THE COMPARISON EFFECT BETWEEN PURE CAFFEINE AND REGULAR COFFEE ON ATTENTION PERFORMANCE AMONG UNIVERSITY STUDENTS

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Abstract: Caffeine is the most consumed beverage worldwide; it has been revealed to produce several effects on human health including the effect on attention performance. A previous study indicated that most people consumed caffeine to enhance alertness and increase overall performance at some stage in mentally and physically intensive situations. The purpose of this study was to compare the effect of pure caffeine (PC) and regular coffee (RC) ingestion on attention performance among local university students. Thirty UiTM Perlis students with low or non-caffeine consumers (aged 20-22 years) were involved in this study. Each group consumed 220 mL of designated caffeine beverages. The study utilized a single-blinded and randomized group. The attention performance was measured at the baseline and experimental trial using the Mackworth Clock Test (MCT). The result showed there was no significant main effect for time with attention score between baseline and experimental trial for both groups. However, a significant main effect between groups was reported on attention performance, $F(1, 28) = 7.652$, $p = .010$. Additionally, the RC group has shown a greater improvement from the baseline (9.8±3.5) to the experimental trial (8.3±3.4) compared to the PC group (baseline=6.9±4; experimental=5.7±2) toward attention performance. This study demonstrated that in healthy university students, the administration of regular caffeine beverages elicited a little enhancement of attention performance. Thus, a need for further study should be done on the physiological and psychological effects to examine the mechanism of the caffeine ingested.

Keywords: Attention test, caffeinated beverages, caffeine consumption, cognitive performance

1. Introduction

Caffeine has been chosen as one of the most widely consumed by 80% of the world's population (Sherman, Buckley, Baena, & Ryan, 2016). Apparently, it was present mostly in the coffee but also found in other beverages such as tea, chocolates and soft drinks. Furthermore, caffeine has been frequently added to food, pain relievers and other products. Since 1987, caffeine was known as psychoactive in doses found in single servings of many beverages and an active ingredient in a relatively new product like energy drinks (Lieberman, Wurtman, Emde, Roberts, & Coviella, 1987; McLellan, Caldwell, & Lieberman, 2016). It has been proven to quickly absorb in the gastrointestinal tract following oral consumption and produce the highest blood concentration after 30 to 60 minutes. Physiologically, caffeine acted as an adenosine receptors antagonist which impeded the binding of adenosine to its receptors in the cell membrane due to the raise of plasma concentration (McLellan et al., 2016). In a study from Ullrich et al. (2015), after caffeine has been ingested, the antagonist characteristic resulted into a mild dilation of blood vessels, increase metabolic rate, increase urine production and increase in blood pressure. Interestingly, a few studies have found expanding effect of caffeine that enhances alertness, reduces fatigue, increases feeling of wellbeing, mental energy, motivation and self-confidence (Haskell-Ramsay et al., 2018; Heinz, Kassel, & Smith, 2009; Lanini, Galduróz, & Pompéia, 2016; McLellan et al., 2016; Terry & Phifer, 1986). Finding from these studies has shown numerous cognitive effects resulting from a rich source of caffeine which acted as psychoactive stimulant. Cognitive benefits from coffee consumption are typically attributed to caffeine, which exerts its effects through non-selective antagonism of adenosine, increasing central cholamine release subsequent in increased arousal and improves cognitive functioning. Even at low doses, it has

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been shown to significantly exert some limited cognitive effects, such as increase reports of alertness, sustained attention and faster reaction time (Adan & Serra-Grabulosa, 2010; Einöther & Giesbrecht, 2013; Nehlig, 2010; Nehlig & Boyet, 2000)

Attention is related to our perceptual and cognitive developments that give us the ability to focus on certain occasions for actions (Le Pelley, Mitchell, Beesley, George, & Wills, 2016). Caffeine effects on attention performance have been proven in some previous studies. The previous studies stated all the positive effects among varying ages of participants. For example, Haskell-Ramsay et al. (2018) stated that caffeine has positive effects on measures of reaction time and sustained attention tasks among elderly who aged 21 to 34 and 61 to 80 years old. In addition, another study stated that the effect of 60 mg caffeine dose has shown a significant improvement in sustaining attention compared with the placebo among participants who aged 40 to 60 years (Wilhelmus et al., 2017). Moreover, a study from Kahathuduwa, Dassanayake, Amarakoon, and Weerasinghe (2017) stated that theanine and caffeine have a similar effect in improving the reaction time among subjects who are healthy male undergraduates at the University of Paradeniya, Sri Lanka.

