Caffeine and cognition: Understanding modern-day caffeine habits and caffeine's effects on complex cognitive functioning.

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Abstract

Aims: This current study sought to broaden the research on the cognitive benefits of caffeine while observing how we interact with caffeine habitually. This study examined the habitual effects of caffeine consumption using the Stroop Colour Word Task (SCWT) and how caffeine correlates with age while proposing a novel method of observing caffeine consumption habits. **Methods:** Participants were recruited online through the use of social media. A convenience method of sampling was utilised. The sample completed an adaptation of the caffeine consumption questionnaire revised (CCQR) (n=173) along with a Stroop Colour Word Task (n=84) **Results:** A Pearson's correlation conveys a positive correlation between high caffeine consumption and SCWT scores. Age was also found to have a positive correlation with an increase in habitual caffeine consumption. A K-means analysis was conducted to observe differences in groups of consumers. Six groups were created within the sample; an ANOVA was run to determine the significance variables had in creating the clusters. Then the averages among each cluster were observed to determine the habits of this sample. **Conclusion:** This study contributes new data to an area with limited research; habitual caffeine consumptions effects on complex functioning. Also, this study creates a novel method of observing consumption habits among a sample population.

Keywords: Caffeine; consumption; cognition; correlation; K-means

Table of contents

Literature review

Introduction

Humans have consumed caffeine for centuries, with records dating back to as early as 1732, when caffeinated beverages like tea and coffee were first created. Today, caffeine is one of the most widely consumed drugs globally, surpassing alcohol and nicotine in usage (Weinberg & Bealer, 2000). With this popularity comes a large-scale obsession with understanding caffeine as a substance. Pioneering research in caffeine consumption conveyed consumption patterns comparing the different age groups. These studies report that tea and coffee are considerably more popular than any other intake method in adult populations. In contrast to this, younger populations have been found to consume soft drinks and hot chocolate more than adults (Barone & Roberts, 1996; Paluska, 2003; Richardson et al., 1995).

Furthermore, caffeine as a substance is a stimulant that can produce both negative and positive effects on people's cognition. Findings convey that caffeine can enhance simple processes, such as reaction time, and reduce mental fatigue, but finds varying results in complex functions such as memory (Nehlig, 2010). Caffeine's adverse effects include reduced sleep quality (Snel & Lorist, 2011) and increased anxiety levels (Rogers & Smith, 2013). Despite a broad scope of research, the world of caffeine consumption is evolving as any other industry in the modern world. New methods of intake and consumption patterns are developing, creating an everlasting need for research on the topic.

Caffeine consumption

With caffeine being the most consumed drug worldwide and possessing the power to alter a person's cognition, it is essential to first understand the trends of caffeine consumption. Early research concludes that daily average caffeine use for adults is between 200mg-250mg per day. In contrast, caffeine consumption in children, teenagers, and young adults can be as low as 40-80mg (Barone & Roberts, 1996; Mandel, 2002; Richardson et al.,

1995). In these studies, the variables being tested were minimal, with tea, coffee, soft drinks, and hot chocolate being the four main methods recorded for caffeine intake. Although a limitation by today's standard, at the time of these studies, these were the primary methods of caffeine consumption. An interesting pattern can be observed in these studies. A breakdown of beverage use was illustrated by Barone and Roberts, where adults consumed bitter beverages such as coffee and tea, as opposed to teenagers who consumed sweeter soft drinks and hot chocolate. Although at the time of this study, it was not theorised as to why this may be the case, later research suggests that children do not well receive bitter beverages because of their harsh taste (Lesschaeve & Noble, 2005). With this knowledge, it can be theorised that this natural distaste for bitter beverages in young people may have a considerable impact on the methods of caffeine consumption within different age groups.

In recent times, there has been a surge in the marketing and distribution of caffeinated beverages to adults and children. A review concerning the purchasing of energy drinks claims a 240% increase in sales since 2004 (Al-Shaar et al., 2017). In addition, initial research on Pre-Workout supplements has generated significant interest, with studies such as this obtaining large sample sizes (Jagim et al., 2019). With the progression of the caffeine industry and the addition of highly caffeinated sweet drinks, there has been an increase in the intake of these beverages among children and teens (Temple, 2019). A reason for this may be their high sugar content appeals to the younger population more so than traditional methods of caffeine consumption.

Another recent increasing market is that of caffeine tablets. Research shows that small but notable numbers of 11% of university students use caffeine tablets consistently for cognitive enhancements (Franke & Bagusat, 2015). Adding to this, it was found in another sample that 90% of individuals who use caffeine tablets do so for "mental energy" (Stachyshyn et al., 2021). Despite these new methods of consumption, both tea and coffee are

still the predominant sources of caffeine overall, with multiple sources reporting that upwards of 50% of individuals who consume caffeine do so with tea or coffee (El-Nimr et al., 2019; Fulgoni et al., 2015; Walter, 2022).

Finding studies that incorporate all methods of caffeine consumption has proven difficult. The studies above tend to assess these substances individually, as opposed to as part of a person's overall diet. It is necessary to update caffeine consumption questionnaires and analysis with newly popularised caffeinated products to obtain the most true-to-life data possible.

Although many different beverages have been promoted and popularised, the overall impact of this on average caffeine use has not been all that catastrophic. Studies assessing caffeine consumption have generally had only slight differences in their overall findings. Reviews assessing trends in caffeine consumption longitudinally have had varied results in differing samples. In China there has been an increase in average caffeine consumption over the last 20 years, with 27 times more individuals being found to consume caffeine in 2018 than in 2014, but still using tea and coffee predominately more than other methods of caffeine intake (Ye et al., 2023). Alternatively, changes in caffeine use in the United States were insignificant overall (Fulgoni et al., 2015). This study's results convey that caffeine usage through tea and coffee has stayed consistent with past research. However, it seems energy drinks have affected the consumption of soft drinks, as there was a 2% increase in consumption for the overall population, whereas soft drinks have seen a drop in consumption of 10%. This pattern occurs in other recent research concerning caffeine consumption. Soft drinks seem to be dropping in popularity, whereas energy drinks are gaining popularity (Kumar et al., 2015; Mahoney et al., 2019). It is also mentioned that the primary use of energy drinks among college students is for cognitive functioning. This result conveys that there is a purpose of enhancement that students are trying to access with the consumption of

these drinks. Proving their understanding of caffeine to be a cognitive stimulant and utilising it as such.

In more recent research focusing on more distinct populations using cross-sectional data, interesting results have been found on how different age groups consume caffeine. When observing the habits of university-age samples, the consumption of energy drinks is prevalent. In cross-sectional studies, it has been found that as high as 76% of university students consume energy drinks (Altalhi et al., 2022; Gallucci et al., 2016). In the above research, there have been more females compared to males which took part, as these studies also found males tend to consume more caffeine which could lead to issues concerning population bias. Additionally, studies assessing caffeine consumption are self-reported, which may cause issues of social desirability and recall bias, leading to inaccurate results (Bergomi et al., 2013). Overall, older populations have remained relatively consistent in their beverage choice. Both coffee and tea have seen steady increases in consumption throughout life, with a 28% increase from 20-70 years of age, while energy drink consumption has inverse numbers decreasing from 10%-0% from ages 14-50 years of age (Drewnowski & Rehm, 2016). An enormous strength of this study was its wide range in sample size, with 22,276 children being assessed and 33,931 adults being assessed. With a sample size such as this, it is much more likely to be representative of the overall population.

Caffeine's relationship with relationship cognitive functioning

When assessing the stimulation of caffeine intake, researchers have two avenues to proceed with immediately when creating their study. This choice is to use dosed caffeine administration or habitual caffeine use to assess the caffeine consumption in their sample. Both methods have both positives and negatives in practice. When dosing participants before testing, a study's experimental potential is improved as it gives control to the researchers as they determine the dosage levels. Most studies which dose participants before administering a

cognitive task increase in 50mg increments along with a placebo group (Kamimori et al., 2005; Rogers et al., 2013). This assessment style works well because a steady increase of stimulation can be administered, and the effects of each increment can be measured. Despite the positives and controlled nature, this style bears little resemblance to the processes of everyday life, which may overestimate the levels of benefits that caffeine creates in a person's daily life. In this case, assessing habitual caffeine consumption excels. Despite this, there are also issues which appear with habitual caffeine testing. Studies that take on this approach suffer from the primary limitations of self-report measures, giving rise to recall bias and social desirability bias, as mentioned in many studies which use this method (Attila & Cakir, 2011; James 2014; Rodda et al., 2020). The main benefits of using a self-reported measure are being able to assess a more significant number of participants and simultaneously gaining more knowledge on caffeine consumption in the chosen populous to develop our understanding of habitual caffeine consumption further, along with the testing having a more true-to-life result.

