BSc in Psychology
Department of Psychology

Effects of Caffeine Withdrawal and Withdrawal Recovery on Alertness and Working Memory Performance Among Undergraduate Students

June, 2020
Student: Dagur Andri Einarsson
ID: 180598-2869
Foreword

Submitted in partial fulfillment of the requirements of the BSc Psychology degree, Reykjavik University, this thesis is presented in the style of an article for submission to a peer-reviewed journal.

This thesis was completed in the Spring of 2020 and may therefore have been significantly impacted by the COVID-19 pandemic. The thesis and its findings should be viewed in light of that.
Abstract

The current study aimed to examine effects of caffeine withdrawal on working memory span and psychomotor vigilance. Participants in the study were college students attending Reykjavík University during the spring semester of 2020. Participants were between the ages of 20 and 31 and the group consisted of 4 females and 3 males. A repeated measures design was used, with two separate groups either receiving caffeinated coffee or decaffeinated coffee. Participants completed an automated operation span task (Aospan) and psychomotor vigilance test (PVT) once per day on three testing days. The first testing day was a baseline measurement conducted on a wednesday, the second measurement was conducted the morning after baseline testing to examine withdrawal effects. The third measurement was conducted 6 days after the second one to examine performance after recovery from withdrawal effects. Results indicated no significant differences on any measurements.

Keywords: Working Memory, Alertness, Caffeine, Withdrawal

Útdráttur


Lykilorð: Viinnsluminni, Árverkni, Koffín, Fráhöfð
Effects of Caffeine Withdrawal and Withdrawal Recovery on Alertness and Working Memory Performance Among Undergraduate Students

Caffeine or trimethylxanthine is a psychoactive drug that is consumed daily by around 80% of the population (James, 1997). This psychoactive drug is most often consumed in the form of coffee, tea or energy drinks. The fact that 80% of the population use this drug daily compels researchers to provide substantial evidence for the many popular beliefs surrounding this drug, especially the one that it may be a cognitive enhancer (Rogers et al., 1995).

Modern caffeine research has two major schools of opinion, on one hand there are those who claim that caffeine has beneficial effects and may possibly acts as a cognitive enhancer (Nehlig, 2010). On the other hand, there are those who assert that caffeine has no beneficial effects on cognition (James, 2005). There has been substantial research concerning the possible benefits of caffeine on cognitive functions (Brice & Smith, 2002; Haskell et al., 2005; Hewlett & Smith, 2006). Researchers have examined the effects of caffeine on certain aspects of cognitive functioning such as attention, memory, reaction time and tapping speed, concluding that caffeine does indeed enhance all of these factors (Borota et al., 2014; Brice & Smith, 2002; Einöther & Giesbrecht, 2013; Haskell et al., 2005; Kahathuduwa et al., 2017; Lieberman et al., 2005). Such research is, however, often tainted with methodological issues. James (2014) has made evident that in most published research articles reporting results of caffeine enhancing cognitive abilities, there are substantial deficits in their methodologies. The deficits mainly pertain to the use of placebo style studies, which assume there are no negative effects of caffeine withdrawal as they do not include run in periods of caffeine abstinence sufficiently long to ensure there are no potential negative effects of caffeine withdrawal (James, 1994, 2014). This practice has continued in research despite evidence to the contrary of their assumptions that caffeine withdrawal has no negative effects (Borota et al., 2014; Brice & Smith, 2002; Haskell et al., 2005; Smith & Nutt, 2014). Indeed, research
EFFECTS OF WITHDRAWAL ON ALERTNESS AND WORKING MEMORY

On caffeine withdrawal has shown it to negatively affect simple reaction time, recognition memory as well as choice reaction time (Rogers et al., 2013).

Caffeine withdrawal is the appearance of negative physical and cognitive symptoms after a period of short abstinence. After 12 hours the symptoms have most likely appeared and are at their worst around 20 to 50 hours after the last consumption of caffeine and include headaches, muscle soreness, trouble concentrating, dizziness, fatigue, and nausea (Juliano & Griffiths, 2004). Caffeine withdrawal can last for up to 6 days (Ozsungur et al., 2009). In a literature review by Juliano and Griffiths (2004) they mention that despite documentation of caffeine withdrawal symptoms in the literature dating back 170 years, proper research has only been conducted recently. One of the more influential hypotheses in caffeine research relating to withdrawal in recent years is the caffeine withdrawal reversal hypothesis first mentioned by Dr. Jack E. James 26 years ago (James, 1994). The withdrawal reversal hypothesis states that caffeine does not have any beneficial effects per se but merely restores cognitive and physical functioning degraded during caffeine withdrawal due to the various negative effects. In an article by James and Rogers (2005) they examined three types of studies that are quite popular in caffeine research, such as those mentioned before, and pondered whether the results achieved in those studies could be attributable to reversal of withdrawal. They concluded by stating that the effects of caffeine on performance could nearly always be attributable to reversal of the withdrawal effects. Research focused on this hypothesis has been underappreciated, as many caffeine studies continue to ignore the possibility of the hypothesis’s implications. James mentioned in a review of caffeine studies in 2014, that recent studies such as the one by Borota et al. (2014) continue to utilize methodology that does in fact not consider the potential effects of caffeine withdrawal reversal.
In a recent study by Weibel et al. (2018) they examined the effects of caffeine withdrawal on vigilance using the PVT. Participants were all coffee consumers and were divided into three groups. One receiving caffeine for 11 days, another receiving caffeine for nine days and then a placebo for two days, and the last group received only placebo. Results indicated that participants’ PVT score was negatively affected by caffeine withdrawal. Additionally, they found the PVT scores of those in the withdrawal group to be worse than of those in the placebo group, indicating that those in the placebo group had, at least partly, recovered from withdrawal effects within those 9 days. There was also no significant difference between the PVT scores among the placebo group and the group receiving caffeine for all 11 days of the experiment indicating caffeine withdrawal reversal mentioned before.

Vigilance or alertness is important in all manner of tasks in daily life as mentioned by Basner and Dinges (2011). Therefore, it is important to continue the exploration of the effects of caffeine withdrawal on alertness.