Frequently, adults were likely to consume coffee and tea in which both contain natural caffeine in their leaves and beans. The habit of consuming caffeine was highly prevalent among young adults particularly aged 25 years or less (Penafort et al., 2016). As far as we are concerned, university students are counted among those who consumed caffeine regularly. Conferring to Sherman et al. (2016), students rely on coffee to improve their academic through a variety of learning skills including memorizing. The author also suggested that caffeine gives a strong memory enhancement during early morning, but it remains unclear whether consuming caffeine would result in better learning. Despite from unclear result, it was reported that caffeine intake increases with age and year of college or university students. This increment has been assumed by Norton, Lazev, and Sullivan (2011) who explained from the view of student's packed schedule as they continue through college. They also showed that upperclassmen consumed caffeine more frequently than underclassmen in a variety of situations, such as studying for test, completing load of assignments and a lack of sleep. Possibly, this was due to the availability and affordability of caffeine beverages in campus.

To be added, an epidemiology study from Franke et al. (2011) implied that the widespread use of coffee and caffeinated drinks among students was aimed at the cognitive enhancement. However, they did not evaluate in detail how much caffeinated drinks or coffee was consumed. Despite the amount of caffeine given before the testing, the period of caffeine absorbed after the test and the type of test used, there was not much greater directly effects of caffeine on learning and attention. Sporadically, caffeine effects on attention and learning were found but these effects produced come from the result of complex interaction with dose, participants and task variables. Therefore, caffeine or caffeinated drink does not present as a direct cognitive enhancer. To date, several studies showed the significant effects of caffeine ingestion on attention among varying ages of subjects such as the elderly, but lack of evidence showed the true effects of caffeine ingestion on local university students. The aim of this study was to compare the effects of pure caffeine and regular coffee ingestion on the attention performance among local university students.

2. Materials and Methods

2.1 Research design

The current study was conducted in a single blinded and randomized trial with two treatment conditions: pure caffeine and regular coffee. This study involves a quantitative research using experimental design to identify the effect of caffeine ingestion on attention performance among university students. Participants were randomly divided into two separate groups with each consisting of 15 participants. During visit 1, they answered demographic questionnaire, Physical Activity Readiness Questionnaire 2019 (PAR-Q), and completed Consent form. They were also asked to do the Mackworth Clock Test for familiarization. During visit 2, after given a standardized light breakfast, both groups undergone the baseline and experimental trials in which they consumed the designated caffeinated beverages and later did the attention test.

2.2 Ethical approval

This study was approved by the UiTM Research Ethics Committee, and all participants provided the informed consent.

2.3 Participants

Thirty students from UiTM Perlis (aged 20-22 years) were selected in this study. Participants completed four sets of questionnaires (CCD, PHQ-9, GAD-7 and Demographic Questionnaire). Participants involved in this study were non-caffeine consumers and low caffeine consumers which scored below 7 for GAD-7 and scored below 14 for PHQ-9 questionnaire.

Participant selection: The screening questionnaires (CCD, PHQ-9, and GAD-7) were distributed to each possible participant before participating in this study. The purpose of screening the participant was to select the non-caffeine consumers or low-caffeine consumers, which consumed 150 mg of caffeine approximately per day or one cup per day (Wilhelmus et al., 2017). If they scored high in both GAD-7 or PHQ-9, they were proven to associate with mood disturbances and clinical conditions. This might impact the endpoints of the study and must be excluded from the study.

