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Bulletproof Coffee and Cognition: A Double-blind, Placebo-controlled Study on the Effects on Working Memory

Original Article

There is evidence that caffeine has positive effects on cognition. Studies have shown that caffeine is an indirect enhancer of cognitive functions such as memory, concentration, and mood. A new caffeine-based trend has emerged, claiming "massive impact on energy and cognitive function." This new beverage, known as Bulletproof coffee, is a combination of coffee, grass-fed butter, and medium-chain triglycerides (MCT) oil. Thus far, these claims have not been supported by any scientific evidence. This research aimed to determine whether these enhancing effects could be corroborated by empirical data, by using a double-blind within-subject design. We hypothesized that participants in the Bulletproof condition would perform better on memory-related

tasks and would score higher on subjective mood ratings. 21 participants performed two working memory-related tasks after consuming a coffee beverage (either decaffeinated coffee, regular coffee, or Bulletproof coffee). Subjective mood ratings were collected before and after coffee consumption as a secondary measure. Results did not show an effect of Bulletproof coffee on cognitive performance during working-memory related tasks. A significant effect was found on subjective measures of mood. Contrary to expectations, participants reported an increase in alertness after consumption of the placebo drink and a decrease in alertness after consumption of regular coffee. However, this finding likely represents a measurement artifact. Further research needs to be conducted to gain more conclusive results.

Keywords: bulletproof coffee, working memory, caffeine, cognitive enhancement, mood

INTRODUCTION

In modern society and working environments, people face enormous pressures to excel. Consequently, there is a growing interest in enhancing human performance (Reissig, Strain, & Griffiths, 2009). Therefore, an increasing number of healthy people are looking for ways to safely enhance their cognition as they seek to increase their learning capacities and abilities. One possibility that is considered safe for cognitive enhancement is the ingestion of caffeine. Caffeine is the most widely used and accepted psychoactive drug in the world (Lyvers, Brooks, & Matica, 2004). It is consumed in many forms (e.g. beverages, food, medication) and readily available on the market. Caffeine is considered a stimulant as it has arousing effects on the central nervous system (CNS), for instance increasing vigilance and alertness (Franke, Christmann, Bonertz, Fellgiebel, Huss, & Lieb, 2011). According to Nehlig (2010), caffeine should be regarded as an indirect cognition enhancer as its positive effects are mediated by mood, arousal levels, and concentration. Specifically, Nehlig (2010) identifies caffeine-facilitating effects on learning in tasks where information is presented passively rather than in tasks in which material is learned intentionally. Most studies however, found improvements on reaction time (Nehlig, 2010; Haskell-Ramsay et al., 2018). Furthermore, cognitive performance was found to be improved in a range of 37.5 to 450 mg of caffeine, which resembles the normal range of moderate coffee drinkers (Nehlig, 2010; Ruxton, 2008).

While there have been many studies focusing on the effects of caffeine on cognitive performance there is no research regarding the

stimulating effects of a beverage called 'Bulletproof coffee'. The creator, and main proponent of Bulletproof coffee, Dave Asprey, designed a rather uncommon mixture of regular coffee, "brain octane" oil, and grass-fed butter, claiming it to have numerous advantageous effects on cognition ("Official Bulletproof Coffee Recipe", 2019). "Brain octane" oil is a purified form of medium-chain triglycerides (MCT) oil, which is derived from coconut oil. The advertisement of this fashionable beverage promises a "massive impact on your energy and cognitive function" ("Official Bulletproof Coffee Recipe", 2019), yet there is no scientific evidence to support these claims. As previous studies have postulated that caffeine, as well as MCT oil, have been shown to improve cognition (Page, Williamson, Yu, McNay, Dzuira, McCrimmon, & Sherwin, 2009), the question is raised whether this combination has additional cognitive enhancing effects compared to regular coffee.