Despite research on the effects of withdrawal on psychomotor vigilance, recognition memory and choice reaction time, there are still many aspects of cognition still to be explored regarding effects of caffeine withdrawal. One such aspect of cognition is working memory. Working memory can be comprehended in short as a system that maintains things in short-term memory while performing complicated tasks (Baddeley & Hitch, 2010). The most popular model of working memory is one developed by Baddeley and Hitch. The model has four constructs, the visuospatial sketchpad, articulatory loop, central executive and episodic buffer (Baddeley & Hitch, 2010). Working memory is imperative to daily functioning as it is an important foundation to many aspects of cognition (Smith, 2012). Establishing the effects of caffeine withdrawal on working memory is therefore important. Degrading effects of caffeine withdrawal on working memory may challenge the underlying assumptions in methodology of many major studies concluding that caffeine is an enhancer.
A recent study by Morava et al. (2019) addressed in part the effects of caffeine and caffeine withdrawal on working memory. In that study Morava et al. set out to study the effects of aerobic exercise on working memory and caffeine withdrawal. Within this study there were measurements of effects of caffeine withdrawal, mentioned as caffeine deprivation in the study, on working memory. Their results, however, yielded findings of no significant changes in working memory between those who experienced caffeine withdrawal and those who did not. However, the study utilized the n-back task as a measure of working memory. As mentioned by Jaeggi et al. (2010) the n-back task is only reliable when detecting inter-individual differences, not intra-individual. Measurements of the effects of caffeine withdrawal on working memory require measurements to be carried out more than once. Therefore, another method of working memory assessment may have been more appropriate.

It is important that we continue to explore how caffeine withdrawal affects certain aspects of cognition, especially since with increasing interest in cognitive neuroscience more caffeine research pertaining to cognition could emerge. In order to avoid the mistakes that have been made and continue to be made to this day, regarding dismissal of the effects of caffeine withdrawal, verifying the effects of caffeine withdrawal on cognitive factors could be imperative in convincing researchers to utilize methodology that avoids the potentially negative effects of withdrawal.

In the current study the effects of caffeine withdrawal on working memory span and psychomotor vigilance were measured. A recovery period of 6 days was also measured in order to provide evidence for or against the caffeine withdrawal reversal hypothesis. Decaffeinated coffee was used in place of a placebo, acknowledging that the trace amounts of caffeine in the decaffeinated coffee may indeed have caused skewed results. As Haskell et al. (2008) pointed out, an amount of caffeine as little as 9mg can have psychoactive effects. Due to lack of resources this was deemed to be the best option and a risk worth taking.
The research questions of the present study were whether caffeine withdrawal affects working memory and psychomotor vigilance and if affected whether a recovery period would reinstate abilities. Presented were two hypotheses, firstly, that withdrawal will have a negative effect on Aospan scores and PVT scores. Secondly, that after a recovery period Aospan and PVT scores will be restored.

**Methods**

**Participants**

Participants (mean age ± SD = 24.57 ± 3.99), consisting of 4 females and 3 males (N = 7), were recruited by means of electronically administering to students who possessed a Reykjavik University (RU) email address a screening questionnaire (see Appendix A) adapted from James et al. (2005). Another modified questionnaire from James et al. (2005) (see Appendix B) was also administered at the end of classes of first- and second-year psychology students at RU. Inclusion criteria were such that the person had to be a student at Reykjavik University and consume at least 3 cups of coffee per day (although this was later changed to 2 cups due to recruitment issues). Distinctions were made in the screening questionnaire adapted from James et al. (2005) pertaining to which kind of coffee participants consumed (e.g. brewed or instant) although that did not affect the inclusion of said participants. Neither sex nor age had any effect on selection of participants, as mentioned above the only requirement was that the potential participant consumed 3 or more cups of coffee per day. Participants entered or wrote down, dependent on whether the participants answered the electronically administered questionnaire or the physical one, their email address on the questionnaire. Participants who matched the selection criteria then received an email elaborating on the experiment and provided with more detail as to what would be required of them, although not revealing so much as to compromise the experiment. The email concluded by asking the potential participant to answer whether he or she would like to
partake in the study. Participants were assigned randomly to one of two experimental conditions.

**Design**

The design of the present study is a repeated measures design with the independent variable being caffeine and the dependent variables being working memory and alertness.

**Materials**

**Coffee.** The coffee used in the current study was Nescafé Azera® instant caffeinated and decaffeinated coffee. The caffeine content of one cup of Nescafé Azera® instant decaffeinated coffee was difficult to acquire information about, as when contacting Nestlé® customer service the only answer given was that this particular coffee was not part of the product line in the Nordics and therefore no information was available. There was no mention of any traces of caffeine on the decaffeinated coffee packaging but there was still some possibility of trace amounts of caffeine being present in the coffee. Information regarding the caffeine content of Nescafé Azera® caffeinated instant coffee was also hard to find although Nestlé® said upon questioning that their regular product range contained 32mg of caffeine per serving. The caffeinated coffee was acquired physically from Costco® and the decaffeinated coffee was acquired from Amazon®. Eighteen cans of caffeinated coffee were acquired (due to large amounts per pack) and 8 cans of decaffeinated. Packaging of the coffee was aluminum with a plastic lid, and each can of coffee contained 55 cups of coffee provided that one cup was defined as one teaspoon per 200ml. Participants did, however, receive the coffee in glass jars with sealable lids.

**Salimetrics® oral swab.** One packet of Salimetrics® oral swab contained a small cylindrical shaped cotton. The cotton was to be placed under the tongue for at least two minutes and then placed into a resealable plastic bag. Use of oral swabs was discontinued after use by 5 participants due to increasing concerns regarding Covid-19.
Resealable plastic bags. A mix of 0.4 liter (14 fl. Oz) and 1 liter (34 fl. Oz) resealable bags from IKEA® were used for containing the oral swabs. Eight bags were included in the kit set. Larger 2.5 liter (96 fl. Oz) resealable plastic bags were used to hold the coffee jars, salimetrics® oral swabs and smaller bags.

Automated working memory span task. The Aospan used in the current study was based on the works of Unsworth et al. (2005). The Aospan consisted of a practice section and the real task. Within the Aospan the task consisted of the appearance of a math equation to be solved and then the appearance of a letter to be recalled later. Set sizes ranged from 2 to 5 (3x2, 3x3, 3x4, 3x5). The appearance of the math equation would last for a time determined by the mean time it took the participant to complete the equations in the practice section plus 2.5 SD. If the math equation was not completed within that timeframe then the equation would disappear and be counted as a math error. The letters would appear for 800 milliseconds and then disappear. Ospan tasks have been shown to be a reliable and valid measure of working memory as well as the automated adaptation utilized in this study (Conway et al., 2005; Unsworth et al., 2005).