Caffeine Consumption Diary (CCD): The questionnaire was adapted from Heinz et al. (2009) which asked about caffeine consumption, reasons of consumption, experience after caffeine consumption and the preferred caffeinated drinks (regular coffee). One of the important questions was to identify whether the participant was none or low caffeine consumer in order to meet the inclusion criteria.

Generalized Anxiety Disorder-7 (GAD-7): There were seven items in this questionnaire which was directly adopted from Srivastava, Mennemeier, and Pimple (2017) and validated with the Cronbach's alpha value of 0.832. Only participants who scored below than 7 were included.

Patient Health Questionnaire-9 (PHQ-9): This is a multipurpose tool for screening, diagnosing, monitoring and measuring the severity of depression. It was directly adopted from the previous study (Srivastata et al., 2017) which consisted of nine items. The Cronbach's alpha value was 0.755. Participants who scored equal or more than 14 were excluded.

2.4 Study protocol

All participants visited the testing location on two separate occasions. During visit 1 upon arrival, participants were asked to sign the consent form and answer the Physical Activity Readiness Questionnaire 2019 (PAR-Q). They were asked to answer the demographic information by using the adopted Demographic Questionnaire (Heinz et al., 2009). They performed the MCT in order to familiarize them with the testing procedure and to minimize procedural learning effects. The testing of tests was done twice during this visit (Wilhelmus et al., 2017). Participants were instructed to abstain from tea, coffee or other caffeinated beverages for at least 12 hours and sleep at least 6 hours prior to the experimental trial (Kahathuduwa et al., 2017).

During visit 2, participants reported to the testing location during morning hours and the testing began at an early time of the day (9 am) in order to avoid the impact of daily tasks (related to mental and physical stress) on the study outcomes (Srivastava et al., 2017). Upon arrival at the testing location, the participants were asked to rest and relax for 15 to 20 minutes. After taking a short rest, participants were given standardized light breakfast which contained the amount of 168 calories that were provided to control variations from possible dietary confound (Srivastava et al., 2017). Baseline data were collected after 30 minutes post breakfast (Srivastava et al., 2017). After collecting the data, participants received the administration of pure caffeine and regular coffee by referring to their group accordingly. No other food or calorie-containing beverages were given during this period. Participants were only allowed to drink water as desired and to relax in a suitable room (Srivastava et al., 2017). After the baseline collection period and the administration of caffeine and regular coffee, the experimental trials began. Participants were asked to rest for 10 minutes to allow the process of caffeine absorption before they start taking the actual MCT (Wilhelmus et al., 2017).

2.5 Procedures

Interventions: The participants were randomly divided into two different groups (pure caffeine and regular coffee). Each group consumed 220 mL of designated beverages. The first group used the amount of 60 mg of pure caffeine with 220 mL water for pure caffeine group (Wilhelmus et al., 2017). The regular coffee data were taken from the participants' most answers in the CCD questionnaire. The number of caffeine doses used in this study was measured with the HAMGEEK Professional Digital Mini Scale TL- series. Both groups were asked to perform the MCT at the baseline and experimental trial in order to collect the data of attention performance.

Mackworth Clock Test (MCT): This test was used to examine participants sustained attention performance before and after consuming the caffeinated beverages. A computer screen displayed a circular arrangement of 60 dots simulating the second's marks on a clock. Dots were briefly illuminated in clockwise rotation at a rate of one per 500 milliseconds. The participants were instructed to watch the clock hand moving circular and they had to press the spacebar immediately when they saw a double jump (within 1 second). They were given feedback immediately if the action was right or wrong. If they pressed the spacebar incorrectly (when there was no double jump), the error signal was detected. Otherwise, if they pressed the spacebar correctly, the green light feedback was shown. The number of missed skips were taken as the score in order to determine the attention performance. The lower number of missed skips recorded by the participants, the better the result of the attention performance.