Since cognition covers a wide range of capabilities that are of increasing importance in modern society, its different domains are continuously being studied. Cognition involves memory, attention and perception among other domains which themselves can be further subdivided into complex aspects (Nehlig, 2010). For example, memory can be broken down into short-term, long-term and working memory (Nehlig, 2010; Haskell-Ramsay et al., 2018). To illustrate the effects of caffeine on cognition we decided to assess working memory since it is considered to be associated with information processing, executive function, problem solving, comprehension and learning (Cowan, 2013). Working memory is a limited capacity system that enables maintaining and manipulating information temporarily in order to guide and execute complex cognitive

tasks (Nehlig, 2010). Since many of the aforementioned studies found significant effects for coffee on multiple cognitive domains, we expect to also find an effect of coffee on working memory.

Since there is no scientific evidence to support the promised cognitive boost of Bulletproof coffee, as advertised on the website, we want to investigate this in our study by using working memory as our primary measurement. We hypothesized that participants in the Bulletproof coffee condition will perform better on cognitive tasks compared to the regular coffee condition, and placebo condition. Additionally, we hypothesized that the regular coffee group will perform better than the placebo condition. For the secondary measurement of mood, we hypothesized that the Bulletproof coffee condition will yield greater scores on positive mood dimensions (alertness, and contentedness).

METHODS

Participants

We recruited 22 second year bachelor students from Maastricht University via the online system SONA to participate in our study on Bulletproof coffee and memory-related performance. The SONA system is an online platform that allows researchers to advertise their studies and recruit participants. Participants can sign up anonymously for time slots and are rewarded in the form of SONA credits corresponding to the time spent participating in a certain study. In our study, the students were compensated with five SONA credits overall. Prior to the experiment, prospective participants were instructed to fill out a pre-screening form. In

order to be included in the study, participants had to be aged between 18 and 40 and moderate coffee consumers (1-4 cups per day). This criterion was necessary, to make sure that participants are approximately equally sensitive to the effects of caffeine. Participants were excluded if they were over the age of 40, pregnant, or had a Body Mass Index outside the range of 18.5-28.0 kg/m^2. Students following a vegan diet or who were lactose intolerant were also excluded, as all three beverages (Bulletproof coffee, regular coffee, decaffeinated coffee) were prepared with at least a hint of grass-fed butter. Further, individuals currently on medication or with a history of mental illness were restricted from participating in this study. In addition, students who took part in the study "Do you like coffee?" were prohibited from participating due to the similarity in research designs, which could bias participants, and therefore influence interpretation of the results. Furthermore, participants were requested to sleep at least six hours the night before testing. We asked participants to abstain from consuming caffeine 12 hours prior to testing and to abstain from alcohol and other drugs 24 hours before. In addition, participants were asked to have a so-called "light breakfast" (maximum 4 slices of bread) which had to be consumed at least two hours before testing. Due to violations of one of the aforementioned criteria, one participant had to be excluded from the study. Therefore, data of in total 21 participants were analyzed. Before participating in the study every student gave written informed consent. The study was approved by the Maastricht's University Ethics Review Committee (ERCPN; ERCPN-Nr.: RP2027_2019_30).

Design and treatment

In order to test whether Bulletproof coffee has an effect on working-memory related performance and mood, a double-blind within-subject design was used. The three treatment conditions were (1) decaffeinated coffee, (2) regular coffee and (3) Bulletproof coffee. Each participant was tested three times; receiving treatment in a counterbalanced order. To control for possible carry-over effects from the cognitive tests, testing-days were separated by a wash-out period of at least four to five days. This time window even exceeds the length of wash-out periods in previous studies (Childs & DeWit, 2006) and can therefore be regarded as a reliable way to prevent possible carry-over effects. All testing sessions were scheduled in the morning (08:30 am - 01:00 pm). To minimize random noise, all three testing sessions took place at the same time. If this was not possible, participants could deviate by one time slot which equated approximately 45 minutes deviation from the original time slot. The coffee conditions were prepared fresh on location just before administration. Bulletproof coffee and coffee were brewed using Senseo "Dark roast" pads (caffeine concentration 70-90mg/100ml) and coffee placebo was brewed using "Decaffeinated" pads (caffeine concentration 3mg/100ml). By taking the average of 70 and 90 mg caffeine (80+/-10mg/100ml) we calculated a caffeine range of 190+/-10 mg /237ml as caffeine concentration used in the experimental conditions. This caffeine concentration was selected based on previous research on the effects of caffeine and cognitive performance (Ruxton, 2008).