PVT. The PVT utilized was based on the works of Basner and Dinges (2011) and consisted of a practice session and then the real task. During the PVT a red square would appear on a black background and after a random amount of time a timer would start. The start was indicated by the appearance of yellow numbers at the center of the red square, reflecting the time passed in milliseconds from the initiation of the timer. The timer would stop after the participant clicked with the mousepad on the screen. This process would be repeated for 10 minutes. The PVT was automated like the Aospan and housed on the same website. As Basner and Dinges (2011) mention, the PVT has been shown to be reliable.
**Procedure**

Participants were contacted through email and asked to provide answers as to whether they would like to participate. If a positive answer was provided an additional email was sent explaining the details of further participation including where they could pick up all necessary supplies. Participants would pick up all supplies needed on a Tuesday including oral swabs, coffee, plastic bags for oral swabs, participation manual (see Appendix C) and answer a short questionnaire including questions concerning their sex, age and level of education at the university (see Appendix D). They also signed an informed consent form delineating details of their participation and possible risks (see appendix E). Participants were asked to not consume any other caffeinated beverages while taking part in the study. Additionally, they were asked to log their caffeine consumption on the back page of the manual (see Appendix C) Participants would then continue their normal daily activities. The day after (Wednesday) they continued consuming their own regular coffee and participated in the cognitive tests online approximately one hour after consuming their first cup of coffee (see Appendix C for pictures of the log in screen and menu). The website housing the tests was developed by a doctoral student at Reykjavík University. Participants would log onto the website using a participant number each time they were scheduled to take the tests. Participants were able to log onto the website between 9 am and 2 pm and complete each test only once during each testing day. They then continued their daily tasks after completing both tests. At the end of the day at approximately 5 pm they placed an oral swab under their tongue for two minutes and then placed the swab in a plastic resealable bag provided in the kit received earlier. On Thursday participants started consuming the coffee provided by the researcher and no other caffeinated beverages. Participants entered the website and logged in with their personal code and completed the Aospan and PVT approximately one hour after their first cup of coffee. Then they again proceeded with their daily activities while
maintaining a consumption of two to three cups per day of the coffee provided by the researcher for the next 6 days and at the end of each day placed the oral swab under their tongue for two minutes and placed it into one of the bags provided. On Wednesday the following week they completed the Aospan and PVT approximately one hour after consuming their first cup of coffee and then the experiment was complete. They returned the experimental kit to the researcher including jars for the coffee and plastic bags containing their saliva samples. Returning of equipment was only completed by 5 of the 7 participants due to the Covid-19 gathering ban. However, data were received from those participants and a photograph of the caffeine consumption diary was sent via e-mail. After the experiment, a debriefing letter was sent to participants (see Appendix F).

Data analysis

Data analysis was performed using IBM SPSS® 26th version. A two-way repeated measures mixed model ANOVA was conducted where Factor 1 (group) was cafffeinated vs decaffeinated conditions and Factor 2 (a 3 level repeated-measures factor) was a comparison of test 1, conducted on Thursday, and test 2, conducted on Wednesday and test 3, conducted on Wednesday the week after. Each participant completed two tests once (Aospan and PVT) on each of the three testing days.

Results

A total of seven participants took part in the study, six participants completed the three Aospan tests of the study and seven participants completed the three PVT’s. Aospan data analysis contained Aospan score calculated as the sum of all perfectly recalled sets, total letters correct, speed errors (when a participant ran out of time when solving a particular math problem), accuracy errors (when a participant provided an incorrect solution to a math problem) and correct math. PVT analysis contained median reaction time, mean 1/reaction time, speed errors, false starts, total errors, number of lapses, probability of lapses and accuracy
errors. The data was analyzed with the aim of detecting whether any differences on said measurements between the caffeine condition and the decaffeinated condition were present.

Aospan

The range, mean and standard deviation of Aospan outcome metrics on the baseline, second and third measurement are displayed in Table 1. Aospan scores, number of correct letters recalled, correct math, accuracy error and speed error are displayed in table 1. for both conditions on all measurements. Average overall performance difference is displayed at the bottom of table 2.

| Table 1. Descriptive statistics for all outcome metrics of the Aospan |
|-------------------------|-------------------------|-------------------------|-------------------------|
| Factor                  | Condition              | Range                   | Mean        | SD          |
| Aospan Scores           | Decaffeinated M1       | 6-8                     | 7.00        | 1.414       |
| Aospan Scores           | Decaffeinated M2       | 7-10                    | 8.50        | 2.121       |
| Aospan Scores           | Decaffeinated M3       | 9-11                    | 10.00       | 1.414       |
| Aospan Scores           | Caffeinated M1        | 7-12                    | 9.25        | 2.217       |
| Aospan Scores           | Caffeinated M2        | 5-11                    | 7.75        | 2.753       |
| Aospan Scores           | Caffeinated M3        | 5-12                    | 9.50        | 3.109       |
| Accuracy Error          | Decaffeinated M1      | 4-5                     | 4.50        | .707        |
| Accuracy Error          | Decaffeinated M2      | 0-8                     | 4.00        | 5.656       |
| Accuracy Error          | Decaffeinated M3      | 1-11                    | 6.00        | 7.071       |
| Accuracy Error          | Caffeinated M1        | 1-4                     | 2.50        | 1.290       |
| Accuracy Error          | Caffeinated M2        | 0-6                     | 2.25        | 2.629       |
| Accuracy Error          | Caffeinated M3        | 1-4                     | 1.75        | 1.50        |
| Letters Correct         | Decaffeinated M1      | 30-36                   | 33.00       | 4.246       |
| Letters Correct         | Decaffeinated M2      | 33-37                   | 35.00       | 2.828       |
| Letters Correct         | Decaffeinated M3      | 34-41                   | 37.50       | 4.949       |
| Letters Correct         | Caffeinated M1        | 30-42                   | 34.75       | 5.852       |
| Letters Correct         | Caffeinated M2        | 26-40                   | 34.00       | 6.683       |
| Letters Correct         | Caffeinated M3        | 19-42                   | 34.75       | 10.719      |
| Math Correct            | Decaffeinated M1      | 37                      | 37.00       | 0.00        |
| Math Correct            | Decaffeinated M2      | 34-41                   | 37.50       | 4.949       |
| Math Correct            | Decaffeinated M3      | 29-41                   | 35.00       | 8.485       |
| Math Correct            | Caffeinated M1        | 37-40                   | 38.25       | 1.50        |
| Math Correct            | Caffeinated M2        | 34-40                   | 37.25       | 2.753       |
| Math Correct            | Caffeinated M3        | 32-40                   | 38.00       | 4.00        |
| Speed Error             | Decaffeinated M1      | 0-1                     | .50         | .707        |
| Speed Error             | Decaffeinated M2      | 0-1                     | .50         | .707        |
| Speed Error             | Decaffeinated M3      | 0-2                     | 1.00        | 1.414       |
| Speed Error             | Caffeinated M1        | 1-2                     | 1.25        | .50         |
| Speed Error             | Caffeinated M2        | 1-5                     | 2.50        | 1.732       |
| Speed Error             | Caffeinated M3        | 1-6                     | 2.25        | 2.50        |