2.6 Data analysis

The data was analysed using SPSS v.23 (IBM Corp., Chicago, IL, USA). The frequency and percentage (%) were used to show the descriptive statistics of subjects' characteristics. The comparison analysis between pure caffeine and regular coffee was analysed using mixed-model ANOVA with the p-value set below than 0.05 ($p<0.05$).

3. Results

Table 1 shows the demographic characteristics of the subjects. The age range for the subjects was between 20 to 22 years. Both groups were randomized equally by mixed gender. Their weight and height were recorded before the trials computed the Body Mass Index (BMI). Based on the norms, most of the subjects were considered in normal category (PC=73.3%; RC=60%). For habitual caffeine consumption, they were documented as equally none and low caffeine consumers based on the CCD questionnaire during the participants' selection.

Table 1: Subject's characteristics (n=30)

Parameters	**Pure Caffeine**		**Regular coffee**	
	Frequency	**(%)**	**Frequency**	**(%)**
Age	n=15		n=15	
20-22				
Gender				
Male	8	53.3	7	46.7
Female	7	46.7	8	53.3
BMI (kg/m^2)				
Underweight	1	6.7	2	13.3
Normal	11	73.3	9	60
Overweight	2	13.3	3	20
Obesity	1	6.7	1	6.7
Habitual Caffeine Consumption				
None	7	46.7	8	53.3
Low	8	53.3	7	46.7

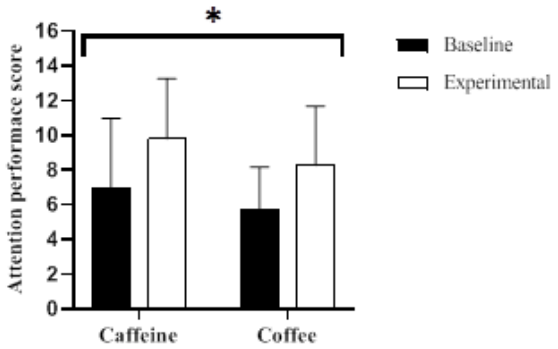

Figure 1: Comparison attention performance scores (Missed skip) between two groups

Figure 1 shows the data on missed skip by the subjects as the score for the attention performance between both groups showed no significant improvement between the baseline and experimental trial. However, a significant main effect between groups of pure caffeine and regular coffee was found with $F(1, 28) = 7.652$ $p<0.05$ (Table 2).

Table 2: Main Effect Between Pure Caffeine and Regular Coffee

	df	**F**	***p*-value**
Group	1	7.652	.010*

Table 3: Comparison of Percentage Improvement

Group	**Baseline M±SD**	**Experimental M±SD**	**(%) improvement**
Pure Caffeine (PC)	6.9±4	5.7±2	7.2
Regular Coffee (RC)	9.8±3	9.8±3	9

Examination the comparison of means (Table 3) indicated that there was a better improvement in attention scores by 9% of subjects among regular coffee at the baseline (9.8±3) to experimental trial (9.8±3), compared to the attention scores from pure caffeine group with lesser improvement by 7.2% (baseline=6.9±4; experimental=5.7±2). Hence, it proved that the administration of 60 mg of pure caffeine did not merely improve much toward the attention performance as we predicted. Yet, little improvement did occur from the regular coffee that university students always consume.

4. Discussion

Regular coffee administration showed better improvement rather than pure caffeine on attention performance. The comparison of mean between baseline and the experimental trial showed that regular coffee had an improvement on the attention performance by 9% higher than pure caffeine's improvement. The situation might be related to the effect of a combination of glucose and caffeine. It is because, for regular coffee, it involved 220 mL of regular coffee which included 60 mg of caffeine, sugar, and milk. The improvement occurred because the consumption of caffeine and glucose was shown to reduce brain activation associated with the task in the bilateral parietal cortex and the left prefrontal cortex in which these two regions actively participated in attention and working memory processes. The improvement was also proven and in line with the previous studies which stated that the combination of caffeine and glucose had a significant effect on attention performance. For example, a study from Adan and Serra-Grabulosa (2010) indicated that the synergistic effect of caffeine and glucose can benefit sustained attention and verbal memory. The study used 75 mg of caffeine plus 75 g of glucose and found a positive result on attention. It also stated that the combined administration of caffeine and glucose was shown to improve that execution in all reaction time tasks except choice, learning, and memory. Next, another study also found a positive result regarding the combination of caffeine and glucose. A study from Scholey and Kennedy (2004) proved that the synergistic effect of