Since Bulletproof coffee is prepared by adding one tablespoon of grass-fed butter and one tablespoon of MCT oil to the coffee (Official

Bulletproof Coffee Recipe, 2019) it differs in taste and appearance from the other two conditions. Therefore, beverages were administered orally in an opaque container. Moreover, ½ teaspoon of grass-fed butter was added to the regular coffee and decaffeinated coffee condition to mask the taste as well as the appearance. The addition of butter to the placebo and regular coffee condition is believed to be small enough to not have a significant impact on cognitive performance. Further, there is no evidence to suggest that the combination of butter and coffee is responsible for enhanced cognitive effects but more so the joint combination of MCT oil, coffee, and butter.

For the first test day, participants performed a practice version of the Spatial Memory Task (SMT) in order to familiarize themselves with this task. This practice version was administered during the 45 minutes waiting period (Figure 1). Subjective mood was assessed with the Bond & Lader (B&L) questionnaire which was administered before receiving the beverage and after testing had been completed (Bond & Lader, 1974). Spatial- and working- memory were assessed 45 minutes after coffee administration as coffee shows cognitively enhancing effects approximately 45-90 minutes after consumption (Nehling, 2010). The participants started with the immediate version of the SMT directly followed by the N-back task. A 30 minutes waiting period between the immediate and the delayed STM task was needed, therefore participants had a second waiting time of about seven minutes before completing the testing with the delayed SMT task (Figure 1). The total testing time was therefore approximately 96 minutes per session.

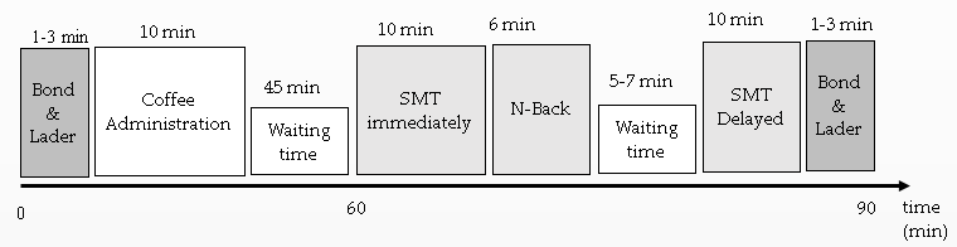

Figure 1. Schematic Overview of the Testing Procedure.

Neurocognitive assessment

The primary aim of this study was to test whether participants in the Bulletproof coffee condition perform better on spatial and working memory tasks than people in the regular and decaffeinated coffee condition. Spatial memory was assessed using the spatial memory task (SMT) which is derived from an object relocation test and consists of an immediate and delayed relocation phase. This task was chosen based on previous research demonstrating significant effects of psychostimulants on spatial memory (de Sousa Fernandes Perna et al., 2016). The immediate SMT consists of six trials, in which ten black and white pictures are presented on different locations on a computer screen (Figure 2). The participants had to remember these locations. After every trial, the pictures reappeared one by one in the middle of the screen followed by the presentation of a '1' and a '2' in different locations. If they opted for number 1, they had to press the z-key, and if they chose number 2 they had to press the m-key on the "QWERTY" computer keyboard. For the delayed relocation performance, the same pictures reappeared in a random order in the middle of the screen, and participants again had to indicate the

correct location by deciding between two given alternatives. The dependent variables of the SMT are quantitative scores: The Immediate Relocation Score (IRS), mean Immediate Reaction Time (mIRT), Delayed Relocation Score (DRS) and mean Delayed Reaction Time (mDRT) (de Sousa Fernandes Perna et al. 2016).