Caffeine as a substance has been known to have many benefits to cognitive ability; this is known by researchers and the public alike. This knowledge is utilised in the case of university students, with studies assessing this population finding that the majority of individuals use caffeine for "cognitive enhancement" (Lee et al., 2009; Rodda et al., 2020) or "to stay awake" (Lieberman et al., 2015). Of course, rudimentary answers of "to stay awake" and "cognitive enhancement" is typically how individuals perceive the benefits of caffeine. However, the specific benefits caffeine creates for an individual's cognitive functioning can only be understood through specific testing using validated psychological tests.

There is widespread agreement among researchers that caffeine improves cognition. Despite this, the intricacies regarding the specific aspects of cognition that caffeine enhances have been heavily debated throughout the literature. It is theorised that caffeine improves

straightforward cognitive tasks such as reaction time and vigilance tasks (Adan & Serra-Grabulosa, 2010; Foxe et al., 2012; Kamimori et al., 2015). However, caffeine's effects on more complex and demanding cognitive tasks seem to diminish or ultimately disappear (McLellan et al., 2016; Tieges et al., 2009). Cognitive tests specifically testing these straightforward cognitive tasks have shown enhanced performance to correlate positively with caffeine intake. The Backan Test (Maridakis et al., 2009) and the Perceptual Speed and Accuracy Test (Aniţei et al., 2011) have illustrated these improvements. Although these tasks may be straightforward, when looking at their prevalence in almost every person's life, it is simple to understand how this creates the broad appeal of caffeine intake.

In contrast, more complex cognitive functions appear resistant to improvements prompted by caffeine consumption. Less research has been conducted on caffeine's effects on complicated cognitive tasks such as decision-making (Killgore et al., 2007) and inhibitory control (Tieges et al., 2009). Studies such as this which assess more demanding cognitive tasks ,end to use multiple measures to ensure adequate testing. For example, the previously mentioned study utilised a modified version of the Continuous Performance Task, the Stop Task and the Flanker Task. The results show that although there seems to be a slight improvement in cognition upon a dosage of 200mg of caffeine, these findings are not significant enough to make any conclusions about the benefits of caffeine on these more complex processes. A task that possesses both complex and straightforward cognitive functioning is the Stroop Colour Word Task (SCWT) (MacLeod, 1991). By testing simple cognitive functions in reaction time and more complex functions in selective attention, this task serves as a perfect bridge between simple and complex functioning. As this is the case, it has been observed to have mixed results when testing for improvements from caffeine use (Brunyé et al., 2010). Even though the SCWT is considered an assessment of complex functioning, its results are typically measured in reaction time which may attribute to

assistance in complex functioning, as we can determine from other studies reaction time is influenced by caffeine. Also, a dosage method of caffeine administration was used to assess the SCW in the above studies. This reduces the real-life applications of these results while leaving a gap in the research for habitual caffeine assessment.

Overview of findings and the current study

Caffeine intake in early research was consistent with its results finding a direct positive correlation between age and caffeine consumption. Over time, the landscape of caffeinated beverages has changed. Although tea and coffee have been consistently the most popular beverages consumed for caffeine intake, the gradual increase in energy drink consumption in many populations is visible, being found to compete with soft drinks in recent research. Additionally, there has been an increase in university-aged students consuming supplements such as caffeine tablets and pre-workout to assist with cognitive functioning and energy levels. The research above shows that these products now have a substantial amount of consumption in young populations. Therefore, this present study will integrate these products into a previously validated caffeine consumption questionnaire to further the accuracy and development of caffeine consumption research. This study will also assess which beverages are most commonly consumed and at what age are they most popular. Although explored in some ways in previous studies, this study hopes to build upon and validate previous research on the topic, along with visualising the average consumption of the studies population through the use of a K-means cluster analysis,

Furthermore, the research surrounding caffeine's effect on cognition suggests that caffeine increases an individual's ability to complete simple cognitive processes improving test scores reaction time and visual tasks. However, when assessing more complex cognitive tasks, the research has produced mixed results. Tasks such as memory recall seem to have little to no improvement when increasing caffeine ingestion. Therefore, this study will utilise

the SCWT to assess both simple functioning in the form of reaction time and complex functioning in the form of selective visual attention in the hopes of assessing both issues in one psychological test.

Therefore, this present study aims to investigate the correlation between caffeine use and improved scores by employing the SCWT. This study also aims to assess if there is a correlation between age and an increase in caffeine consumption. This study also aims to investigate the range of caffeinated beverages consumed by teenagers and young adults. The research questions and hypotheses produced through these aims are as follows:

Research question 1. Does increased caffeine consumption prompt better scores on complex functioning?

Hypothesis 1: There is expected to be a positive correlation between caffeine use and improved test scores, in line with previous research.

Research question 2. Does average caffeine consumption increase with age?

Hypothesis 2: In line with most previous research, there is expected to be an increase in caffeine consumption with age.

Research question 3. Do teenagers and young adults consume a broader range of caffeinated beverages compared to those older than them?

Hypothesis 3: In line with previous research, young adults and teenagers will consume a broader range of caffeinated beverages than those older than them.

Methods

Participants

To calculate the apt number of participants needed for a statistically powerful analysis, the software G*Power (v3.1.9.7) was used. A large effect size (.50) was called for while inputting Pearson's correlation. The optimal size for this study was 84 participants (Faul et al., 2009). A total of 173 participants were recruited for this study and completed the caffeine questionnaire (Male n=72, Female n=96, Other n=5. Mean age=32, Standard deviation=±10.3). Despite this, only 84 participants proceeded to complete the Stroop test after the questionnaire. A non-probability convenience sampling method was used for this study. This study was advertised online through various social media sites (Instagram, Twitter) with the use of a digital poster created by the researcher containing a link to the questionnaire (Appendix A). The study was also promoted on psychologically focused forms (Reddit), here a small abstract was written to inform readers of the nature of the study along with the link to participate. Additionally, posters identical to the digital poster were pinned to notice boards around the college. No incentives were used to recruit participants, we relied on the willingness of individuals to participate. This study was carried out according to the guidelines of the NCI ethics board. Therefore, an age restriction was placed on participation in this study, making it only available to individuals over the age of 18.

Design

This current study implements an experimental cross-sectional research design as the participant's data was collected at a specific point in time. This study employs a quantitative approach to data collection, utilising a questionnaire and attention task, which produced numerical data upon completion. Pearson's correlation was carried out to assess the study's first aim if caffeine intake predicts higher scores on cognitive tasks. Pearson's correlation was also used, to assess the second aim of the study, does caffeine intake increase with age. A K-

Means cluster analysis was conducted to assess the study's third aim, do young adults and teenagers consume a broader variety of caffeinated beverages. The independent variable for the first aim is caffeine consumption, with the dependent variable being the Stroop interference this aim will be recorded using the Stroop Colour Word Task (SCW). As for the second aim, the independent variable is age, and the dependent variable is caffeine consumption. These values were recorded using the caffeine consumption questionnaire. As for the third aim, each variable on the adapted version of the caffeine questionnaire was utilised in a K-means algorithm which then determined the number of statistical clusters that the data set produced, from there a K-Means cluster analysis was conducted to observe the consumption patterns of these groups. These consumption variables were recorded in the adapted caffeine consumption questionnaire.

Measures & Materials

The demographics of this study were obtained before the administration before the caffeine questionnaire through google forms. The demographics obtained were first and last name, gender (Male, Female and Other) and age.

Caffeine consumption questionnaire

The questionnaire used in this study is adapted from the Caffeine Consumption Questionnaire Revised (CCQR) (Irons et al., 2016). The initial Caffeine Consumption Questionnaire (CCQ) (Landrum R.E, 1992) was developed as the first self-report measure of caffeine consumption. One of the primary objectives of the CCQ is bypassing the need for participants to be aware of the specific caffeine content they consume by simply asking them to answer how many units of a selection of different drinks they consume. The revised version of the CCQ helps modernise the original version, adding pictures for each beverage and introducing modern caffeine beverages such as energy drinks. For this current study, I am adapting the CCQR to suit the current study. Firstly, questions asking about of the newly

marketed and popularised methods of caffeine use (Pre-Workout supplements, Caffeine tablets and energy drink shots). Along with this as this study wishes to focus on beverages, foodstuffs and medication has been removed from the questionnaire. This study has been conveyed to provide accurate results when being adapted in the past, for example this questionnaire has been adapted to a Portuguese (Batista et al., 2022) sample and a Polish sample (Bulczak & Chmurzynska, 2023).

