or at equivalent timepoints for the sober comparison condition.

2.2.2. Remote Associates Test (RAT)

RAT items with solutions that formed good two-word phrases with all problem words were selected from both a large normed set (Bowden & Jung-Beeman, 2003b) and previous experiments (Wiley, 1998). Items were presented via computer with a 1 min time limit per problem. Participants were instructed to press a key when they knew the solution to each item, then to type in the answer and press enter. After 1 min, if the item had still not been answered, the item disappeared and a screen appeared asking participants to enter an answer to the item. Participants completed 15 items total, selected to cover a range of difficulty so as to not discourage participants (performance from a previous data set of 109 participants: $M = .48$, $SD = .17$) Prior solution rates ranged from .17 to .77, including 5 easy problems (typically solved by 60% or more of subjects), five difficult problems (typically solved by 30% or less) and five intermediate problems (solved by more than 30% and less than 60% of subjects).

Feeling of insight ratings were also collected after each RAT item. Instructions for insight ratings were adapted from those used previously by Bowden & Jung-Beeman (2003a). Rating instructions were as follows:

> After each problem you will be asked to rate how you came to the solution on a scale of 1 to 7. A rating of 1 means that at first, you didn't know whether a solution word was the answer, but after thinking about it strategically (for example, trying to combine the single word with each of the three problem words) you figured out that it was the answer. A rating of 7 means that the solution came to you suddenly, and you immediately knew that it was the answer (''It popped into my head''; ''Of course!'' ''That's so obvious''; ''It felt like I was already thinking that''). Ratings of 2 to 6 indicate feelings somewhere in between. It is up to you to decide what rating to give each of your responses. There are no right or wrong answers for the ratings you choose.

2.3. Procedure

2.3.1. Alcohol intoxication condition

Intoxication procedures closely followed Sayette et al. (1994). Participants were instructed to refrain from using alcohol and drugs for 24 h before the experiment, and to avoid food and caffeinated beverages for 4 h before the experiment. Upon arrival, weight, an initial breathalyzer reading, and consent were obtained, and participants ate a weight-adjusted snack of bagels (Sayette et al., 1994). After the meal, participants completed the first OSpan task, then received a vodka cranberry drink. The dose of alcohol (100-proof Smirnoff vodka) was calibrated by weight (.88 g/kg body weight), and was mixed in front of the participant at a 1:3 vodka to cranberry juice ratio. The drink was administered in three equal doses over 10 min periods. Participants watched an animated feature film (Ratatouille) while they consumed the alcoholic beverages. Following drink administration, participants rinsed out their mouths, and completed a breathalyzer reading ($M = .069$, $SD = .14$, range = .044–.094). During the ascending arm of intoxication, participants completed several background tasks. After they reached peak intoxication (about an hour into the study), participants completed the second Ospan task. Following this, the participants' BAC was measured again immediately before completing the RAT (BAC: $M = .075$, $SD = .008$, range = .059–.091).

2.3.2. Sober comparison condition

Participants in the sober comparison condition engaged in the same tasks as the intoxication condition including watching Ratatouille, but they did not complete the intoxication procedures (e.g., they did not eat the snack and did not drink a beverage). As participants do not find a BAC of .07 to be credible in placebo studies, a placebo design was not employed (Martin & Sayette, 1993).

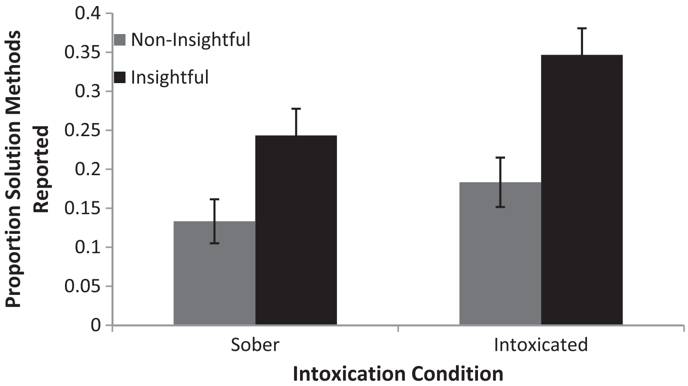

Fig. 1. Proportion of attempted problems reported as having insightful vs. noninsightful solution processes for sober and intoxicated participants. Only correctly solved RAT problems were categorized by perceived solution method. Error bars represent one standard error of the mean.

3. Results

3.1. RAT

The first analysis explored whether perceptions of the problem solving process differed between the conditions. On average, intoxicated individuals tended to rate their experience of problem solving as being more insightful ($M = 3.98$) than the sober participants ($M = 3.35$, $t(38) = 1.78$, $p < .08$). These ratings were examined in another way by analyzing the number of ratings placed on the lower part and upper part of the scale for correctly solved problems (with scores 1–3 meaning solved non-insightfully and 5–7 meaning solved insightfully). As can be seen in Fig. 1, sober and intoxicated individuals did not differ in the average number of analytical solutions they reported, $t(38) = 1.18$, *ns*, but intoxicated participants reported significantly more insightful solutions than sober participants, $t(38) = 2.14$, $p = .039$, $d = .69$. Thus, intoxication seems to have affected the perception of the problem solving process in the two conditions.