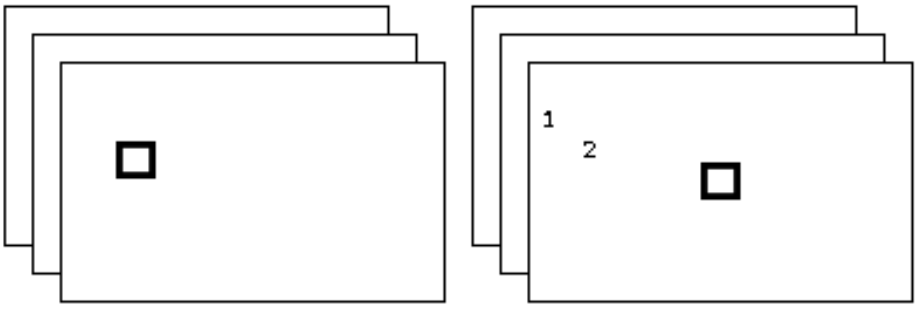

Figure 2. Spatial Memory Task. Participants have to remember the location of black and white pictures appearing at different locations of the screen (left). Subsequently, participants indicate the previous location of the pictures by deciding between two given alternatives (right).

Working memory performance was assessed with the N -back task. Earlier research gave sufficient evidence that this task is sensitive to stimulant drugs (Mattay et al., 2000) and reliably activates the dorsolateral prefrontal cortex (dlPFC), which is believed to be the brain area most implicated in working memory (Van Ruitenbeek, Hernaus, Dennis, Mehta, & Mitul, 2018). Participants were presented with blocks composed of 14 letters. The letters were presented successively on a computer screen each for a duration of 2 seconds. Target stimuli had to be identified by pressing the 3-key, and non-target stimuli by pressing the "z"-key. A target was defined as either the letter X in the 0-back condition or if the presented

letter was identical to the one 2 letters before (i.e., A-B-A) in the 2-back condition (Figure 3). The two conditions 0-back and 2-back appeared in a random order. The participants were required to respond as quickly and accurately as possible. The dependent variables of the N-back task are quantitative scores: average reaction time and number of correct responses (Van Ruitenbeek, 2018).

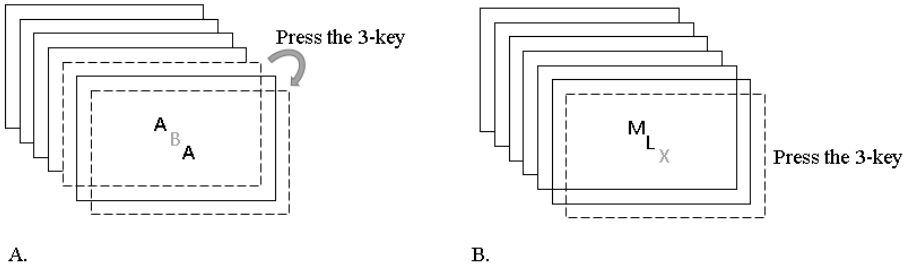

Figure 3. N-Back Task. A. 2-back Task: Participants have to indicate whether the present letter is the same as the letter that appeared two times before it by pressing the 3-key. B. 0-back Task: The participants have to indicate whether an X appears.

Subjective assessment

The secondary interest of the current study was to assess whether the participants' subjective mood was dependent on the different conditions. This was carried out by means of the B&L questionnaire consisting of 16 visual analogue scales (VAS) for subjective feelings. As opposed to normal Likert Scales which includes numbers, participants had to specify their current mood state on a scale between two given mood dimensions (e.g. calm vs. excited). The B&L VAS has been proven to be effective in evaluating alertness, contentedness, and calmness and can therefore be used as a reliable measurement for the dependent variable subjective mood

(Bond & Lader, 1974; Van Ruitenbeek et al., 2018). To increase efficiency, we transferred the original questionnaire to the QualtricsXM software, an online questionnaire platform, which facilitated the participant's access to the questionnaire and stored the data anonymously.

Statistics

Data were analyzed using a general linear model (GLM) repeated measures analysis of variance (ANOVA). Overall, seven analyses were conducted. For the SMT and the N-Back task, Accuracy and Reaction Time was analyzed separately. SMT scores were analyzed with a 3x2 factorial design with main factors Coffee condition (Bulletproof Coffee, Regular Coffee, Placebo) and Delay (Immediate Recall and Delayed Recall). N-back scores were analyzed with a GLM repeated measures ANOVA with main factor Coffee condition. B&L mood questionnaire ratings were analyzed on three different dimensions (Alertness, Contentedness, Calmness) separately using a 3x2 factorial design with main factors Coffee condition and Time point (prior and after coffee consumption). In cases where sphericity was violated, the Greenhouse Geisser epsilon correction was used. Given the small sample size of n=21, possible violations of the normality assumptions must be considered. The data was examined carefully and the distribution of scores was found to be approximately normal, thus a repeated-measures ANOVA could be validly applied. The alpha criterion significance level was set at α=0.05. All statistical analyses were conducted with SPSS version 24.0.

