Alcohol Consumption Reduces Effortful Fatigue After Sleep: Testing A Theory of Metabolite Depletion and Subsequent Supercompensation

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ABSTRACT
The current work examined whether greater alcohol consumption at night would predict less effortful fatigue the next morning. The theory is that effortful thought and behavior benefit from additional stored metabolites, and that drinking alcohol temporarily reduces metabolites but later increases them. Participants attended a drinking, social event at night. The next morning, they completed an effortful task (a breath-blowing task requiring forceful exertion and persistence) before and after a mentally fatiguing task (controlling attention). Consuming more alcohol during the event predicted less fatigue on the effortful breath-blowing task, computed as the difference between performance on the task before and after the attention control task. Alcohol consumption might be one strategy for reducing later fatigue on effortful tasks.

Indexing terms/Keywords
alcohol, fatigue, supercompensation, glycogen, sleep, metabolism

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INTRODUCTION

Although alcohol often is viewed negatively or as harmful, such as for its potential to impair social relationships and lead to regrettable behaviors, alcohol also can have positive effects, such as moderate alcohol consumption providing health benefits. The current study examined whether alcohol consumption could increase the capacity for effortful behavior by reducing susceptibility to effortful fatigue.

The capacity for work is directly related to the amount of energy available to perform that work. Recent research demonstrates that the psychological capacity for effortful thought and behavior is directly related to the amount of available metabolic energy. Specifically, an extensive literature review and several experiments indicate that effortful thought and behavior (e.g., self-control) require optimal levels of blood-glucose (DeWall, Baumeister, Gailliot, & Maner, 2008; Fairclough & Houston, 2004; Gailliot & Baumeister, 2007; Gailliot et al., 2007; Gailliot, Peruche, Plant, & Baumeister, 2009; Masicampo & Baumeister, 2008). When blood-glucose is low, effortful thought and behavior are impaired. For instance, one study found that completing a self-control task (attention control) caused impairments on a later self-control task (the Stroop task), but that drinking a glucose drink eliminated these impairments (Gailliot et al., 2007).

An exhaustive review on brain glycogen found strong support for the view that effortful thought and behavior maintains a similar relationship with brain glycogen as with blood-glucose (Gailliot, 2008). Effortful thought and behavior (e.g., persistence at physical exercise) requires optimal levels of brain glycogen. When brain glycogen is low, effortful thought and behavior are impaired.

Studies demonstrate that alcohol consumption can reduce levels of blood-glucose and brain glycogen. Drinking alcohol can reduce glucose in both the body and brain (e.g., Altura, Altura, Zhang, & Zakhari, 1996; Haier, Schandler, MacLachlan, Soderling, Buchsbaum, & Cohen, 1999; Volkow et al., 1990; Wang et al., 2003; Zhu, Volkow, Ma, Fowler, & Wang, 2004). One illustrative study found that blood-glucose decreased among participants who had consumed wine (Kokavec & Crowe, 2003). People addicted to alcohol are more likely than others to experience low blood-glucose (see Wright, 1977), suggesting that drinking alcohol might contribute to low levels of blood-glucose. Processes that reduce blood-glucose tend to reduce brain glycogen as well (for a review, see Gailliot, 2008). Alcohol reduces blood-glucose, and therefore might reduce brain glycogen. Indeed, some evidence is consistent with the idea that alcohol decreases brain glycogen (see Marieb, 1998).

That alcohol can reduce blood-glucose and might reduce brain glycogen suggests that drinking alcohol should impair effortful thought and behavior. Consistent with this idea, drinking alcohol can impair self-control and other effortful processes (e.g., Bartholow, Dickter, & Sestir, 2006; Haier, Schandler, MacLachlan, Soderling, Buchsbaum, & Cohen, 1999; Hull, 1981; Baumeister, Heatherton, & Tice, 1994).

The current work, however, examined whether alcohol consumption can later improve effortful behavior. This hypothesis is suggested by work on supercompensation, in which temporarily depleting brain glycogen causes increases in the total amount of brain glycogen (for a review, see Gailliot, 2008). The brain demonstrates an effect of supercompensating, such that glycogen levels increase to levels higher than they were before being depleted.

Supercompensation is one plausible mechanism that allows for reductions in susceptibility to fatigue on effortful tasks. Work on self-control has found that regularly exerting self-control over extended time periods reduces fatigue after self-control tasks. For instance, some studies had participants either exert self-control regularly for 2 weeks, such as by regularly monitoring and improving their posture, changing their handedness behavior (e.g., using one’s left instead of right hand for various tasks), or altering their verbal mannerisms (e.g., avoiding the use of curse words) or not exert self-control and instead complete only a journal (Gailliot, Butz, Plant, & Baumeister, 2007; Muraven, Baumeister, & Tice, 1999). After the 2 weeks, participants returned to the laboratory and completed two self-control tasks. Participants who had not exercised self-control regularly for the 2 weeks showed a pattern of self-control-fatigue, such that they showed impaired self-control on the second task. Participants who exercised self-control regularly, however, exhibited no signs of fatigue, and performed relatively well on the second self-control task. These results have been replicated using different self-control exercises, different time periods of exercise (e.g., 2 months), and different dependent measures (Oaten & Cheng, 2006a, 2006b, 2006c).