More importantly, a second set of analyses examined whether intoxication affected the actual solution of these creative problems. On average, intoxicated participants solved significantly more RAT problems ($M = .58$, $SD = .13$) than their sober counterparts ($M = .42$, $SD = .16$), $t(38) = 3.43$, $p = .001$, $d = 1.08$. Interestingly, this increase in solution success was accompanied by a decrease in time to correct solution for intoxicated individuals ($M = 11.54$ s, $SD = 3.75$) compared to sober controls ($M = 15.24$ s, $SD = 5.57$), $t(38) = 2.47$, $p = .02$, $d = .78$.

3.2. WMC

A repeated measures analysis of variance (ANOVA) was used to examine whether alcohol intoxication impacted performance across the two administrations of the Ospan task. Because two participants' scores were lost for the second administration, both those participants and their matched counterparts were omitted from this analysis. With the removal of these participants, initial Ospan scores were still matched (sober condition: $M = .66$, $SD = .14$; intoxicated condition: $M = .67$, $SD = .14$; $t(34) = -.21$, *ns*).

While there was no main effect of intoxication condition in the ANOVA, $F < 1$, there was a significant effect for the timing of the span task, $F(1,34) = 4.14$, $p = .05$, $\eta^2 = .11$, such that performance generally improved from the first to the second administration. However, this effect was moderated by a significant interaction, $F(1,34) = 5.23$, $p = .03$, $\eta^2 = .14$. As shown in Fig. 2, sober individuals demonstrated significant practice effects on the second span task, while intoxicated individuals did not.

4. Discussion

The results of the current study supported the prediction that moderate alcohol intoxication would improve performance on a creative problem solving task. Intoxicated participants not only showed an improvement in RAT accuracy compared to sober, WMC-matched participants, but they also solved problems more quickly. Additionally, participants in the intoxicated condition perceived their problem solving to be less analytic and more intuitive than the sober controls. These changes were accompanied by decreased performance on measures of WMC as compared to sober controls.

The current data fit in well with other data regarding executive processes and creative problem solving (Wiley & Jarosz, 2012). Previous research has suggested that a deficit in executive functioning can provide benefits in creative tasks (Ansburg & Hill, 2003). Multiple studies have explored how deficits in inhibitory abilities affect the opportunistic use of hints or cues in later RAT performance (Kim et al., 2007; May, 1999). For example, older adults, who tend to have inhibitory deficits, are more

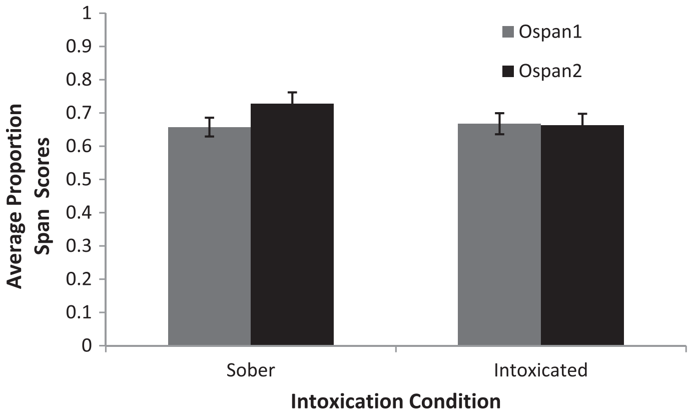

Fig. 2. Average proportion span scores on Ospan tasks across two administrations for participants in the sober and intoxication conditions. Error bars represent one standard error of the mean.

likely than college students to be able to take advantage of hints embedded in the distracting information of a previous, "unrelated" reading-with-distraction task (Kim et al., 2007). The apparent lack of inhibition of this "distracting" information aids performance on later tasks, providing access to solution cues that would otherwise be ignored. It is worth noting that the inhibitory accounts mentioned above relate the lack of inhibition in older adults to deficits in working memory capacity, and that these accounts are considered quite similar to controlled attention accounts of working memory capacity (Conway, Jarrold, Kane, Miyake, & Towse, 2007), suggesting that the inhibition and attentional control findings may go hand in hand.

Deficits in executive function have also been demonstrated to provide benefits in creative problem solving beyond using incidentally presented hints. High WMC individuals are more likely to be fixated by misleading associates on the RAT are primed by their prior knowledge (Ricks et al., 2007), while low WMC individuals are less likely to persist in using unnecessarily complex strategies on difficult problems (Beilock & DeCaro, 2007), and are quicker to switch to less effortful approaches during complex category induction tasks (DeCaro, Thomas, & Beilock, 2008). Indeed, many of these studies found that the advantage of low WMC individuals was driven by their use of simple heuristics and less persistence in using complex, resource intensive approaches (Beilock & DeCaro, 2007; DeCaro, Carlson, Thomas, & Beilock, 2009). The present data can be seen as consistent with this idea; suggesting that with intoxication, individuals may opt for more passive or associative approaches to solving the RAT problems, which in turn ends up to be beneficial.