both caffeine and glucose improved and enhanced the high demand sustain attention process. The study also stated that the improvement did not occur with the separated administration of caffeine and glucose which suggested that it only occurred with the combined administration because it may be more effective as a cognition enhancer for the type of task given. Lastly, the study by Rao, Hu, and Nobre (2005) also examined the combination of caffeine and glucose on attention performance by using tasks on sustained selective attention. The study produced the expected result in which the combination drink enhanced the behavioural performance in both terms of accuracy and speed of reactions. In conclusion, even though the regular coffee was used as controlled group in this study, it still proved to produce an improvement on the attention performance. The result produced from previous studies indicated that regular coffee with the combination of caffeine and glucose could also achieve a significant effect on human attention performance.

The findings showed there was a significant main effect between pure caffeine and regular coffee on attention performance among local university students. The result produced in this current study might be influenced by the caffeine doses that participants ingested. The different amount of caffeine doses ingested has different effect on participants. It also had a significant effect on the outcome of the study. In this study, it involved a low dose of caffeine which was 60 mg. The result showed a little improvement in attention performance among regular coffee group by 9% higher than pure caffeine group which was only 7.2%. These observed effects might occur due to the known effects of caffeine that stimulate the A1 receptors of the brain. Caffeine will directly involve in neuronal activity in several parts of the brain such as hippocampus, cerebral cortex, and cerebellum. Caffeine is also involved in numerous hypothalamic nuclei, explaining its effects on enhancing arousal vigilance and attention based on the study by Ferré (2010). Inversely, a study by Wilhelmus et al. (2017) showed that the intake of 60 mg caffeine doses had a significant effect in sustained attention when compared to placebo which showed a significant effect on reaction time performance. Starting from low doses, caffeine can give effect in the human brain and it has a significant effect on the cognitive performance. However, the result of this current study indicated that even the use of low caffeine doses did not produce a significant effect on sustained attention performance.

The findings of this current study might also be influenced by the effect of habitual caffeine consumption of the participants. In this study, participants involved were none and low-habitual caffeine consumers. Habitual caffeine consumption was one of the factors that need to be considered regarding an experimental study using caffeine doses. It is because someone can possess and have a significant effect that can help them to improve the number of adenosine receptors in their brain and influence the outcome of this study. Based on the previous study, if the participants consume a high number of caffeine doses, they will get the same benefits as participants who are low habitual caffeine consumer (Varani et al., 2000). It has been proven that low habitual caffeine consumers benefited more from the positive effect of caffeine compared to non-habitual caffeine consumers. For example, the little improvement result showed in this current study was similar to the previous study which involved participants who were low habitual caffeine consumers since it influenced a simple task of Digit Vigilance and a complex task of Cognitive Reflection (Hewlett & Smith, 2006). Low habitual caffeine consumers involved in this current study were proven to achieve better results when it comes to attention performance.

The result of this study also found there was no significant effect between baseline and experimental trial for both groups. Peak plasma concentration of caffeine might be the possible reason that causes the result. Peak plasma concentration will occur after the ingestion of caffeine and caffeine is directly move into the human body fluid and tissues. Peak plasma concentration refers to the optimum concentration of caffeine that gives an effect on the human body. If the caffeine reaches the peak of the concentration, it will give major benefits to its effect. After ingestion, caffeine will be completely absorbed into the body, and the time to achieve the optimum plasma concentration varied between 15 minutes until 2 hours (Alsabri, Mari, Younes, Alsadawi, & Oroszi, 2018). According to Wilhelmus et al. (2017), the study found that the concentration of caffeine peaked at approximately 70 minutes after 60 mg of caffeine administration and dropped or disappeared at 180 minutes after its ingestion. The previous study also demonstrated that after oral administration of a single dose, it resulted in rapid absorption which was 26.4 minutes after ingestion (Teekachunhatean, Tosri, Rojanasthien, Srichairatanakool, & Sangdee, 2013). Besides, Ruxton (2008) stated that the peak plasma concentration of caffeine will occur after 60 to 90 minutes post ingestion. The finding of previous studies proved that