*M = Measurement
Table 2. Mean performance on different outcome metrics of the Aospan

<table>
<thead>
<tr>
<th>Outcome metric</th>
<th>Aospan</th>
<th>Letters</th>
<th>Math Correct</th>
<th>Accuracy ER</th>
<th>Speed ER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caffeine</td>
<td>9.25</td>
<td>35.20</td>
<td>38.25</td>
<td>2.50</td>
<td>1.25</td>
</tr>
<tr>
<td>Placebo</td>
<td>7.00</td>
<td>33.00</td>
<td>37.00</td>
<td>4.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Difference</td>
<td>-2.25</td>
<td>-2.2</td>
<td>-1.25</td>
<td>-2.00</td>
<td>-.75</td>
</tr>
<tr>
<td>Day 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caffeine</td>
<td>7.75</td>
<td>34.75</td>
<td>37.25</td>
<td>2.25</td>
<td>2.50</td>
</tr>
<tr>
<td>Placebo</td>
<td>8.50</td>
<td>35.00</td>
<td>37.50</td>
<td>4.00</td>
<td>0.50</td>
</tr>
<tr>
<td>Difference</td>
<td>-.75</td>
<td>-.25</td>
<td>-.25</td>
<td>-1.75</td>
<td>-2.00</td>
</tr>
<tr>
<td>Day 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caffeine</td>
<td>9.50</td>
<td>34.75</td>
<td>38.00</td>
<td>1.75</td>
<td>2.25</td>
</tr>
<tr>
<td>Placebo</td>
<td>10.00</td>
<td>37.50</td>
<td>35.00</td>
<td>6.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Difference</td>
<td>-.50</td>
<td>-2.75</td>
<td>-3.00</td>
<td>-4.25</td>
<td>-1.25</td>
</tr>
<tr>
<td>Average performance difference</td>
<td>-1.66</td>
<td>-3.36</td>
<td>-1.50</td>
<td>-2.66</td>
<td>-1.33</td>
</tr>
</tbody>
</table>

*Letters = Number of letters correct. ER = Error. Aospan in outcome metric line = Aospan score

Results for Aospan scores showed that Mauchly’s test of sphericity indicated that there was no violation of sphericity ($\chi^2(2) = 4.62, p = .099$) and therefore sphericity was assumed. Tests of within subject effects revealed no significant main effect of Aospan scores ($F(2, 8) = 2.852, p = .116$), similarly there was no significant main effect of conditions ($F(1, 4) = .029, p = .874$). Tests of within-subjects effects revealed that there was no significant interaction between the Aospan scores and conditions ($F(2, 8) = 2.245, p = .168$). The mean Aospan scores in each condition on each measurement can be seen in figure 1.
Figure 1. Mean Aospan scores with the different conditions participants were assigned to. Days represent the different measurements. Error bars shown with 95% confidence interval.

Two-way repeated measures ANOVA was run for the accuracy error, number of letters recalled correctly, number of math equations correct and speed errors. Mauchly’s test of sphericity was non-significant ($\chi^2(2) = .396, p = .821$) for accuracy error and therefore sphericity was assumed. Tests of within-subject effects revealed no significant main effect of accuracy error ($F(2, 8) = .146, p = .867$), and like before there was no significant main effect of conditions on accuracy error ($F(1, 4) = .029, p = .874$) Tests of within-subjects effects revealed that there was no significant interaction ($F(2, 8) = 2.245, p = .168$). Results of the two-way mixed ANOVA of all other Aospan outcome metrics can be seen in table 3.

Table 3. Summary of two-way mixed model ANOVA for outcome metrics of the Aospan displaying F values, degrees of freedom and mean square errors ($N = 6$)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Letters</th>
<th>Math</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition</td>
<td>1</td>
<td>.013</td>
<td>.308</td>
<td>1.778</td>
</tr>
<tr>
<td>Outcome metric</td>
<td>2</td>
<td>.537</td>
<td>.183</td>
<td>.444</td>
</tr>
<tr>
<td>Condition x Outcome metric</td>
<td>2</td>
<td>.563</td>
<td>.346</td>
<td>.272</td>
</tr>
<tr>
<td>Condition Error</td>
<td>4</td>
<td>132.45</td>
<td>23.125</td>
<td>4.000</td>
</tr>
<tr>
<td>Outcome metric Error</td>
<td>8</td>
<td>12.771</td>
<td>10.188</td>
<td>1.938</td>
</tr>
</tbody>
</table>

*Main effects and interaction were not significant at $p = .05$
PVT

The main component of the PVT analyzed was mean 1/RT as it is recommended that it serve as the primary outcome metric (Basner & Dinges, 2011). Mauchley’s test of sphericity was significant ($\chi^2(2) = 7.746, p = .021$) and consequently Greenhouse-Geisser correction was implemented. Tests of within-subject effects proved to be non-significant and therefore it was concluded that there was no main effect of mean 1/RT ($F(1.078, 5.389) = .116, p = .764$) An interaction also proved to be non-significant ($F(1.078, 5.389) = .660, p = .462$). Tests of between subjects effects showed non-significant results for main effects of condition as well ($F(1, 5) = .168, p = .699$) (see figure 2.)

![Figure 2](image.png)

Figure 2. Mean 1/RT by the different conditions participants were assigned to. Days represent the different measurements. Error bars shown with 95% confidence interval.

10% slowest and fastest RT were analyzed. Mauchly’s test of sphericity was significant for slowest 10% RT ($\chi^2(2) = 20.543, p = <.001$) though not for fastest 10% RT ($\chi^2(2) = 2.546, p = .280$). Greenhouse-Geisser corrections were utilized for 10% slowest RT. Results indicated no significant main effects of condition for slowest 10% RT ($F(1, 5) = .856$,
EFFECTS OF WITHDRAWAL ON ALERTNESS AND WORKING MEMORY

$p = .397$) and fastest 10% RT ($F(1, 5) = .002, p = .965$). Likewise, no significant results were obtained on within subjects effects, both regarding the main effects of 10% slowest RT ($F(1.003, 5015) = .314, p = .600$) and 10% fastest RT ($F(2, 10) = .1.708, p = .230$). An interaction was non-significant as well on both 10% slowest RT ($F(1.003, 5.015) = .357, p = .577$) and 10% fastest RT ($F(2, 10) = .3.356, p = .077$) (see figure 3. and figure 4.)

Figure 3. 10% slowest RT (ms), calculated as the mean of ten slowest RT. Days represent the different testing days. Error bars shown with 95% confidence interval.