RESULTS

Spatial Memory Task (SMT)

GLM analyses revealed no significant difference in SMT performance- neither Accuracy nor Reaction Time between the experimental conditions (Bulletproof Coffee, Regular Coffee, Placebo). There was a significant difference in performance- for both Accuracy and Reaction Time between Immediate recall and Delayed recall task (Acc: p=0,024; Cohen´s d=1,05; RT: p=0,000; Cohen´s d= 0,12). As expected, performance in the Delayed recall task decreased compared to Immediate recall performance. Follow-up analyses comparing each of the experimental conditions separately (paired sample t-test, Bonferroni correction applied) revealed no significant difference in SMT performance (Accuracy and Reaction Time).

N-Back task

GLM analyses revealed no significant difference in performance in the N-back task between experimental conditions. No significant effect of bulletproof coffee on Accuracy and Reaction Time was found. Follow-up analyses comparing each of the experimental conditions separately revealed no significant difference in N-back performance (Accuracy and Reaction Time).

Bond & Lader Mood Questionnaire

Effects on three mood dimensions were assessed: Alertness, Contentedness and Calmness. No significant main effect of the Coffee condition on any of

the three mood dimensions was found. However, GLM analyses revealed a significant interaction effect between Coffee condition and Time point (pre and post-test) with p=0,038 (Figure 4). Subjective mood ratings indicate that Alertness increased significantly after consumption of the Placebo drink, whereas a significant decrease in Alertness could be observed after consumption of Regular Coffee. Within-Subjects contrast analysis revealed a significant interaction effect for the Placebo and Regular coffee condition, but not for the Bulletproof Coffee condition.

DISCUSSION

This study investigated the effect of Bulletproof coffee on working-memory related performance using the immediate and delayed spatial memory task (SMT) and the N-back task. Additionally, it was explored whether the consumption of Bulletproof coffee was associated with changes in mood by means of the B&L Mood Rating Scale (BL-VAS - Bond & Lader VAS). The present study is one of the first randomized controlled trials that assessed the effect of Bulletproof coffee on cognitive performance. We hypothesized that adding MCT oil and butter to coffee (Bulletproof coffee) will have additional enhancing effects on memory compared to regular coffee. However, the findings of the current study, indicate that working memory performance was not affected by Bulletproof coffee. We hypothesized that adding MCT oil and butter to coffee (Bulletproof coffee) will have additional enhancing effects on memory compared to regular coffee. Surprisingly, regular coffee also did not have an effect on working memory performance.