the peak plasma concentration of caffeine had varied starting from 15 minutes until 200 minutes. It contrasted with this study's procedure based on the gap of time given between caffeine ingestion and the experimental trial. This current study only provided 10 minutes of caffeine absorption period before the participants started with their experimental trial. Based on previous study, the time given for caffeine absorption for this current study was not enough in order to gain the benefits of caffeine especially when caffeine was on the peak of its concentration based on the comparison made by previous studies.

This study used GAD-7 and PHQ-9 as a screening tool in order to select the participants. These questionnaires were known to examine the emotional state of the participants and if they get high scores for GAD-7 and PHQ-9 questionnaires, they were proven to be associated with mood disturbances and clinical conditions. These questionnaires used during the screening process were assumed to exclude a person who was proven to associate with mood disturbances and clinical conditions such as anxiety and depression. The positive result produced in this study might be influenced by participants who have been declared as an emotionally healthy person. It is because, previous studies have stated that the emotional state of a person can influence the cognitive performance. If a person has been associated with anxiety and depression, this situation is known to impact the endpoints of the study that involve cognitive performance like attention (Srivastava et al., 2017). Cognitive performance such as attention can be affected by the emotional state of the participants involved in the study (Luck & Vogel, 2013; Owens, Stevenson, Hadwin, & Norgate, 2012). In the emotional area, major factors that can affect cognitive performance include stress and anxiety and both symptoms are clearly linked to impair cognitive performance (Maloney, Sattizahn, & Beilock, 2014; Moran, 2016). Besides, stress and anxiety act in a similar way to reduce attention performance as they are allocated to the potential threat. A person with anxiety will impair attention performance because it has been proved that anxiety has a significant effect on attention performance. Furthermore, according to Sapolsky (2015), it stated that based on the inverted-U theory of acute stress, the effect depends on the stress level related to the test situation. For example, when stress is at a moderate level, it may enhance cognitive performance, but when the stress is in both low (un-motivating) and high (overwhelming) conditions, stress will be associated with the drop or decline of the cognitive performance. A finding has been found regarding the relationship between stress and attention tasks. A study from Petrac, Bedwell, Renk, Orem, and Sims (2009) found a moderate positive correlation between everyday stress and error rates on attention tasks in both auditory and visual in undergraduates' students. The positive result was similar to previous study that also used GAD-7 and PHQ-9 to screen their participants. According to Srivastava et al. (2017), the study also used those questionnaires and it resulted in the significant increase of caffeine group on alertness scores when compared to baseline.

5. Conclusion

The main finding of this study revealed that the ingestion of 60 mg caffeine enhanced the sustained attention performance's score. Both groups increased the attention score after caffeine ingestion, but better scores were found among the regular coffee group with 9% higher than the pure caffeine group from the baseline to the experimental trial. Since the regular coffee has been plentifully consumed by the university students (based on the CCD questionnaire), they might continue to drink it. This study was designed only to collect the data before and after caffeine ingestion, and later it was tested on sustained attention performance. More exquisite study should be done in this area to examine other variables on the effect of caffeine beverages.

6. Future Recommendation

The academic background could be a major contribution that can influence or have a significant effect on their attention performance. The result produced from the study could also be useful in order to see any relationship between academic performance and attention performance. Besides, a future study can compare the effect of caffeine ingestion between gender in order to gain information such as the relationship between gender and attention performance. Furthermore, an upcoming study should be planned to control the dietary intake and sleeping time of the participants in the days prior to the experimental trial due to the major influence that might affect the outcome of the study.

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