Median RT was analyzed as well. Mauchly’s test of sphericity was non-significant ($\chi^2(2) = 2.852, p = .240$) and there proved to be no main effect of median RT as tests of within subject effects was non-significant ($F(2, 10) = .079, p = .925$). Tests of between-subject effects resulted in non-significant main effects of conditions ($F(1, 5) = .046, p = .839$). Range, median and standard deviation of other PVT outcome metrics can be seen in table 4. The Mean RT for participants was calculated and analysis yielded non-significant results of the Mauchly’s test ($\chi^2(2) = 4.677, p = .096$). Non-significant results were also
obtained for main effects of median RT \((F(2, 10) = 2.184, p = .163)\) as well as for an interaction \((F(2, 10) = 1.507, p = .268)\). Tests of between subjects effects revealed non-significant results for main effects of condition \((F(1, 5) = .293, p = .612)\). Descriptive statistics for all outcome metrics of the PVT can be seen in table 4, displaying range, mean and standard deviation on all measurements.

Two-way repeated measures ANOVA was run for all other PVT outcome metrics. However, nothing was significant (see table 5). Mauchly’s test of sphericity was non-significant for false start and total error but significant for lapses and probability of lapses and Greenhouse-Geisser corrections were utilized in order to correct degrees of freedom (see table 5.).

![Figure 4. 10% fastest RT (ms), calculated as the mean of the ten fastest RT](image)

Table 4. Descriptive statistics for outcome metrics of the PVT. Continued on next page.

<table>
<thead>
<tr>
<th>Outcome metric</th>
<th>Condition</th>
<th>Range</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>False start</td>
<td>Decaffeinated Day 1</td>
<td>2-4</td>
<td>3.00</td>
<td>1.414</td>
</tr>
<tr>
<td>False start</td>
<td>Decaffeinated Day 2</td>
<td>1-4</td>
<td>2.50</td>
<td>2.121</td>
</tr>
<tr>
<td>False start</td>
<td>Decaffeinated Day 3</td>
<td>1-5</td>
<td>3.00</td>
<td>2.828</td>
</tr>
<tr>
<td>False start</td>
<td>Caffeinated Day 1</td>
<td>0-8</td>
<td>3.40</td>
<td>3.130</td>
</tr>
</tbody>
</table>
EFFECTS OF WITHDRAWAL ON ALERTNESS AND WORKING MEMORY

Table 5. Summary of two-way mixed model ANOVA for outcome metrics of the PVT displaying F values, degrees of freedom and mean square errors (N = 7)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Total Error</th>
<th>Number of Lapses</th>
<th>Prob. of lapses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition</td>
<td>1</td>
<td>.017</td>
<td>.030</td>
<td>.027</td>
</tr>
<tr>
<td>Outcome metric</td>
<td>2/1.015*×/1.016×</td>
<td>.190</td>
<td>.310</td>
<td>.264</td>
</tr>
<tr>
<td>Condition x Outcome metric</td>
<td>2/1.015*×/1.016×</td>
<td>.337</td>
<td>.316</td>
<td>.359</td>
</tr>
<tr>
<td>Condition Error</td>
<td>5</td>
<td>659.653</td>
<td>744.380</td>
<td>.092</td>
</tr>
<tr>
<td>Outcome metric Error</td>
<td>10/5.076*×/5.078×</td>
<td>80.313</td>
<td>66.140</td>
<td>.004</td>
</tr>
</tbody>
</table>

*Main effects and interaction were not significant at p = .05

• Greenhouse-Geisser corrected degrees of freedom for number of lapses

× Greenhouse-Geisser corrected degrees of freedom for probability of lapses

Discussion

The present study is one of few studies that have addressed the effects of caffeine withdrawal on working memory and likely the first one to do so utilizing an automated Ospan test. The current study attempted to address whether caffeine withdrawal had a negative effect on performance on working memory span and vigilance. Depending on the data the results would then either support or not support the notion that caffeine withdrawal interferes with results of study’s utilizing traditional placebo style methodology, particularly pertaining to effects of caffeine withdrawal on cognitive factors (James, 2014; James & Rogers, 2005). The current study also attempted to provide evidence for or against the withdrawal reversal.
hypothesis mentioned by James (1994), by attempting to detect differences between those continuing caffeine use and those experiencing withdrawal on the second measurement and none on the recovery measurement. However, no such conclusions could be reached due to statistical non-significance on all outcome metrics of both the Aospan and the PVT. The two hypotheses generated in the introduction chapter were not supported by any of the statistical results. The first hypothesis, that Aospan scores and PVT scores would be negatively affected by caffeine withdrawal was not supported. Results showed no statistically significant differences between the group receiving the caffeinated coffee and the one receiving decaffeinated coffee on any measurement of working memory span. The second hypothesis generated was that after a recovery period negative effects of caffeine withdrawal would no longer be observable. This hypothesis was not confirmed by the data, especially since it relied on the first hypothesis being true. There was no significant difference between any measurement of Aospan nor PVT. The results concerning working memory are similar to results obtained in the study by Morava et al. (2019) in which they found no deterioration of working memory scores during caffeine withdrawal compared to continued caffeine use. Although the current results showed no detectable difference on the PVT measurements, results of Rogers et al. (2013) found vigilance and reaction speed to be negatively affected by caffeine withdrawal. As the methodology of Rogers et al. was good and they had a sizeable N of 369 and significant results, those results can be considered to have more credibility. An increase in the size of the N could therefore alter the results of the current study. Additionally, the study by Weibel et al. (2018) showed that there were significant differences on number of lapses on the PVT between those that continued consuming caffeine and those who ceased caffeine consumption with those ceasing consumption performing worse on the PVT.

As mentioned before there are two schools of opinion with one asserting that caffeine has beneficial effects and the other that caffeine does not (James, 2005; Nehlig, 2010). The
methodology utilized in many of the studies that purportedly showed beneficial effects of caffeine assume that caffeine withdrawal has no effect on performance (James, 2014). As the data presented in this study was analyzed from a very small $N$ and with quite a few limitations then no conclusions can indeed be made regarding whether such assumptions are correct or not with regard to working memory. Additionally, results of the PVT in the current study can not add to the existing body of literature of reaction time measurements regarding caffeine withdrawal due to the limitations of the study discussed below.

**Limitations**

While conducting the current experiment an encounter of several problems limited the data collection. One of which and surely one of the more severe limitations was the global pandemic of Covid-19. This outbreak of a viral infection resulted in the ceasing of all data gathering as well as no saliva samples being collected for the last two participants in the study. As samples were not to be analyzed either way this did not directly affect the results but does pose the problem of inconsistency within the experimental procedures. The ceasing of all data gathering did however result in a ceasing of all further experiment operations resulting in fewer than acceptable number of participants. Even if experiment operations were to have resumed, no further saliva samples could be obtained as well as a probable lack of willingness to partake in an experiment at the current time due to Covid-19. Another limitation pertains to the number of participants as tragic personal events of one Reykjavík university staff member unfortunately delayed the start of the experiment. As 23 participants had already expressed willingness to be part of the study such delays resulted in a significant decrease of willing participants. Despite repeated attempts to contact participants that before expressed willingness to participate few answers were received. Additionally, some previously interested participants withdrew due to personal circumstances. Another limitation of the study was the use of decaffeinated coffee. Decaffeinated coffee does still often contain
a small amount of caffeine, and as pointed out by (Haskell et al., 2008) only 9mg of caffeine can have psychoactive effects, the presence of small amounts of caffeine could have interfered with the results.