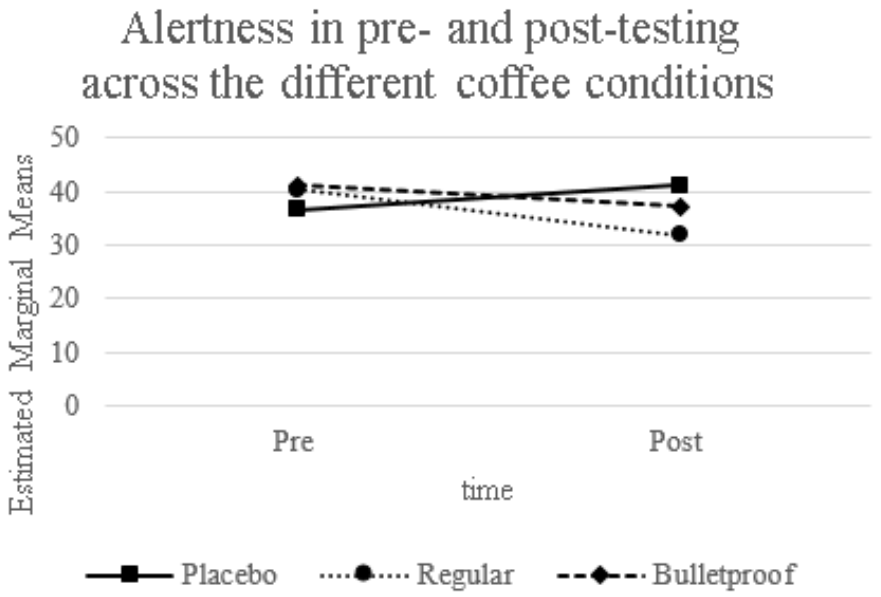

Figure 3. Interaction Effect. Graph displaying the coffee conditions on the Alertness dimension of the B&L Questionnaire. The x-axis is representing timepoint of measurement (pre-testing and post-testing). The y-axis is displaying the estimated marginal means for the different conditions. The solid line is representing the estimated marginal means in the placebo condition across pre- and post-testing, the dotted line is representing the means in the regular coffee condition and the dashed line representing the Bulletproof coffee condition.

Since regular coffee was not found to have a significant effect, it is not surprising that also Bulletproof coffee failed to significantly enhance memory-related performance. Participants that consumed Bulletproof coffee did not perform better in any of the cognitive tasks or subjective

assessments compared to the participants in the regular or decaffeinated coffee condition.

Nevertheless, we found a significant interaction between coffee type with time of measurement on feelings of alertness. Interestingly, participants in the regular coffee condition reported being more alert at the pre-measurement (before coffee intake) compared to the post-measurement (after coffee intake). Furthermore, the opposite was observed for participants in the decaffeinated coffee condition who reported being more alert at the B&L post-measurement compared to the pre-measurement. This could be explained by the peak time of the effects of caffeine which appears at 45 minutes after consumption. The B&L post-measurement was taken 95 minutes after beverage consumption. The decrease in alertness in the regular coffee condition could be explained by the decreasing arousing effects of coffee at 50 minutes past peak time. Another potential explanation for the decrease in alertness may be a result of the duration of the testing procedure, instead of the coffee beverage itself. The post-measurement for subjective mood ratings was applied after the immediate and delayed SMT, and N-back task. Mood may have been influenced by these cognitive tasks as well. Interestingly, there was no significant main effect of Bulletproof coffee on alertness. This may be due to the possibility that the addition of MCT oil and butter may have a potential influence on alertness and that Bulletproof coffee may evoke a prolonged peak of caffeine. However, this possible effect needs to be further investigated in future research.

The non-significant effect of coffee on working memory performance is in line with the controversy around the performance-

enhancing effects of coffee. Although research suggests an effect of coffee on cognitive performance, findings were inconsistent regarding the effect size and the domain of cognitive performance. Concerning, the cognitive domain, performance-enhancing effects of coffee have most frequently been reported for vigilance and alertness and less for memory (Sherman, Buckley, Baena, & Ryan, 2016).

When Nehlig (2010) investigated the effect of coffee on memory for materials presented passively and material studied intentionally he found that coffee only improved performance on passively studied material. The spatial memory task in the present study focuses on intentionally studied material and therefore the non-significant result on this task in the present study is consistent with the results found by Nehlig (2010). Also, most studies supporting the effect of coffee on memory have focused on coffee as an enhancer under suboptimal conditions, for example during a non-optimal time of the day (Nehlig, 2010). Hogervorst, Riedel, Schmitt, & Jolles (1998) found that coffee improved memory performance during distraction in a sample of middle-aged individuals. The unique enhancing effects of coffee on memory in a student population under suboptimal conditions was also demonstrated by Sherman et al. (2016). More specifically, students performed better during their non-optimal time of the day (6am-7am) when consuming normal coffee compared to decaffeinated coffee (Sherman et al., 2016). The present study investigated the effects of coffee under normal conditions- participants were well rested and no distraction or stress was induced. The lack of significant results therefore is in line with previously reported findings and the hypothesis that the cognitive-enhancing effects of coffee only emerge under suboptimal conditions.