In the CCQR, open-ended questions are utilised, allowing for no upper limit placed on participants' answers. When scoring this questionnaire in this study, the original scoring method used by Irons et al was utilised for mg per beverage. In the study conducted by Irons et al, the CCQR demonstrated great criterion validity, with the average participant self-report scores having 85% accuracy in agreement with an in-person assessment conducted by a researcher. Furthermore, the Cronbach's alpha was calculated for this study (α=.73) showing good reliability (Taber, 2018). As this current study adds different methods of caffeine consumption, it was necessary to determine the caffeine levels of these individual items. Desk research was conducted observing the market of Pre-Workout supplements caffeine tablets and caffeine shots, noting different brands that are most common, along with the most common caffeine levels for these products. There are a limited amount of research papers surrounding these products. Despite this, psychological articles were consulted where possible (Cappelletti et al., 2018; Da Costa et al., 2021; Harty et al., 2018; Walter, 2022). Overall, the data of these products vary considerably, containing between 150mg-400mg of caffeine depending on the brand. This method is not optimal but necessary for the adaptation of the questionnaire. After this, it was determined that for this study Pre-Workout Supplements were to be scored as 270mg per serving, caffeine tablets were marked as 200mg per serving and caffeine shots were marked as 150mg per serving.

Stroop colour word task (SCWT)

To test for caffeine's effects on cognition, this study will utilise the SCWT created by J.R Stroop in 1935 was utilised (MacLeod, 1991). In this task, participants are presented with words of colours in different ink (e.g., the word "BLUE" in red ink). The task measures the ability to selectively attend to the relevant information (i.e., the colour of the ink). The Stroop task relates to "selective attention," which is the ability to focus on one aspect of the environment while ignoring others. (MacLeod & MacDonald, 2000). An online version of the SCW with keyboard responding was used for this study using the Inquisit6 software through Millisecond.com. The scores were automatically computed and recorded the mean reaction times of incongruent and congruent stimuli for both reaction time and percentage of correct answers. The Stroop test has been used in a wide array of research since its conception, proving its reliability as a cognitive task (C. Lee et al., 2019; Yuan et al., 2020).

Procedure

The data for the adapted caffeine consumption questionnaire was collected using a questionnaire on Google Forms. The questionnaire then redirects the participants to the Inquisit6 software, where the SCWT is completed. The study was first piloted to five volunteers, this was done to determine the length of the study and test for any user interface issues. Completing the questionnaire and the SCWT took approximately 15 minutes, and the transition between the two data collection methods was straightforward, as noted by the pilot study volunteers. Following this testing, the consent form before the questionnaire was edited to inform participants of the test length.

The study was advertised online on the researcher's personal social media accounts (Twitter, Instagram, Reddit), with an informative poster containing a link to the study, the age exclusion criteria and a small synopsis of the study. Participants would then follow the link to the questionnaire page. This same poster was also printed and posted on notice boards around

the college campus, with a QR code that brought participants to the questionnaire page (Appendix A).

After opening the link or scanning the QR code created for the poster, participants are brought to the Participant Information Sheet provided for the study (Appendix B) The document contained details about the objectives and nature of the research, as well as a brief overview of the questionnaire and cognition task. Participants were informed that their participation in the study was entirely voluntary and that they had the right to withdraw from the study at any point during the survey. Additionally, the exclusion criteria for the research was communicated to the participants. They were informed that their information would be treated in accordance with the NCI ethics board's guidelines. Finally, participants were notified that their data would be archived in the NCI library and could potentially be presented at a conference in the future.

After marking their understanding, the next page of the Google Forms is the Informed Consent Sheet (Appendix C) Here participants are provided crucial information concerning the handling of their data and how it will be stored in accordance with NCI's data retention policy and will be de-identified during analysis. The information on the sheet above concerning the age requirements for the study was reiterated, along with the participant's right to withdraw from the study at any time. However, they were informed that they could not withdraw from the study upon submission.

Upon giving their consent, participants were brought to the demographic section of the questionnaire. Here, participants are asked their name (first and second name), age and gender (Male, female, other) (Appendix D) Following this, the adapted version of the CCQR was administered (Appendix E) Each question in this google form was programmed as a required field, requiring participants to mark 0 even if they did not consume the caffeinated beverage in question. As well as this, the questions were in an open format leaving no limit

on the answers participants could submit. Once the participants submit an answer in each field of the study, they submit their answers and are brought to the final page of the questionnaire. A message informing participants that they have yet to finish will appear, with a link provided to download the Inquisit6 software and complete the SCW task, as well as a short debriefing paragraph and again giving the participants an email address to contact if they have any questions about the research (Appendix F). Once clicking the link at the end of the questionnaire, participants must download the Inquisit6 software either on windows or the app store on their smartphone. On Windows, the software will automatically begin to download upon clicking the link and once downloaded, the software will automatically launch on the page required to complete the task. On mobile phones, the link will bring participants to the app store to confirm the software download, and then participants must launch the app on their phones, from here the task will start.

Once opened, participants will be asked to give their first and last names to match their questionnaire data. Then there will be a small tutorial on how to complete the SCW, which is programmed into the Inquisit6 software (Appendix G). After reading this, a trial period was programmed into the task to accustom participants to the trial before the real task starts. After this, participants will then complete the genuine SCWT.

After completion of the SCWT, the participant's data will automatically be stored by the Inquisit6 software. Participants will then be given a thank you message informing them that they have completed the study along with being provided with the email address previously given to them they can contact if they have any questions or concerns about the study.

Ethical considerations

There was minimal ethical risk in taking part in this study. The data was collected and stored according to the ethical guidelines of NCI. There was no coercion or deception

involved in recruiting participants. Each participant provided written consent before taking part. In the consent form, participants were made aware that this study could be added to the NCI library. Participants data will be de-identified during data analysis by removing their names from both data sets before conducting the statistical analysis.

Results

Descriptive statistics

The data for this current study was collected from a sample of 173 which will be referred to from now on as Sample 1. Participants in this group completed the initial caffeine questionnaire although only a portion of them completed the SCWT. This group consisted of females at 56% (*n*=96), males at 41% (*n*=72) and other at 3% (*n*=5). This sample will be used to investigate research question number 2 and 3.

Within this group, a total of 84 participants completed both the questionnaire and the SCWT. This sample will be referred to as Sample 2 from now. This group consisted of females at 44% (*n*=37), males at 55% (*n*=46) and other at 1% (*n*=1). This sample will be used to investigate research question 1.

Table 1

Descriptive statistics for age, caffeine intake and Stroop interference

Variable	Group	*M [95% CI]*	*SD*	Range
Age	Sample 1	32[30.46-33.54]	10.3	18-66
Caffeine intake	Sample 1	261[224.00-298.00]	248	0-1874*mg*
Age	Sample 2	33	10.1	20-66
Caffeine intake	Sample 2	265 [207.47-322.53]	269.8	0-1874*mg*
Stroop interference	Sample 2	225.4 [197.4-253.4]	126.4	28.6-530.3*ms*

Inferential statistics

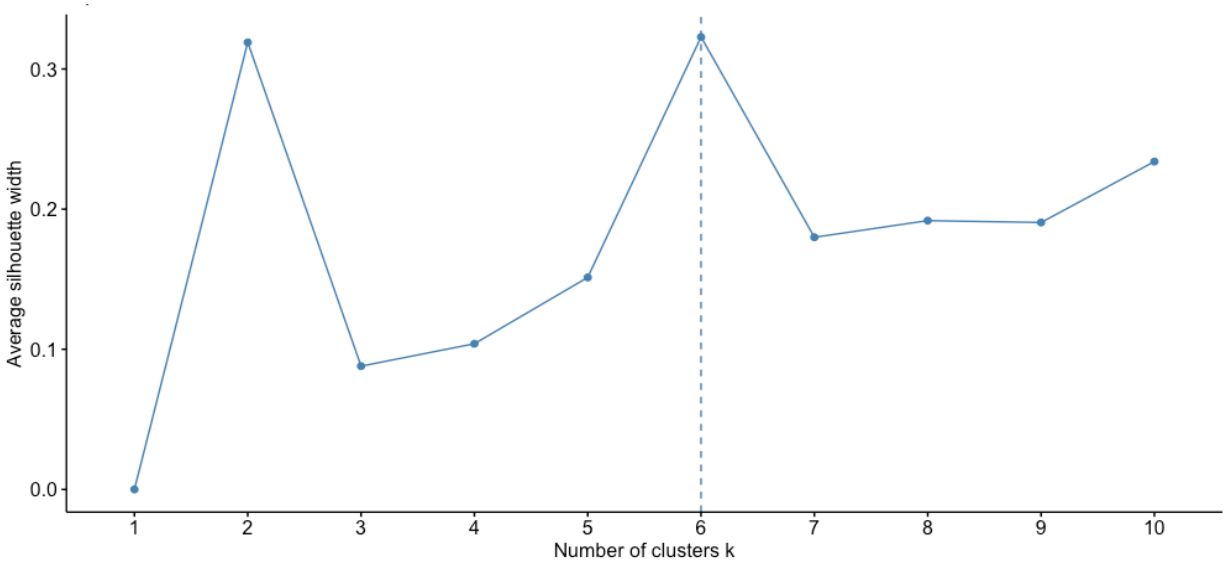
To investigate research question 1: Does increased caffeine consumption prompt better scores on complex cognitive functioning. A Pearson's correlation coefficient was utilised. A preliminary analysis was conducted to investigate violations of normality, linearity and homoscedasticity, no violations were observed. This research question was investigated using data from Sample 2 (n=84). There was a significant, moderate, positive effect between caffeine consumption and Stroop interference (r=.29, p=.007), this means an 8.6% of variance was shared between the two variables. This result indicates that a high caffeine intake improves scores on the SCWT.