**Strengths**

The current study, despite suffering from many limitations, does have some strengths. One is the experimental methodology and utilizing saliva swabs in order to increase cooperation of participants. Additionally, utilizing an Aospan could have enabled a great number of participants to complete the tests on their own at the same time as other participants. Unfortunately, due to previously mentioned limitations that aspect was not utilized fully.

**Future research**

Future research could employ the same methods used here to identify the effects of caffeine withdrawal with the addition of saliva testing. Future research could also employ a longer recovery time than 7 days to increase chances of full recovery from withdrawal. Future research may also want to add a caffeine challenge whereby after successful recovery participants would receive caffeine again. This has been done before but not while utilizing Ospan tests. Additionally, future research could implement a greater number of cognitive tests in order to measure a wider array of cognitive functions. Future studies should also consider using a placebo that is absolutely caffeine free as was not the case in the current study due to lack of resources.

**Conclusions**

In conclusion, this study examined effects of caffeine withdrawal and recovery on working memory and psychomotor vigilance. Results indicated no significant differences between either condition. This is not in accordance with previous research on the subject regarding reaction time performance. The results are hampered by several limitations severe enough that results presented cannot be deemed credible at all.
References


EFFECTS OF WITHDRAWAL ON ALERTNESS AND WORKING MEMORY


Appendix A

Spurningalisti um koffíneyslu

Þessi spurningalisti er skimunarlisti og er notaður til þess að ákvarða möguleika á þátttöku í koffírannsókn sem verður gerð eftir áramót. Vinsamlega skráðu tölvupóstfang þitt hér að neðan svo hægt verði að hafa samband við þig ef þú mætir þeim kröfum sem gerðar eru til þátttakenda rannsóknarinnar. Þeir sem fá að taka þátt í rannsókninni eiga möguleika á að vinna 2 biomiða ef þeir ljúka þátttöku í rannsókninni. Einnig munu þátttakendur rannsóknarinnar fá fritt kaffi í 5 daga á meðan á rannsókninni stendur. Frekari upplýsingar verða veittar í tölvupóstini til þeirra sem uppfylla þátttökkurfræfur.

* Æskilið

Netfang *

Ekki er hægt að fylla út netfang fyrirfram.

Á hvaða námsstigi eirt þú?

- Grunnnámi
- Meistarannámi
- Doktorskýti
- Annað:

Drekkur þú KAFFI? *

- Já
- Nei

Hlutí 2. Kaffineysla

Að meðaltali, hve marga bolla af kaffi (t.d. Espresso eða uppáhelt) drekkur þú Á DAG? (miðað við að bolli af Espresso sé 120ml og bolli af uppáheltu sé 340ml)

Velja
Að meðaltali, hve marga bolla af instant kaffi drekkur þú Á DAG? (míðað við að bolli sé 340ml)

Velja

Hluti 3. Te-neysla

Drekkur þú TE? (Svart eða grænt en útilokaðu jurtate). *

☐ Já

☐ Nei

Hluti 4. Te-neysla

Að meðaltali, hve marga bolla af heitu Tei drekkur þú Á DAG? (míðað við að bolli sé 340ml)

Velja

Hluti 5. Gosneysla

Drekkur þú gosdrykki sem innihalda koffín? (t.d. Pepsi eða Coca cola). *

☐ Já

☐ Nei
Hlutí 6. Gosneysla

Að meðaltali, hve margar dósr af gosdrykkjum drekkur þú Á DAG? (miðað við að 1 dósi sé 330ml)

Velja

Hlutí 7. Orkudrykkir

Drekkur þú orkudrykki? (t.d. Red Bull, Nocco eða Monster). *

☐ Já

☐ Nei

Hlutí 8. Orkudrykkir

Að meðaltali, hve margar dósr af orkudrykkjum drekkur þú venjulega Á DAG? (Miðað við að 1 dósi sé 330ml)

Velja

Orkudrykki frá hvaða vörumerki drekkur þú oftast?

☐ Red Bull

☐ Monster

☐ Nocco

☐ Magic

☐ Burn

☐ Annað:
Appendix B

Department of Psychology
Reykjavik University, Iceland

Drinks you might consume

Section 1. Coffee

1.1 Do you drink COFFEE?     Yes ❑     No ❑
If NO, go to Section 2.

If YES, on average, how many cups of:

1.2 non-instant (“brewed”) coffee (i.e., percolated, filter, espresso) do you drink per weekday? .....  
1.3 non-instant (“brewed”) coffee do you drink per day on the weekend? .....  
1.4 instant coffee do you drink per weekday? .....  
1.5 instant coffee do you drink per day on the weekend? .....  
1.6 how many teaspoons of instant coffee do you normally use per cup? .....  
1.7 decaffeinated coffee do you drink per weekday? .....  
1.8 decaffeinated coffee do you drink per day on the weekend? .....  

Section 2. Tea

2.1 Do you drink TEA? (exclude herbal teas)     Yes ❑     No ❑
If NO, go to Section 3.

2.2 If YES, on average, how many cups of hot tea do you drink per weekday? .....  
2.3 On average, how many cups of hot tea do you drink per day on the weekend? .....  

Section 3. Cola Drinks

3.1 Do you drink COLA DRINKS (e.g., Coke, Pepsi)?     Yes ❑     No ❑
If NO, go to Section 4.
3.2 If YES, on average, how many glasses* of cola do you drink per weekday? ......

3.3 On average, how many glasses* of cola do you drink per day on the weekend? ......
*(Assume 1 can = glasses, and 1 litre bottle = 8 glasses)

Section 4. Energy Drinks

4.1 Do you drink “ENERGY” DRINKS (e.g., Red Bull, Nocco) Yes ☐

No ☐

If NO, go to Section 5.

4.2 If YES, what brand/s do you usually drink?

.......................................................... ..........................................................