Similarly, recent studies with frontal lobe patients also suggest that deficits in attentional control may positively affect creative problem solving. Reverberi, Toraldo, D'Agostini, and Skrap (2005) demonstrated a specific advantage for lateral-frontal lobe patients on matchstick arithmetic problems. Matchstick arithmetic problems involve altering incorrect arithmetic equations composed of Roman numerals to make them correct by moving a single matchstick (Knoblich, Ohlsson, Haider, & Rhenius, 1999). For example, the equation "II = III + I" could be solved by moving one of the sticks in the III on the right side of the equation to the II on the left side of the equation, to form "III = II + I." Problems can be made more difficult by changing the type of stick that must be moved; for example, individuals are much less likely to solve an item that requires changing a plus sign into an equals sign than they are to solve a simple problem such as the one above. Reverberi et al. found that while lateral-frontal lobe patients and healthy control participants performed equally well on easy problems, the lateral-frontal lobe patients showed a considerable advantage on difficult items, solving almost 40% more problems. These findings are especially relevant given the connection between the dorsolateral prefrontal cortex and attentional control (Kane & Engle, 2002).

A comparable set of findings has emerged in recent sleep research. Research into sleep and creativity has demonstrated that individuals are more likely to come up with creative solutions to problems if allowed to sleep during an incubation period. In one study, individuals were exposed to a number reduction task which required them to alter a string of numbers according to a specific pattern in order to reach a final "solution" number. They were then either allowed to sleep, or were kept awake before an additional block of trials (Wagner, Gais, Haider, Verleger, & Born, 2004). Those who slept were more likely than those who stayed awake to find a shortcut to the solution embedded in the task. Similarly, Cai, Mednick, Harrison, Kanady, and Mednick (2009) demonstrated that those who underwent a period of REM sleep after their first exposure to RAT items were able to take advantage of cues presented in an "unrelated" task before their second exposure to the RAT items, while those who remained awake or experienced non-REM sleep were not. They attribute these findings to increased spreading activation during REM sleep due to a decreased inhibition of recurrent connections in the neocortex, a suggestion that aligns well with the current findings. This also coincides with recent work on the effects of positive mood on creative problem solving, where it has been suggested that positive affect increases activation in the anterior cingulate cortex, which increases access to competing associations in memory (Subramaniam, Kounios, Parrish, & Jung-Beeman, 2009). A decreased focus of attention due to intoxication may also allow for a greater spread of activation in memory.

Related to these findings is earlier work (Beeman & Bowden, 2000; Bowden & Beeman, 1998; Bowden & Jung-Beeman, 2003a) concerning differences in processing between the hemispheres of the brain. In particular, this work discusses how the two hemispheres may be attuned to particular types of processing, with the left hemisphere specializing in using fine processing to narrow the activation in the semantic network to one predominant or a few closely related concepts, while the right hemisphere uses coarse processing to activate a broad, diffuse array of remote associates. It is only after the strong activation of the most dominant associates by the left hemisphere is reduced that the weaker, more diffuse activation of the more distant associates by the right hemisphere can rise to the surface. These theoretical propositions have been supported by priming studies demonstrating solution activation is maintained over time specifically in the right hemisphere (Beeman & Bowden, 2000). This work makes sense in tandem with an attentional control theory of WMC (Engle, 2002). As attentional control decreases with intoxication, the ability to maintain attention on the closely-related associates activated by the left hemisphere may be reduced, while remote associates activated by the right hemisphere may then gain easier access to the focus of attention. While detrimental for analytic problem solving, this is exactly the type of dynamic required for success in creative problem solving. Further supporting this interpretation is the finding that solution priming in the right hemisphere is particularly related to experiencing a feeling of insight (Bowden & Jung-Beeman, 2003a). In the present study, insight ratings were also affected by intoxication due to alcohol.

In conclusion, the results of this study provide support for earlier suggestions that creative problem solving may benefit from a more diffuse attentional state (Ansburg & Hill, 2003; Finke, Ward, & Smith, 1992; Martindale, 1995) and show that moderate intoxication may be one way to alter attentional states to be more conducive to creative processing. It has long been thought that intoxication unleashes the creative juices of individuals. Though only a first step, the current research represents the first empirical demonstration of alcohol's effects on creative problem solving, while also providing suggestions of the critical underlying mechanisms that allow for this benefit in problem solving performance. This in turn begs for continuing research using conceptually related measures, such as classical insight problems, and other measures of executive control to generalize these findings.

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