To investigate research question 2: Does caffeine consumption increase with age. A Pearson's correlation coefficient was utilised. Preliminary analysis was conducted to investigate any violations of normality, linearity and homoscedasticity, no violations were observed. This research question was investigated using data from sample 1 (n=173). There was a significant weak positive effect between age and caffeine consumption (r=.16, p=.007), this means a 2.5% of variance is shared between the two variables. This result indicated that there is an increase in caffeine consumption with the increase in age.

To investigate research question 3: Do adults consume a broader range of caffeinated beverages compared to teenagers and young adults. A K-means clustering algorithm was utilised. A prior analysis was conducted to observe the silhouette variation of the data to create the clusters for the sample. This analysis revealed that six groups were optimal for natural grouping this can be seen in figure 1. Consequently, the K-means clustering algorithm was re-run with a pre-determined parameter of six groups.

Figure 1

Optimal cluster numbers



To assess the validity of this K-Means cluster analysis, an initial analysis was conducted, which ran for 6 iterations before stopping; iterations of the data are stopped when there is no more variance observed within the cluster centroids. To ensure this data was suitable, another K-Means cluster analysis was run to verify the final cluster centroids, which ran for 13 iterations. This created a vastly different set of data compared to the initial test. This was then conducted another three times, where the same 13 iterations were produced while creating the same final cluster of centroids. This means that upon running the data multiple times it is optimal to use the analysis which ran for 13 iterations. Along with this to validate the quality of the cluster centroids a two-step cluster validation was conducted; this current data set indicated a fair cluster quality (CQ=.4) where the first analysis produced a poor cluster quality (CQ=.1). With this analysis we can utilise the best quality final cluster centroids.

After obtaining the final cluster centroids, an ANOVA was conducted to investigate the significance of variables when determining cluster inclusion. It was determined that Instant coffee, 8oz takeaway coffee, 12oz takeaway coffee, 16oz takeaway coffee, black tea, red bull, monster, pre-workout supplements and age, all possessed a statistical significance individually (p=.001) in creating the final cluster centroids, this can be seen in Appendix H.

These results indicate that each of these variables was significant in determining the average consumption in each of the final cluster centroids.

The participants were conveyed to primarily belong to two clusters, with 95% of participants belonging to either cluster 1 or cluster 6, this can be seen in Table 2.

Table 2

Number of participants in each cluster

Variable	Participants (%)
Cluster 1	60 (35%)
Cluster 2	4 (2%)
Cluster 3	1 (.5%)
Cluster 4	3 (2%)
Cluster 5	1 (.5%)
Cluster 6	104 (60%)

These final cluster centroids can be observed to report the mean demographics for each question administered in the caffeine consumption questionnaire each of these clusters can be observed individually in Figures 2 through 7.