4.3 On average, how many cans/bottles do you drink per weekday? ......

4.4 On average, how many cans/bottles do you drink per day at the weekend? ......

Section 5. Contact Info.
Participant E-mail
address:.......................................................... ..........................................................
Appendix C

BSc RANNSÓKN: ÁHRIF KOFFÍNFRÁHVARFA Á VINNSLUMINNI OG ÁRVERKNI.
LEIÐBEININGAR OG UPPLÝSINGAR

LEIDBEININGAR Á NÆSTU SÍÐUM.
Ef einhverjar spurningar vakna eða þörf er á að hafa samband við rannsakanda skal gera það annaðhvort í tölvupósti eða gegnum síma
Tölvupóstur: dagure17@ru.is
Sími: 863-0522
EFFECTS OF WITHDRAWAL ON ALERTNESS AND WORKING MEMORY

GRUNDVALLARREGLUR RANNSÓKNAR:

1. Ekki má neyta annarra koffínvarnings á meðan á rannsókn stendur, til dæmis:
   a. orkudrykkja (Red Bull, Nocco)
   b. “Pre-workout” drykkja s.s. Amino Energy eða slíks varnings
   c. Mikið af súkkulaði (þar sem súkkulaði inniheldur koffín, þó það sé ekki í miklu magni þá getur mikil neysla þess haft áhrif á niðurstöður rannsóknar)
2. Aðeins má neyta þess kaffis sem rannsakandi gefur þátttakandi þar sem möguleiki er á að þátttakandi hafi fengið koffínlaust kaffi.
3. Taka á vinnsluminnis- og árverknipróf á þremur dögum yfir þá 8 daga sem þátttakandi er hluti af rannsókninni.
   a. Þeir dagar eru Miðvikudagur, Fimmtudagur og Miðvikudagur víku síðar.
   b. Vinnsluminnis- og árvekniprófi er lýst nánar síðar.
4. Taka á munnvatnssýni alla daga rannsóknar
   a. Opna á einn pakka og setja bómul sem er í pakkanum upp í munn
   b. Geyma á bómul undir tungu í 2 mínútur
   c. Bómullinn er tekinn úr munnínnum og settur beint ofan í poka sem rannsakandi gefur þátttakanda
      i. Óþarfi er að geyma munnvatnssýni í frysti þar sem koffín í munnvatni er mjög stöðугt.

LEIDBEININGAR FYRIR KAFFI RANNSÓKNAR

1. Setja skal að minnsta kosti 1 teskeið af kaffi í heitt vatn
2. Hræra skal kaffið þar til það leysist alveg upp.
3. Ef þörf er á meira kaffi skal hafa samband við rannsakanda í tölvupósti
dagure17@ru.is eða síma 863-0522
LEIDBEININGAR FYRIR SKRÁNINGU KAFFINEYSLU
*Dæmi um útflýlt skráningarblað*

1. Það skal skrá hvern kaffibolla á blaðið
2. Sé neytt tveggja eða fleiri bolla á sama klukkutímanum skal skrá viðeigandi fjöldu í sama kassa.
3. Sé neytt kaffis á undan eða eftir þa tíma sem eru í boði á skráningarblaðinu skal skrá X fyrir aftan síðasta kassann (þann sem inniheldur 20:00-21:00) og síða tímasetninguna sem bollinn er drukkinn fyrr ofan X-íð
4. Sé orkudrykka eða annars kaffis neytt skal setja hring í viðeigandi reit fyrr hverja dós eða bolla. Þó skal með ólli forðast að neyta þessa þar sem niðurstöður rannsóknar byggja á því að þátttakandur drekki ekki orkudrykki eða annað kaffi.

<table>
<thead>
<tr>
<th></th>
<th>06:00-07:00</th>
<th>07:00-08:00</th>
<th>08:00-09:00</th>
<th>09:00-10:00</th>
<th>10:00-11:00</th>
<th>11:00-12:00</th>
<th>12:00-13:00</th>
<th>13:00-14:00</th>
<th>14:00-15:00</th>
<th>15:00-16:00</th>
<th>16:00-17:00</th>
<th>17:00-18:00</th>
<th>18:00-19:00</th>
<th>19:00-20:00</th>
<th>20:00-21:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miðvikudagur</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fimmtudagur</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Föstudagur</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laugardagur</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ólendagur</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miðvikudagur</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fimmtudagur</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Tímavél fyrir kaffin │ Itt X = Einn boli*

1. Það skal skrá hvern kaffibolla á blaðið
2. Sé neytt tveggja eða fleiri bolla á sama klukkutímanum skal skrá viðeigandi fjöldu í sama kassa.
3. Sé neytt kaffis á undan eða eftir þa tíma sem eru í boði á skráningarblaðinu skal skrá X fyrir aftan síðasta kassann (þann sem inniheldur 20:00-21:00) og síða tímasetninguna sem bollinn er drukkinn fyrr ofan X-íð
4. Sé orkudrykka eða annars kaffis neytt skal setja hring í viðeigandi reit fyrr hverja dós eða bolla. Þó skal með ólli forðast að neyta þessa þar sem niðurstöður rannsóknar byggja á því að þátttakandur drekki ekki orkudrykki eða annað kaffi.

LEIDBEININGAR FYRIR VINNSLUMINNIS- OG ÁRVEKNIPRÓF

1. Vinnsluminnisprófið og árvekniprófið eru rafræn og er tekin á vefslóð sem rannsakandi sendir þátttakendum.
2. Prófin taka saman um 25 minútur í senn
3. Þátttakandi á aðeins að taka hvert próf einu sinni þann dag sem taka á prófin.
   a. Dagarnir eru:
      i. Miðvikudagur 18. mars
      ii. Fimmtudagur 19. mars
      iii. Miðvikudagur (1 viku síðar) 25. mars
4. Þáttakandi fær þátttakendanúmer frá rannsakanda
   a. Dæmi um þátttakendanúmer
      i. CR089
5. Prófið er opið frá 09:00-14:00 á þeim dögum sem þátttakandi á að taka prófið.
6. Þáttakandi á að taka prófið klukkutíma eftir neyslu kaffis.

**MYNDRÆNAR LEIDBEININGAR FYRIR VINSLUMINNISPRÓF OG PVT**

1. Farið er inn á hlekkinn sem rannsakandi sendir þátttakanda
2. Þegar hlekkur er opnaður ætti þetta að líta svona út:

   3. Þá er slegið inn þátttakandanúmerið sem rannsakandi lét þátttakanda hafa.
5. Eftir að það er slegið inn ætti þetta að birtast:

   5. Þá er valið C-OSPAN og prófið hefst
6. Lesið leiðbeiningar í prófinu vel og vandlega
7. Prófið tekur um 10-15 minútur
8. Eftir að próf er klárað skal ekki loka glugganum strax heldur leyfa gögnnum að sendast, ætti ekki að taka nema nokkrar sekúndur. Svona ætti þetta að líta út þegar gögnin eru búin að sendast og þá smella á fara heim.
9. Þá ætti þetta aftur að birtast en ekki með C-OSPA

10. Síðan er smellt á PVT og prófið hefst
11. Prófið tekur um 10-15 min
12. Lesið leiðbeiningar og síðan hefst prófið
13. Við lok prófs birtist sami gluggi og áður

14. Þá má ýta á fara heim og svo loka glugganum.
15. Þá er verkefnum dagsins lokið.
EFFECTS OF WITHDRAWAL ON ALERTNESS AND WORKING MEMORY

LOK RANNSÓKNAR
Þáttakendur mæta þegar þeim hentar á fimmtudegi eða föstudægi og skila koffínkrukkum, munnvatnssýnum og leiðbeiningarheftinu. Rannsakandi hefur samband varðandi tíma og staðsetningu.