One plausible underlying mechanism for these effects is the supercompensation of brain glycogen (Gailliot, 2008). Self-control tasks reduce blood-glucose and perhaps brain glycogen (Gailliot & Baumeister, 2007; Gailliot et al., 2007; Gailliot, 2008). This depletion then causes supercompensation, in which brain glycogen increases to levels higher than before. The additional brain glycogen then reduces fatigue on self-control tasks by providing additional metabolic energy allowing for the effortful thought and behavioral actions that self-control requires.

The hypothesis of the current work was that alcohol consumption could reduce effortful fatigue through a similar process. The rationale was that drinking alcohol temporarily reduces glucose and, consequently, brain glycogen. After a night’s sleep, stores of brain glycogen should increase, thereby reducing susceptibility to effortful fatigue.

Participants attended a drinking social event at night in which they consumed as much alcohol as they preferred. The next morning, they completed an experimental session that included effortful tasks. The prediction was that consuming higher amounts of alcohol would be associated with better performance on the later effortful tasks, indicating less effortful fatigue.
METHOD

Sixteen college students (11 women, 5 men) participated on a voluntary basis. Two participants (1 woman, 1 man) did not return for the experimental session in the morning. Their data were excluded from all analyses, leaving a final sample size of fourteen. Participants were blind to the hypothesis.

Participants attended a drinking, social event, beginning at 8pm. They were provided with liquor (rum, vodka, whiskey, and moonshine), beer (light and regular), wine (white and red), and champagne, and were told that they could drink as much as they liked or nothing at all. During the event, participants were allowed to socialize, dance, listen to music, and use the Internet. Participants were allowed to leave when they wanted. On average, participants stayed for 4 to 7 hours.

Participants were given a questionnaire to complete during the event. On the questionnaire, they recorded the amount of alcohol they consumed. The questionnaire also contained items for which participants indicated the amount of food they consumed during the day, the number of days each week that they normally drink, whether they are a light to heavy drinker, their tolerance to alcohol, how well they slept the night before, how many hours of sleep they obtained the night before, and how many hours of sleep they would have preferred. These questions were intended to assess possible mediating variables and alternative explanations.

Immediately before leaving the event, participants completed another questionnaire that assessed how much fun they had at the event, how fulfilling they found the event, and the extent to which they developed social relationships during the event. These questions were intended to test for potential mediators and alternative explanations.

Participants attended a separate experimental session the next morning. They first completed a questionnaire that assessed how well they slept during the night, how many hours of sleep they obtained, how many hours of sleep they would have preferred, and how hungry they were.

Participants next completed a task intended to measure effortful capacity. Specifically, they were instructed to blow a folded piece of paper across a table, blowing it as far as they could using the fewest number of attempts. The blowing task assesses effortful capacity because it requires the expenditure of effort—blowing using the strongest and longest-lasting force one can muster.

After the blowing task, participants completed a task designed to induce effortful fatigue. Specifically, they watched a 6-minute video of a woman talking (without sound). During the video, words appeared in the bottom corner of the screen. Participants were instructed to focus on the woman and direct their attention away from the words. The task is effortful because participants must override automatic tendencies to look at novel stimuli appearing in the environment (Shiffrin & Schneider, 1977). Past work using this task confirms that it is mentally fatiguing (e.g., Gailliot, Schmeichel, & Baumeister, 2006). Last, participants completed the blowing task again, as a final measure of effortful capacity.

RESULTS

A measure of effortful fatigue was computed by subtracting the total distance the paper was blown at the end of the session from the total distance the paper was blown at the start of the session (distance1 – distance2 = fatigue). Higher numbers indicated blowing farther at the start than end of the session, thus indicating more fatigue.

Drinks were standardized by the amount of alcohol they contained. As predicted, the amount of alcohol consumed correlated negatively with fatigue on the blowing task, r (14) = -.48, p < .05. The more participants drank, the less fatigue they exhibited.

Analyses provided little or no evidence for the influence of other factors (potential alternative explanations) on the pattern of results. No other variables assessed on the questionnaires correlated significantly with both drinking amount and fatigue. For variables that correlated with either drinking amount or fatigue (p < .05), correlations with the other main variable (drinking amount or fatigue) were non-significant, .26 ≤ ρ's ≤ .83.

The amount of alcohol consumed ranged from 0 to 12 drinks (M = 3.93, SD = 3.27). This suggests that the effects obtained occur within this range of drinking.

DISCUSSION

The current study found that participants who drank more alcohol during a nighttime social event showed less fatigue the next morning on an effortful task (blowing a piece of paper) after completing a different effortful task (attention control). Participants who drank less alcohol showed more fatigue.