The absence of a significant effect of coffee can also be explained by age as previous research suggests that the effect of coffee on memory performance is age dependent. Since caffeine supposedly has greater effects on elderly than the young, a possible explanation for these insignificant findings could be the limited age range of our sample (Swift & Tiplady, 1988), which only included University students. Also, it is likely that university students are, on average, more used to regular coffee consumption and thus less sensitive to the effects of caffeine than the ageing population. Also, the study by Hogervorst et al. (1998) demonstrated that coffee improves memory during distraction in middle-aged participants but not in young or old participants. This finding is also supported by Jarvis (1993) who found an effect for coffee in old but not young participants. The results of the present study are in line with the findings that old or middle-aged people are more susceptible to the memory-enhancing effect of coffee as our sample was limited to second-year bachelor students. A more heterogenous sample with regard to age would have been optimal but since the majority of young people are coffee consumers it is relevant to also focus research on this age group (Brazier, 2016).

The current study is limited by the narrow age range and size of the sample. Future studies should include larger and more varied samples to increase the power of the statistical analysis and the generalizability of the results. A varied sample should be used in order to determine if the effects of caffeine beverages are uniform across subpopulations. Moreover, there are several factors that could have confounded the results of our studies. For example, the current study did not control for gender. However,

previous studies were able to demonstrate that women might be more sensible to the effect of caffeine than men, as there seems to be an interaction between caffeine and the level of estrogen found in the female body (Arnold, Petros, Beckwith, Coons & Gorman, 1987). Consequently, we advise future research to also control for the intake of contraceptives in females. In addition, there also seems to be an interaction between smoking and caffeine on the effects of arousal (Rose & Behm, 1991). Hence, future studies should control for smoking in order to obtain more accurate results on the B&L questionnaire.

Conclusion

To conclude, the present findings fit into the controversy surrounding the enhancing effects of caffeine. No significant effects of Bulletproof coffee on cognition were found. However, this study proposes important implications for future research. More research is needed to investigate potential cognitive-enhancing effects of Bulletproof coffee, especially since this is one of the first studies on this matter so far. Future research should continue to compare Bulletproof coffee with regular and placebo coffee, to discover whether this beverage has any health and cognitive advantages over the former.

REFERENCES

Arnold, M., Petros, T., Beckwith, B., Coons, G., & Gorman, N. (1987). The effects of caffeine, impulsivity, and sex on memory for word lists. *Physiology & Behavior, 41*(1), 25-30. doi: 10.1016/0031-9384(87)90126-

Bond, A., & Lader, M. (1974). The use of analogue scales in rating subjective feelings. *British Journal of Medical Psychology*, *47*(3), 211-218.

Brazier, Y. (2016, March 8). "Adolescents drink too much caffeine." Medical News Today. Retrieved from https://www.medicalnewstoday.com/articles/307526.php.

Clegg, M. E. (2017). They say coconut oil can aid weight loss, but can it really? *European Journal Of Clinical Nutrition, 71*, 1139. doi:10.1038/ejcn.2017.86

Cowan, N. (2014). Working memory underpins cognitive development, learning, and education. *Educational Psychology Review, 26*(2), 197-223. doi: 10.1007/s10648-013-9246-y

Cunnane, S. C., Courchesne-Loyer, A., St-Pierre, V., Vandenberghe, C., Pierotti, T., Fortier, M., ... & Castellano, C. A. (2016). Can ketones compensate for deteriorating brain glucose uptake during aging? Implications for the risk and treatment of Alzheimer's disease. *Annals of the New York Academy of Sciences*, *1367*(1), 12-20. doi: 10.1111/nyas.12999

de Sousa Fernandes Perna, E. B., Papaseit, E., Pérez-Mañá, C., Mateus, J., Theunissen, E. L., Kuypers, K. P. C., ... & Ramaekers, J. G. (2016). Neurocognitive performance following acute mephedrone administration, with and without alcohol. *Journal of Psychopharmacology*, *30*(12), 1305-1312. doi:10.1177/0269881116662635

Franke, A., Christmann, M., Bonertz, C., Fellgiebel, A., Huss, M., & Lieb, K. (2011). Use of coffee, caffeinated drinks and caffeine tablets for cognitive enhancement in pupils and students in Germany. *Pharmacopsychiatry,44*(7), 331-338. doi:10.1055/s-0031-1286347