SAMANTEKT

1. Þáttakendur drekka bara það kaffi sem þeir fá og neyta ekki annarra koffínvara.
2. Þáttakendur skrá koffínneysluna sina á skráningarblað
3. Þáttakendur taka munnvatnssýni alla daga rannsóknar (fyrsti dagur er þá miðvikudagur)
4. Þáttakendur taka vinnsluminnispróf 3x yfir 8 daga
   a. Á miðvikudægi, fimmtudegi og svo aftur á miðvikudægi viku eftir
5. Þáttakendur skila öllu sem rannsakandi lét þá hafa s.s. krúkkur, munnvatnssýni og leiðbeiningarhefti í lok rannsóknar.
### Effects of Withdrawal on Alertness and Working Memory

<table>
<thead>
<tr>
<th>Time (UTC)</th>
<th>Alertness</th>
<th>Working Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>06:00-07:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>07:00-08:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>08:00-09:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09:00-10:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:00-11:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:00-12:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00-13:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:00-14:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14:00-15:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15:00-16:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16:00-17:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17:00-18:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18:00-19:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19:00-20:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20:00-21:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21:00-22:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22:00-23:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23:00-00:00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix D
Following is the questionnaire used to gather data for participants when recruited:

Spurningalisti fyrir koffínfráhvarfarannsókn.

Þáttakendánúmer____________________________________________________________

Hvert er kyn þitt?
☐ Karl
☐ Kona
☐ Annað

Hver er aldur þinn?
________________________________________________________________________

Hvert er núverandi menntastig þitt?
☐ Grunnnám
☐ Meistaranám
☐ Doktorsnám
☐ Annað

Ef annað, hvað?____________________________________________________________
Appendix E

Following is the informed consent form:

Eyðublað fyrir upplýst samþykki

Rannsókn: Samband Koffínfráhvarfa, vinnsluminnisspannar og árvekni

Ábyrgðarmaður rannsóknar: Dr. Jack Ernest James, Sálfræðisvið Háskólinn í Reykjavík, jack@ru.is

Tílgangur þessa eyðublaðs er að tryggja að þátttakandi skilji bæði tílgang rannsóknarinnar og hvert hans hlutverk er í rannsókninni. Eyðublað þetta verður að veita nægur upplýsingar svo þátttakandi geti tekið upplýsta ákvörðun um þátttöku sina í rannsókninni. Vinsamlegast leiðið til rannsakandans ef einhverjar spurningar vakna eftir lestur þessa eyðublaðs.

Tílgangur:
Tílgangur þessarar rannsóknar er að rannsaka samband koffínfráhvarfa, vinnsluminnisspannar og árvekni.

Verkefni:
Í þessari rannsókn verður þú beðin(n) um að leysa ákveðin verkefni, eins og að leysa einfaldar jöfnur, leggja stafarunur á minnið og bregðast við áreitum. Einnig verður spurt um kyn, aldur og menntastig. Verkefnið eru 2 talsins og verða tekið á netinu 3x á 7 dögum, fyrsta verkefinum verður daginn eftir að allur nauðsynlegur búnaður er söttur, annað verkefinum daginn eftir fyrsta prófl og þriðja próf 7 dögum eftir fyrsta próf. Þetta er útskyrt nánar í leiðbeiningahefti sem rannsakandi gefur þátttakendum. Einnig er þátttakandi beðinn um að taka munnvatnssýni einu sinni á dag á meðan á rannsókn stendur til þess að tryggja að ekki sé neytt annars en þess kaffis sem þátttakandi fær frá rannsakanda. Ekki skal neyta orkudrykka (s.s. Nocco) gösdrykkja með koffíni í (s.s. Coca-Cola, Pepsi eða Mountain Dew) eða te (s.s. svart, grænt eða íste).annað verkefni rannsóknarinnar er neysla kaffis sem rannsakandi gefur þátttakanda. Þátttakandi skal halda áfram að drekka sinn venjulega fjölda bolla eða fleiri ef hann svo kýs þó ekki færri. (míða skal við 3 bolla af kaffi á dag) Eins og áður var minnst á skal þátttakandi einungis neyta þess kaffis sem rannsakandi gefur þátttakanda.

Tími og stæðsetning:
Þátttaka í rannsókninni mun taka u.þ.b. 75 mínútur í heildina og fer fram hvar sem þátttakandi ákveður að gera verkefni. Verkefnið skal þó taka um 1 klukkustund eftir fyrsta kaffibolla dagins. Verkefnið eru tvö talsins og taka um 25 mínútur eða skemur. Munnvatnssýni skulu tekið um klukkan 17:00 á hverjum degi á meðan á rannsókn stendur og sett í litla rauða/bleika poku sem fylgja með búnaði. Stuðust er við leiðbeiningahefti varðandi framkvæmd munnvatnssýnistöku.

Möguleg áhætta eða óþægindi:
Það ætti ekki að fylgja nein áhætta með þátttöku í rannsókninni. Hins vegar getu sumir þátttakendur fundið fyrir smávægilegum hausverk og örlíttli þreytu fyrst um sinn en það ætti að hverja snögglega. Ef hins vegar þú finnur fyrir miklum kvíða og/eða óþægindum á meðan
Nafnleynd/trúnaður:

Réttur til að hætta þátttöku:
Þú hefur fullan rétt á að hætta þátttöku í þessari rannsókn hvenær sem er.

__________________________
Nafn: ________________________________  Dagsetn.: __________________

__________________________
Undirskrift: __________________________  Vottur: ______________________

á rannsókn stendur, vinsamlegast láttu rannsakanda strax vita í síma 863-0522 eða með því að senda póst á tölvupóstfangið dagure17@ru.is.
Appendix F
Following is the debriefing e-mail sent to all participants after study was complete:

Sæl/Sæll,


Kaffið sem þú fékkst var: Koffínlaust/Með koffíni

Kær kveðja,
Dagur Andri Einarsson