The results are supported by the rationale that drinking alcohol can temporarily reduce metabolites (e.g., blood-glucose and brain glycogen). After a delay (e.g., a night’s sleep), however, metabolite stores (brain glycogen) increase to levels higher than they were before. The additional stored metabolic energy then provides energy needed to resist fatigue on effortful tasks (Fairclough & Houston, 2004; Gailliot; 2008; Gailliot et al., 2007; Masicampo & Baumeister, 2008).

Little or no support was found for other explanations for the obtained pattern of results. The relationship between increased drinking and decreased effortful fatigue did not appear due to differences in food eaten, hunger, typical or habitual drinking behavior, tolerance to alcohol, sleeping patterns, enjoyment of the drinking event, or social benefits of the drinking event. The best theoretical explanation for these results is changes in metabolic stores.
Drinking alcohol was found to reduce effortful fatigue on a blowing task. Alcohol might be used in a similar way to reduce fatigue on other effortful tasks. Self-control (Gailliot & Baumeister, 2007; Gailliot et al., 2007), memory (Riby, 2004), and controlled processing (Masicampo & Baumeister, 2008) have been found to rely on blood-glucose to a greater extent than other processes. This suggests that, following a delay, drinking alcohol might reduce susceptibility to fatigue on these tasks. Alcohol therefore might cause similar effects as longitudinal self-control exercise (Gailliot, Butz, et al., 2007; Muraven et al., 1999; Oaten & Chang, 2006a, 2006b, 2006c). Physical exercise has been found to improve executive processes (Dishman et al., 2006), perhaps partly by increasing brain glycogen (for a review, see Gailliot, 2008), suggesting that alcohol might also have effects similar to physical exercise. The potential costs and harmful consequences of alcohol consumption suggest that drinking alcohol to reduce effortful fatigue might not be an ideal strategy, yet the practice might have some practical benefits (e.g., engaging in controlled drinking at night so as to improve the ability to diet the next day).

Similar effects might be found in non-human animals. Studies on rats have found that regular wheel running during 1 week increased learning and memory performance (Vaynman, Ying, & Gomes-Pinilla, 2004). There is reason to believe that this effect is mediated by the supercompensation of brain glycogen, suggesting that alcohol might also improve more effortful or energy-demanding cognition in animals, following a delay or sleep.

Metabolic stores or brain glycogen were not measured in the current study, and so it is not certain that metabolism was the causal mechanism operative in the current effects. These data therefore should be followed-up with studies that directly measure changes in brain glycogen. A more general theory of alcohol, metabolism, and effortful mental processes could also be tested. Alcohol reduces metabolites temporarily, thereby impairing effortful processing, but increases metabolites after a delay or sleep, thereby reducing fatigue on effortful tasks.

A theory involving metabolite depletion might explain also the enjoyment of drinking. Happiness or enjoyment often entails having or being able to use surplus metabolic energy (Gailliot, 2007). For example, pursuing goals entails regular use of metabolic energy. When a goal is met, happiness increases (e.g., Diener & Lucas, 2000; Haybron, 2008; Michalos, 1980), and the metabolic energy used previously for the goal is then a surplus that can be used leisurely. The enjoyment of alcohol might occur through the depletion of metabolic energy, as one savors in using up their stored energy.

Though the current work assessed the effortful fatigue of behavior (blowing with force), it is possible that decision-making also is relevant. Increased metabolic stores might lead to increases in the willingness or decision to exert effort. Drinking more may have been associated with decreases in fatigue because it biased decision-making toward engaging in more effortful processes.

No participants in the current sample drank heavily to the extent of having a hangover the next morning. It is questionable whether drinking large amounts of alcohol to the extent of later sickness or ill feelings would reduce effortful fatigue, even if brain glycogen does supercompensate. Hence, a curvilinear relationship might exist between the amount of alcohol consumed and resistance to effortful fatigue, with high levels of drinking failing to show a link with reduced fatigue.

If alcohol can be used to reduce effortful fatigue then, in some cases, alcohol consumption could ironically be one strategy for reducing alcoholism. By drinking alcohol, one can extend the capacity to exert the effort required to avoid drinking alcohol. This might be an alternative for extreme alcoholics who cannot maintain complete abstinence or for people seeking moderation, such that they can drink to the extent of supercompensation one day, thereby allowing them to avoid drinking alcohol the next day.

In closing, alcohol consumption can have both positive and negative effects. Alcohol can help people to bond, or it can tear them apart. Alcohol can impair effortful psychological capacities, yet, as the current work suggests, it can also improve them. Perhaps controlled, responsible drinking can be used to improve a broad range of effortful psychological capacities, helping people to exert extended control over effortful aspects of their lives.

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REFERENCES


Author’s biography with Photo

Matthew T. Gailliot graduated with a Bachelor's in Psychology from Kennesaw State University in 2003 and a Master's and Ph.D. in Social Psychology from Florida State University in 2005 and 2007. He has worked as a professor of Psychology at The University of Amsterdam, Zirve University, and Stephen F. Austin State University.