Griffiths, R. R., & Woodson, P. P. (1988). Caffeine physical dependence: a review of human and laboratory animal studies. *Psychopharmacology, 94*(4), 437-451. doi:10.1007/bf00212836

Haskell-Ramsay, C., Jackson, P., Forster, J., Dodd, F., Bowerbank, S., & Kennedy, D. (2018). The acute effects of caffeinated black coffee on

cognition and mood in healthy young and older adults. *Nutrients, 10*(10), 1386. doi:10.3390/nu10101386

Hindmarch, I., Quinlan, P. T., Moore, K. L., & Parkin, C. (1998). The effects of black tea and other beverages on aspects of cognition and psychomotor performance. *Psychopharmacology*, *139*(3), 230-238.

Hogervorst, E., Riedel, W., Schmitt, J., & Jolles, J. (1998). Caffeine improves memory performance during distraction in middle-aged, but not in young or old subjects. *Human Psychopharmacology: Clinical and Experimental, 13*(4), 277-284. doi:10.1002/(SICI)1099-1077(199806)13:43.0.CO;2-W

Jarvis, M. (1993). Does caffeine intake enhance absolute levels of cognitive performance? *Psychopharmacology, 110*(1-2), 45-52. doi:10.1007/BF02246949

Lyvers, M., Brooks, J., & Matica, D. (2004). Effects of caffeine on cognitive and autonomic measures in heavy and light caffeine consumers. *Australian Journal of Psychology,56*(1), 33-41. doi:10.1080/00049530410001688119

Mattay, V., Callicott, J., Bertolino, A., Heaton, I., Frank, J., Coppola, R., . . . Weinberger, D. (2000). Effects of dextroamphetamine on cognitive performance and cortical activation. *Neuroimage, 12*(3), 268-275. doi:10.1006/nimg.2000.0610

Nehlig, A. (2010). Is caffeine a cognitive enhancer? *Journal of Alzheimer's Disease: Jad, 20*, 85-94. doi:10.3233/JAD-2010-091315

Official Bulletproof Coffee Recipe. (2019). Retrieved 24 July 2019, from https://www.bulletproof.com/blogs/recipes/official-bulletproof-coffee

Page, K., Williamson, A., Yu, N., McNay, E., Dzuira, J., McCrimmon, R., & Sherwin, R. (2009). Medium-chain fatty acids improve cognitive function in intensively treated type 1 diabetic patients and support in vitro synaptic transmission during acute hypoglycemia. *Diabetes,58*(5), 1237-44. doi:10.2337/db08-1557

Reissig, C., Strain, E., & Griffiths, R. (2009). Caffeinated energy drinks—a growing problem. *Drug and Alcohol Dependence, 99*(1-3), 1-10. doi:10.1016/j.drugalcdep.2008.08.001

Rose, J., & Behm, F. (1991). Psychophysiological interactions between caffeine and nicotine. *Pharmacology Biochemistry And Behavior, 38*(2), 333-337. doi: 10.1016/0091-3057(91)90287-c

Ruxton, C. H. (2008). The impact of caffeine on mood, cognitive function, performance and hydration: A review of benefits and risks. *Nutrition Bulletin, 33*(1), 15-25. doi:10.1111/j.1467-3010.2007.00665.x

Sherman, S. M., Buckley, T. P., Baena, E., & Ryan, L. (2016). Caffeine enhances memory performance in young adults during their non-optimal time of day. *Frontiers in psychology, 7*, 1764. doi:10.3389/fpsyg.2016.01764

Swift, C., & Tiplady, B. (1988). The effects of age on the response to caffeine. *Psychopharmacology, 94*(1), 29-31. doi: 10.1007/bf00735876

Van Ruitenbeek, P., Hernaus, D., & Mehta, M. A. (2018). A proof-of-principle study of the effect of combined haloperidol and levodopa administration on working memory-related brain activation in humans. *Human Psychopharmacology: Clinical and Experimental*, *33*(5), e2675. doi:10.1002/hup.2675