Figure 2

Final cluster centroids

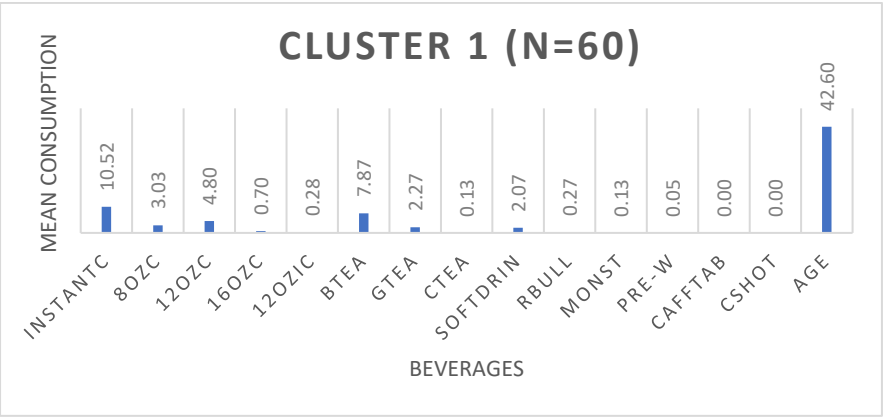


Figure 3

Final cluster centroids

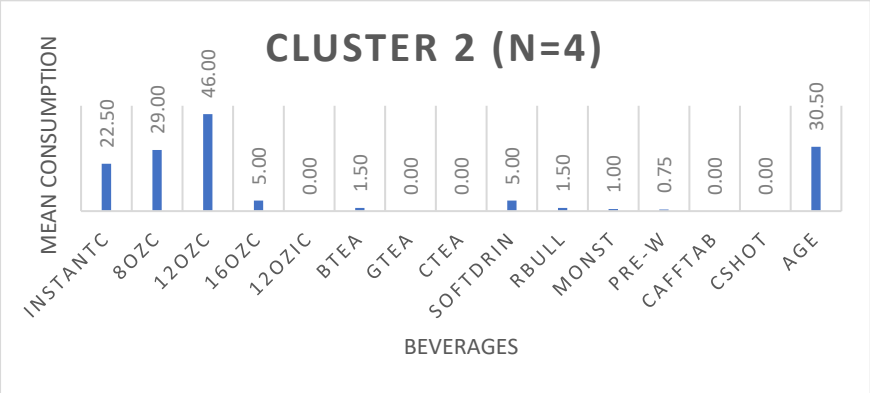


Figure 4

Final cluster centroids

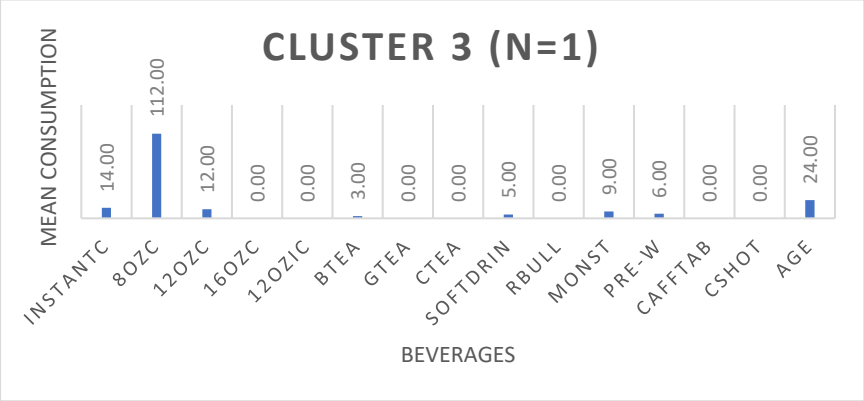


Figure 5

Final cluster centroids

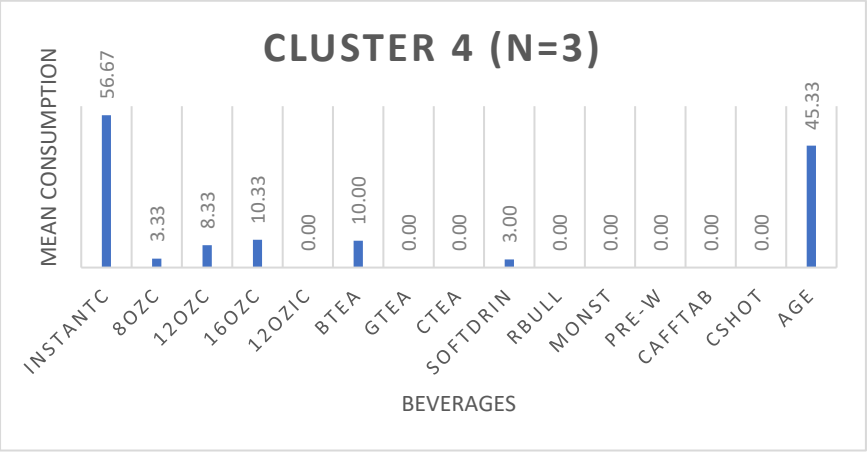


Figure 6

Final cluster centroids

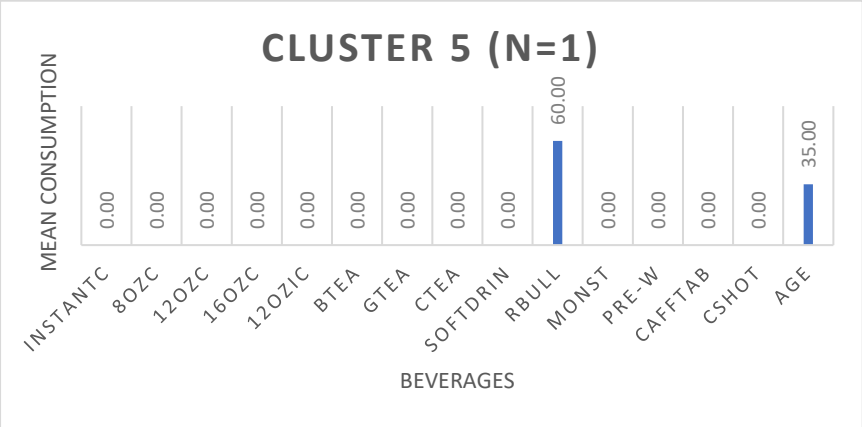
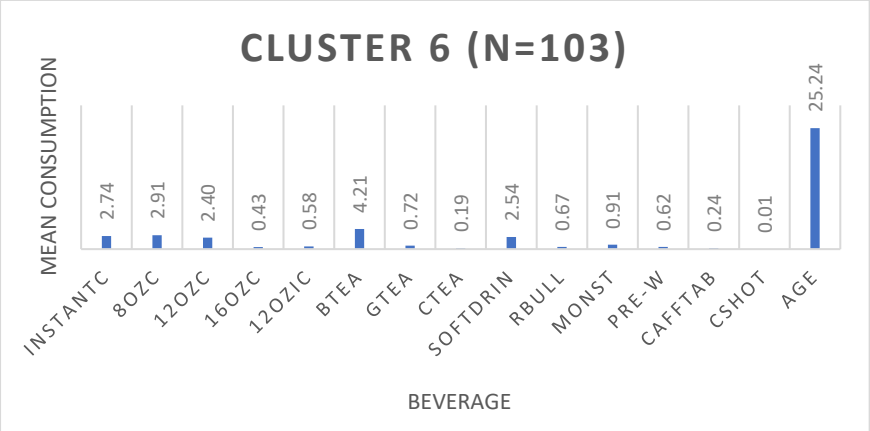


Figure 7

Final cluster centroid



Based on the final cluster centroids, several observations can be made. The clusters reveal that there are severe outliers which consume extreme amounts of caffeine, Cluster 2 (*M*=1150mg/d), Cluster 3 (*M*=2020mg/d), Cluster 4 (*M*=876mg/d), and Cluster 5 (*M*=686mg/d) whereas Cluster 1 (*M*=271mg/d) and Cluster 6 (*M*=204mg/d) fall closer to previous research.

Two main differences can be observed within the two main data clusters: age (Cluster 1: *M*=43 and Cluster 6: *M*=25) and beverage consumption patterns. Based on the observations made in Figure 2 and Figure 7, it is evident that Cluster 1 tends to consume traditional forms of caffeinated beverages, such as instant coffee, 8oz takeaway coffee, 12oz

takeaway coffee, black and green tea and soft drinks almost exclusively. On the other hand, on average in Cluster 6, although there are fewer beverages consumed overall, the consumption rates are dispersed widely across the graph.

From these results, we can determine that the older population in Cluster 1 tend to consume more habitually than the younger population in Cluster 6, this is evident in their lack of consumption of different beverages and heightened consumption of longer existing caffeinated beverages. As for the younger population in Cluster 6, Figure 7 conveys that they tend to consume a far wider range of caffeinated beverages meaning they consume their caffeine in a variety of different methods, albeit in smaller amounts, leading to a lower average caffeine intake in the group. Evidence of data can be seen in Appendix H.

Discussion

Since research on caffeine consumption began, there has been a growing understanding of people's relationships with the substance. Therefore, this current study set out to broaden our understanding of caffeine consumption and its effects on cognition. Firstly, this study investigates the effects of caffeine on cognitive functioning using the Stroop Colour Word Task. This study also set out to examine correlations between age and caffeine consumption. Finally, this study sought to understand the patterns of modern-day caffeine consumption.

In acceptance of the first hypothesis, caffeine intake increases scores on the SCWT; the results found that there is a significant moderate positive effect of caffeine use on cognitive tasks. This indicates that high daily caffeine intake improves cognitive functioning compared to individuals with a lower daily caffeine intake. The second hypothesis; would there be an increase in caffeine consumption with age, was also accepted. The results found a significant weak positive effect of age and increased caffeine consumption. This indicates that when increasing in age, daily caffeine intake also increases. The third hypothesis, that young adults and teenagers consume a broader range of beverages compared to older adults was also accepted; the results found that the average teenager and young adult tend to consume a broader range of caffeinated beverages that is more evenly dispersed than those older than them, despite some radical outliers.

It is widely accepted that caffeine intake increases performance in simple cognitive functioning, with studies that test for functions such as reaction time and vigilance tasks finding results to support this idea (Foxe et al., 2012; Kamimori et al., 2015; Murphy, 2018; Wilhelmus et al., 2017). It is in caffeine research concerning complex cognitive functioning where there are varying results, with studies finding that caffeine intake does not improve scores in inhibition control and decision-making tasks (Killgore et al., 2007; Tieges et al.,

2009). Whereas others have conveyed improvements in complex cognitive functioning (Einöther & Giesbrecht, 2013; Heatherley et al., 2005). The SCWT fits into complex and simple functioning as it is based on reaction time while simultaneously testing for a more complex function in Stroop interference. For this reason, it was utilised in this study as an attempt to measure a range of functioning in one test.

One possible explanation for the moderate correlation between caffeine intake and improved Stroop interference in this study could be that Stroop interference is calculated through the difference in participants' incongruent and congruent mean reaction times. Reaction time is a simple cognitive function. Although selective attention is considered a complex function, a general improvement in reaction time could improve the related complex function, reducing Stroop interference. Other studies which have measured Stroop interference using the same formula have found similar results to this current study, although they adopted a dosed method of caffeine administration (Dixit et al., 2012; Paulus et al., 2015).

Opposite results can be seen in functioning not rooted in simple cognition, such as memory tasks (Nehlig, 2010; Schmitt et al., 2003). These results serve the purpose of developing our understanding of caffeine’s effects on cognition, as the SCWT serves as a bridge between simple and complex functioning as it assesses both of these in one; tasks such as this should be utilised more in this field of research in order to assess the intricacies of caffeine as a cognitive enhancer as opposed to using cognitive tasks which assess one facet of cognitive functioning. To obtain a more true-to-life report of the effects caffeine creates, this study opted not to dose participants and instead assess habitual caffeine consumption. This method comes with conflicting opinions in previous research as interruptions such as sleep and everyday fatigue can interfere with subsequent test results (Filip et al., 2020; Nikić et al., 2014). These issues may have also affected this current study. Furthermore, previous research

has obtained the education levels of individuals to assess their reading level; there have been mixed results on the influence of reading level and Stroop performance (Parsons et al., 2013; Zimmermann et al., 2015), this study did not allow for an investigation of this variable which could also influence scores, assessing for this variable would be necessary for future research to obtain a better understanding of external variables.

Age and caffeine consumption has been observed to rarely deviate from previous results that show an increase in age increases caffeine consumption (Chen et al., 2020; Treur et al., 2016; Watson et al., 2016). This study is no exception. Despite this study falling in line with previous research, it was necessary to challenge the field with a more relevant questionnaire adapted to suit the current-day caffeinated beverage market. This serves as further upkeep for this area as this correlation has been investigated in studies regarding caffeine consumption since the beginning of the research in this field till this day (Barone & Roberts, 1996; Chen et al., 2020; Drewnowski & Rehm, 2016; Mandel, 2002; Heatherley et al., 2005).

The study's findings on caffeine consumption habits are consistent with previous research, finding that young people consume a broader range of caffeinated beverages. However, this study utilised a K-means analysis to better visualise how individuals consume caffeine. Previous research tends to convey beverage consumption individualistically, providing percentages of the consumption per beverage within the sample (Mahoney et al., 2019; Rodas et al., 2020; Shohet & Landrum, 2001; Temple, 2019) or in other cases, assessing caffeine consumption without distinction of each beverage in question (Dark et al., 2015; Nova et al., 2012). Although this study is conducted similarly to those mentioned above regarding questioning despite having more variables, the difference in this study is the analysis conducted. The K-means cluster provides an accurate description of the average caffeine consumer, providing the mean average consumption of each beverage and age within

each data cluster. This is relevant to the field as it gives us a better visualisation of the actual habits of individuals and patterns of how they consume beverages, as noted in the results section. It is because of this analysis that we can observe how caffeine use is distributed more evenly across beverages in young people compared to those older than them. This, of course, when observed from an individual beverage consumption standpoint, poses many issues from a health policy perspective as beverages are observed to be consumed in high percentages when in reality younger people consume more beverages, but in very low amounts per week. As this is the case, young people consume less caffeine compared to those older than them.

One possible explanation for this dispersion of beverages in the younger population may simply be a preference for taste. This idea aligns with previous research that conveys that young people tend to avoid bitter beverages (Lesschaeve & Noble, 2005). It is also possible that habits have formed over time, keeping older individuals from trying new beverages (Van ’t Riet et al., 2011). In this respect, a motivation for consumption section could also be added to this questionnaire to cluster motives for consumption. If conducted in the future, a caffeine consumption questionnaire such the one utilised in this study along with a questionnaire such as the Motives for Caffeine Consumption questionnaire would be a component to add to further research (Ágoston et al., 2018).

Strengths & Limitations

A key strength of this study is its attempt to expand upon the previous methods of understanding habitual caffeine use in a novel way. To our knowledge, this study is the first to utilise this analysis method. Previous studies struggle to create an idea of the average caffeine habits of individuals within an average week because they assess variables individually; this study helps us understand people’s consumption habits with a broader scope. Along with this, this study attempts to observe cognitive testing with a broader scope than previously in caffeine literature, with its ideas that simple cognitive functioning has

intense direct effects on cognitive tasks that may assess complex and simple cognitive functioning, such as the results of Stroop interference being calculated with reaction time. This method of observation could prove helpful in further research as methods of scoring tasks may score in favour of simple cognition as with the SCWT.

Furthermore, in psychological studies, it is typical to have a disproportionate number of females compared to males (Smith, 2008). Despite this, the study had an almost even distribution of males and females in both samples of data used in the statistical analysis; this adds to the scientific quality of the analysis as it reduces the possibility of gender bias in the studies results. In addition, the reliability and validity of tests used in this study is a notable strength, with the SCWT being used in countless previous studies (e.g. Dixit et al., 2012; Parsons et al., 2013), along with the adapted caffeine consumption questionnaire demonstrating high reliability and validity.

Several limitations can be observed in this study. Firstly, although the optimal number of participants was obtained, a large number of participants did not complete the SCWT. We can speculate some reluctance on the part of the participants to download a software using an online link. It may also be the case that the ending page of the questionnaire was not clear enough in its instructions, this could be considered for further research. It is possible that google forms may not be optimal for studies which transfer participants to another software. Furthermore, in terms of the questionnaire, self-report measures have consistently been observed in research to be susceptible to biases which tend to skew questionnaire results. Despite being found to have high validity and reliability this may have altered results. Finally, as using a K-means analysis is novel in this field, there was no standardised measure to work from when reporting results. Other areas of research were observed, and tests of validity, normality and homoscedasticity were conducted accordingly, as well as the

preceding analysis conducted. For future research, a standardised method of reporting would serve well to compare subsequent findings in this area.

Implications for further research

The current study adds to the existing literature surrounding cognitive performance and caffeine consumption. As cognitive function is a multi-faceted topic which can be influenced by sleep, fatigue and health, assessing how caffeine can influence all of these variables is essential. It is for this reason that this study observed caffeine influence from habitual caffeine use, as although dosed-based experiments are useful in a controlled experiment context, there is a distinct lack of research regarding habitual caffeine consumption in comparison. Therefore, this study provides more understanding of where there is a disparity in the literature.

This study also introduces a method of attempting to create the idea of a consumer as an individual using the K-means cluster analysis. This method builds a description of an average individual and their relationship with caffeine. Although not unheard of in previous literature, finding studies that use a method similar to this proved difficult (Ágoston et al., 2018). The method of analysis utilised for the third aim of this study could prove helpful for emerging studies in the field that wish to understand the true-to-life habits of caffeine consumption per individual, whether for pleasure or cognitive stimulation. Although the results aligned with previous research, many studies fail to consider the context in which caffeine is consumed. Therefore, we hope that this study can create a trend of observing caffeine consumption in the context of everyday life, in further research observe other variables such as mental health conditions, occupation, sleep etc., to further understand the habits of consumers. The use of K-means analysis is also helpful in identifying outliers within a data set which, in the case of this study, were far exceeding the safety limits for caffeine consumption per day (Verster & Koenig, 2018). This analysis could assist in policy

development regarding beverages or consumption patterns which may lead to adverse health implications.

Conclusion

With caffeine consumption and its effects on cognition being a widely researched topic, this study set out to obtain more data in areas with conflicting research while creating a novel method of observing patterns in beverage consumption. Along with this, the topic of caffeine use and age was investigated. This was done to upkeep the data in this area while testing for more caffeinated beverages, that have not previously been incorporated into a consumption questionnaire.

This present study found that caffeine intake has a moderate correlation with better SCWT results, similar to previous literature. This study assists in providing more high-quality results in a field with varying outcomes. However, further research is needed to understand precisely how caffeine assists us in tasks involving inhibition control or other complex cognitive functions. While this study provides a good assessment, future research would prove well to assess other variables from the SCWT scores, such as correct answer percentages. Age still serves to increase caffeine consumption; this has been a consistent finding in the field. Finally, this study hopes to inspire an alternative method of observing how consumers interact with caffeinated beverages as a whole instead of how they interact with each beverage individually.

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Appendices

Appendix A-Recruitment poster

Appendix B-Participant information sheet

Modern caffeine intake: The effect of caffeine tolerance and consumption on attention.

This information sheet is being provided for participants of my independent research study. This sheet will give you all the necessary information that is needed about the study taking place. Any further information needed can be requested using the email address below.

What is the point of this study?

I am currently a final year student in National College of Ireland. As a part of my Psychology course, I must complete an independent research project. For this project I wish to assess how caffeine consumption affects complex cognitive functioning. My supervisor for this research is Dr. Caoimhe Hannigan.

What will you be asked to do in this study?

There will be a questionnaire that will ask about your general use of caffeine. The questionnaire will take no longer then ten minutes.

After this there will be a cognitive test administered through the questionnaire. You will be asked to follow a link that will bring you to this attention task (Stroop test). You will be required to download the Inquisit app installer, on your laptop or mobile phone through the app store. Further details can be found here where you will be walked through how to complete the test.

Am I able to take part?

To take part in this study you must be aged 18 years or over.

After reading this do I have to take part?

There is no obligation to take part in this study. You are able to withdraw at any time up until the point you submit your data, and there will be no consequences. The data is collected anonymously and therefore once submitted; it is not possible to withdraw your data from the study.

Will the information I provide be confidential and will my data be secure?

The information that you will be providing in this study is identifiable, you will have to submit your full name in two instances for this study as it will be used to identify questionnaire and test data. Furthermore, all of the data collected will be handled with care and following guidelines of the ethics committee. After initial data analysis the data the names will be removed and replaced with unique id numbers to protect anonymity. The data may be archived for secondary analysis (which means that other researchers could access the data to analyse it). No identifying information is contained in the data for archival.

Where can I find the results to this study in the future?

The findings of the study will be submitted as a dissertation for examination and will be archived in the NCI library after its completion. There is also a possibility that the information will be submitted to an academic journal for publication. Along with this it is possible that the results may be presented at an academic conference.

Where can I ask any further questions i have concerning this study ?

Please email: céilimrowsomekellyfyp@gmail.com with any questions you may have concerning this study. Thank you !

Appendix C-Participant consent form

When agreeing to take part in this study I am confirming I have read clearly and understand the information below.

o The procedure used to carry out this study has been reviewed and approved by the NCI ethics committee. Despite this it is the above students duty to make sure these guidelines are followed in their business with the participants of this study.

o I am aware that I can withdraw from this study at any time no matter how much of the study has been completed. I have no obligation to finish the study once started.

o Despite the above information I understand that I am unable to withdraw from the study once my information has been submitted upon completion of the study.

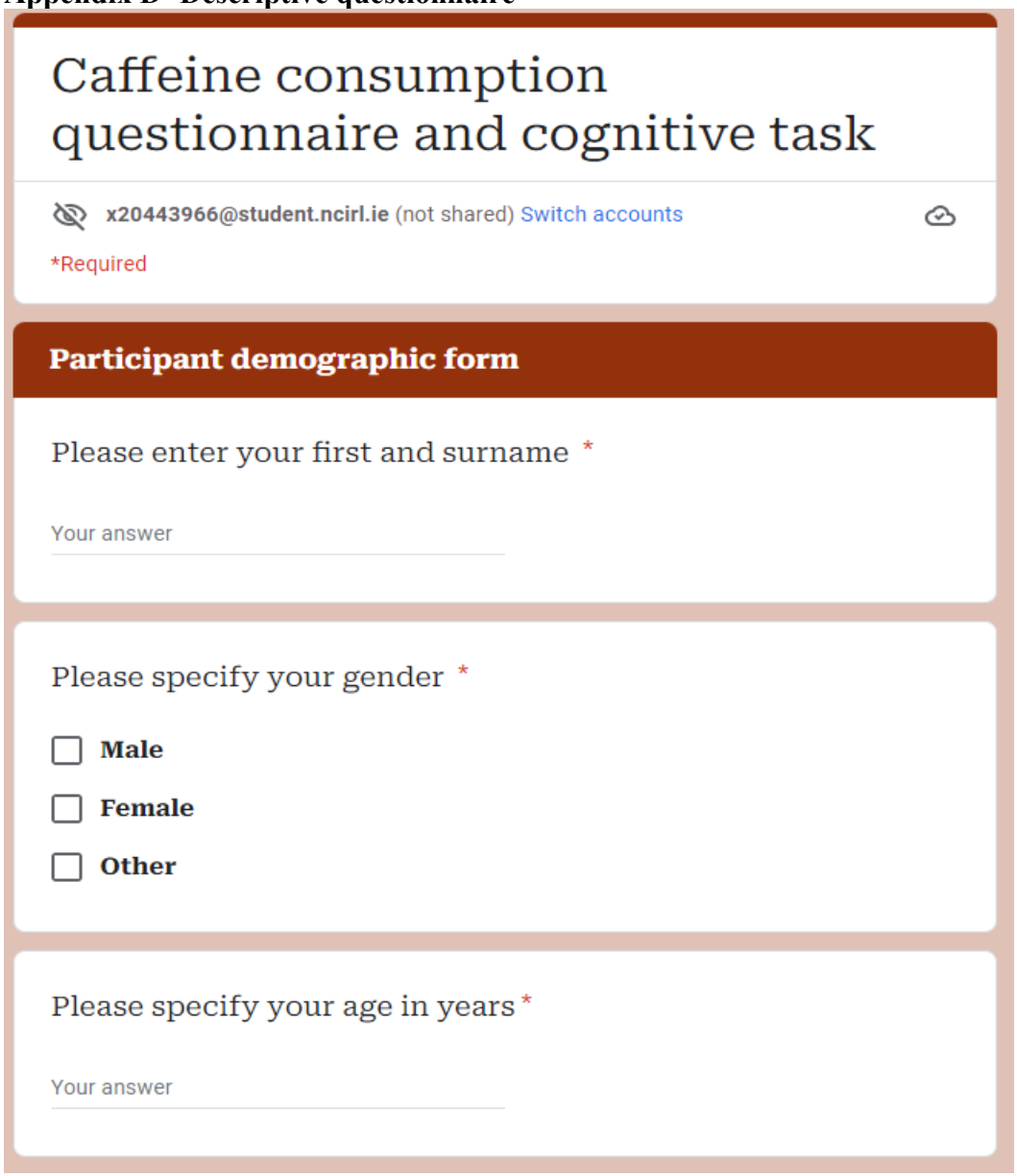
o I am aware that the data I submit today will be managed in accordance with the NCI data retention policy.

o I am aware that any questions or concerns that I have at the end of the study will be addressed

o I have been given a brief overview of the study

o The data that I submit will be stored in accordance with the NCI data retention policy. The anonymous data may be archived for secondary analysis (which means that other researchers could access the data to analyse it). No identifying information is contained in the data for archival.

Appendix D- Descriptive questionnaire



Appendix E-Caffeine consumption questionnaire

Caffeine consumption questionnaire

Please state your answers in digit form for example "2, 5, 14" when answering each question.

Do you drink coffee at least once a week? *

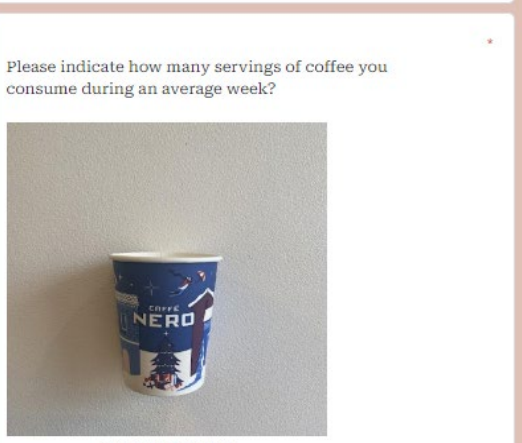
- [ ] Yes
- [ ] No

Please indicate how many servings of coffee you consume during an average week? *

Instant coffee

Your answer

Please indicate how many servings of coffee you consume during an average week? *



8oz "small coffee"

Your answer

Please indicate how many servings of coffee you consume during an average week? *

12oz "medium coffee"

Your answer

Please indicate how many servings of coffee you consume during an average week? *

16 oz "Large coffee"

Your answer

Please indicate how many servings of coffee you consume during an average week? *

12oz iced coffee

Your answer

Back Next Clear form

Tea consumption

Do you consume tea at least once a week? *

- [ ] Yes
- [ ] No

Please indicate how many cups of tea you consume during an average week? *

Black tea

Your answer

Please indicate how many cups of tea you consume during an average week? *

Green tea

Your answer

Please indicate how many cups of tea you consume during an average week? *

Chai tea

Your answer

Back Next Clear form

Caffeinated soft drink consumption

Do you drink soft drinks at least once a week?

- [ ] yes
- [ ] No

Please indicate how many servings of soft drinks you consume during an average week?

Any popular soft drink

Your answer

Do you drink energy drinks at least once a week?

- ○ Yes
- ○ No

How many servings of energy drinks do you consume during an average week?

Average 250ml energy drink

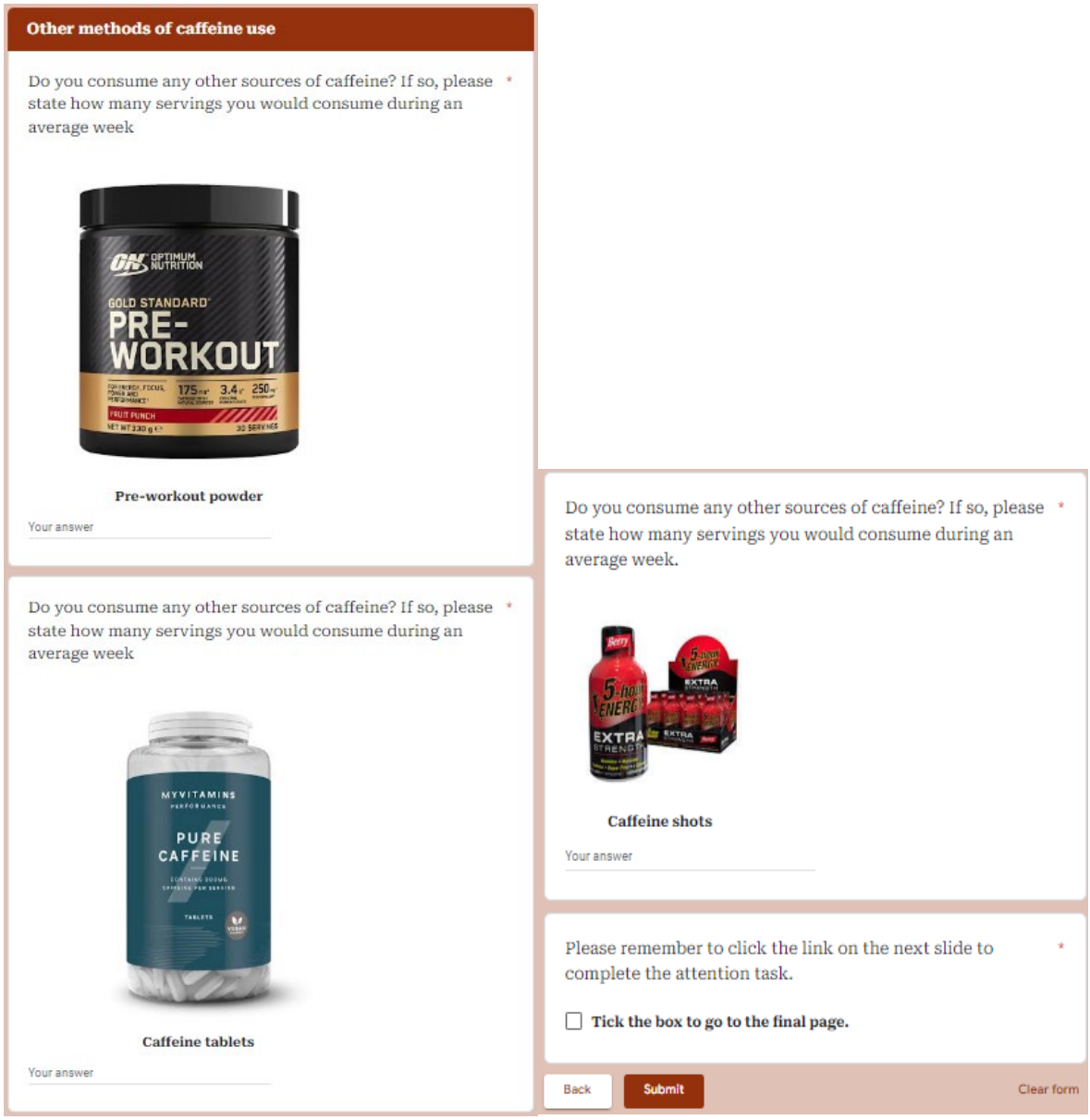
Your answer

How many servings of energy drinks do you consume during an average week?

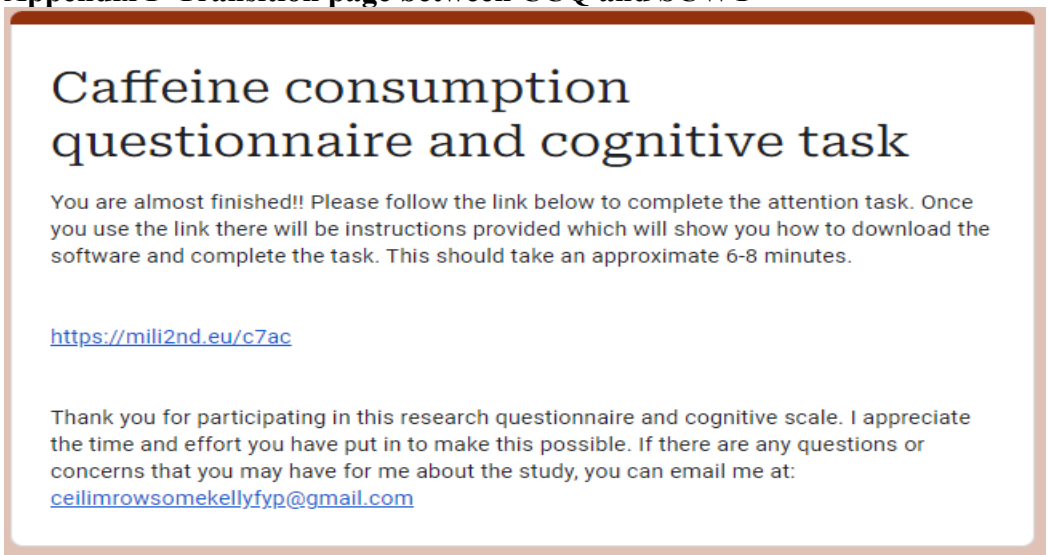
Average 500ml energy drink

Your answer

Back Next Clear form



Appendix F-Transition page between CCQ and SCWT



Appendix G-SCWT information sheet

In the following trials you will see words presented in different colors. Your task is to indicate the COLOR in which each word is printed in while ignoring what the words actually say.

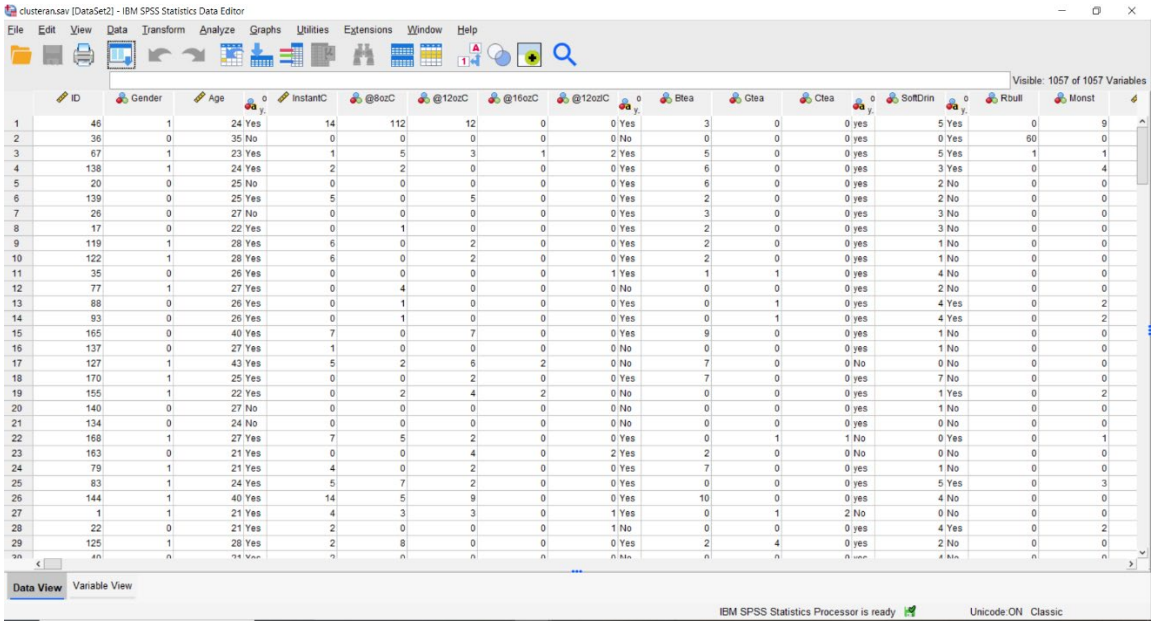
Indicate the color of the word by pressing either of the following F,G,H,J

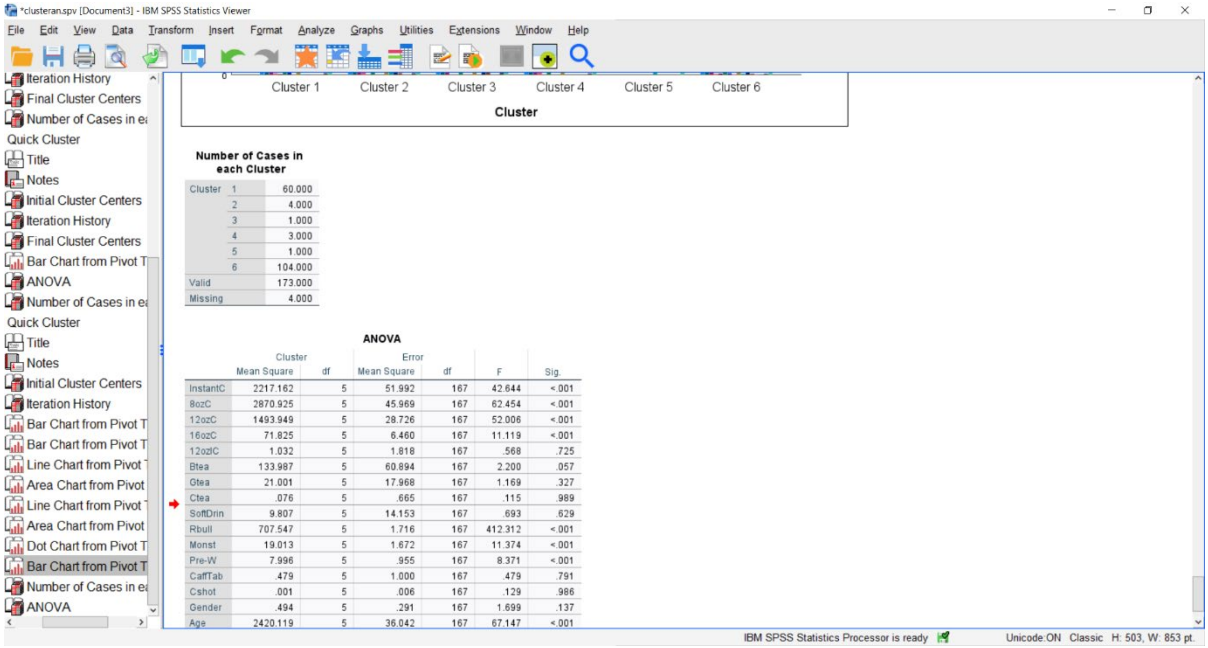
- - F for **red** words
- - G for **green** words
- - H for **blue** words
- - J for **black** words

Example: if you see the word **RED** printed in the color GREEN press G for green words regardless of the meaning of the word.

Try to respond as quickly and accurately as you can, because you will be timed. If an incorrect response is made, a red X will be flashed onto the screen.

Appendix H-Evidence of data

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Final Cluster Centers
Number of Cases in ea
Quick Cluster
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Bar Chart from Pivot T
Number of Cases in ea
ANOVA
Cluster 1
Cluster 2
Cluster 3
Cluster 4
Cluster 5
Cluster 6
Cluster
Number of Cases in each Cluster
Cluster 1 60.000
2 4.000
3 1.000
4 3.000
5 1.000
6 104.000
Valid 173.000
Missing 4.000
ANOVA
Cluster Error
Mean Square df Mean Square df F Sig.
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8ozC 2870.925 5 45.969 167 62.454 <.001
12ozC 1493.949 5 28.726 167 52.006 <.001
16ozC 71.825 5 6.460 167 11.119 <.001
12ozIC 1.032 5 1.818 167 .568 .725
Btea 133.987 5 60.894 167 2.200 .057
Gtea 21.001 5 17.968 167 1.169 .327
Ctea .076 5 .665 167 .115 .989
SoftDrin 9.807 5 14.153 167 .693 .629
Rbull 707.547 5 1.716 167 412.312 <.001
Monst 19.013 5 1.672 167 11.374 <.001
Pre-W 7.996 5 .955 167 8.371 <.001
CaffTab .479 5 1.000 167 .479 .791
Cshot .001 5 .006 167 .129 .986
Gender .494 5 .291 167 1.699 .137
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