THE EFFECT OF EVERYDAY CAFFEINE CONSUMPTION ON REPORTS OF ATTENTION AND MEMORY PERFORMANCE IN DIFFERENT AGE GROUPS: A PRELIMINARY INVESTIGATION

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ABSTRACT

Research suggests that caffeine consumption may be associated with a reduction in cognitive impairment in the elderly. This topic was investigated by examining associations between regular caffeine consumption and subjective reports of attention and memory problems across different age groups. One hundred volunteers completed a survey which recorded caffeine consumption and subjective memory (the Everyday Memory Questionnaire [EMQ]; the Subjective Memory Questionnaire [SMQ]) and attention (the Everyday Attention Questionnaire {EAQ]). The analyses showed no statistically significant correlations between daily caffeine intake and either measure of memory performance (the SMQ or EMQ). There was, however, a weak but statistically significant correlation between daily caffeine consumption and the measure of subjective attention (the EAQ), with, as might be expected, high caffeine consumption being associated with better performance. In younger and middle-aged people, there were no significant associations between daily caffeine consumption and subjective cognitive performance, but in the group aged 55 years and older high daily caffeine consumption was associated with better everyday attention and memory performance (as measured by the EAQ and SMQ). These results from the older participants suggest further investigation, possibly using objective memory tests that would also enable acute effects of caffeine to be separated from long-term effects.

KEYWORDS: Caffeine, age, memory, attention, habitual caffeine consumption, subjective memory questionnaire [SMQ], everyday memory questionnaire [EMQ], everyday attention

questionnaire [EAQ].

1. INTRODUCTION

The present article describes a study which is part of a research programme on the real-life impact of caffeine on cognition. The research considers the effects of habitual caffeine consumption across different age groups. Smith[1,2] carried out secondary analyses on data from the Bristol Stress and Health at Work survey[3] and the Cardiff Health Survey.[4] Higher consumption of caffeine was associated with fewer cognitive problems and a reduced number of accidents and injuries. A systematic review and meta-analysis[5] covered nine cohorts and two case-control studies investigating associations between caffeine consumption and cognitive impairment in the elderly. The analysis showed that caffeine had a protective effect. Kromhout et al.[6] examined associations between behavioural problems in the elderly in care homes and their caffeine consumption. The analyses showed that increased caffeine consumption was associated with a reduction in behavioural problems.

Smith[7] conducted secondary analyses of epidemiological data with a sample of 3659 volunteers (average age of 70 years; range = 61-98 years). Information about regular caffeine consumption was collected, and associations with cognitive failures were examined. Higher caffeine consumption was associated with a reduction in cognitive failures. The present study examined self-reported memory problems with a specific focus on semantic memory and executive function. It has been found that acute ingestion of caffeine reliably produces statistically significant increases in performance on indices of semantic memory and executive function (see[8; 9; 10; 11; 12; 13; 14] for reviews).   Both semantic memory and executive function are highly relevant to real-life memory usage, semantic memory in terms of access to frequently used information[15] and executive function in terms of attention and problem solving[16] and language comprehension.[17] It is therefore considered possible that the effects of caffeine on these facets of memory could potentially influence real-life memory performance in the general population.

Jarvis[18] found that, for a large sample of the general public (n = 7414), there was a significant association between increasing daily caffeine intake and improved performance on a memory task with incidental encoding. This effect was still highly significant after controlling for the demographic variables of age, sex, class, education, housing tenure, self-rated health, alcohol, tobacco and tranquilliser use. The study also found statistically significant associations between reaction time and visuospatial reasoning, and interestingly it

was found that the association between cognitive performance and increased caffeine intake was more prominent in older adults than in younger adults. It is noted that Jarvis[18] unfortunately did not control for the short-term effects of caffeine because no abstinence from caffeine was requested prior to cognitive testing, and it is, therefore, possible that the effects of so-called habitual consumption may have reflected acute caffeine effects.

Other results have suggested that acute caffeine consumption reliably affects certain aspects of memory and that learning executive function tasks could be enhanced by habitual consumption. Therefore unlike Jarvis' study[18], which presumed daily caffeine consumption would produce only long-term effects, it appears likely that regular caffeine consumption will produce both acute and long-term cognitive effects. As a preliminary investigation, however, the present study did not attempt to distinguish between these effects but aimed to look at the global effects of level of regular caffeine consumption and then to separate short-term and long-term effects with more detailed studies if effects were found. One approach would be to use a battery of objective memory tests. Such tests tend to address very specific theoretical sub-components of memory and suffer from the lack of ecological validity described and criticised by Neisser.[19] On a more practical level, a battery of objective memory tests analogous to real-life memory function would also have been likely to be relatively time-consuming. This approach might have led to recruitment and logistical problems in a study dealing exclusively with the public outside the laboratory.

Fortunately, the problems associated with using objective memory tasks can be overcome using standardised subjective memory questionnaires that directly measure everyday memory performance and, importantly, do not require any experimental procedures. Commonly used subjective memory questionnaires are the Subjective Memory Questionnaire (SMQ)[20] and the Everyday Memory Questionnaire (EMQ)[21], which were initially developed to distinguish the degree of everyday memory impairment in head-injured patients but which have since proved sensitive enough to detect age-related memory impairment and memory impairment as a result of neurological disorders.

The SMQ lists 35 items related to everyday memory for which participants evaluate their memory on a 5-point rating scale ranging from' very poor' to 'very good' and seven statements which participants are asked to rate for frequency of occurrence on a five-point scale from 'very rarely' to 'very often'. Items considered conceptually related to semantic memory, or executive function were identified, and scores for each type of memory were then calculated

and analysed separately. Self-rating and ratings by close relatives have been found to correlate significantly with the Rivermead Behaviour Memory Test (RBMT).[22] The SMQ contains ten items directly related to semantic memory (e.g. items involving names of public figures, the meaning of traffic signs and the spelling of words). The questionnaire also appears sufficiently sensitive to detect subtle differences in memory performance, such as age-related differences in memory[20] and differences due to social class.[21] The questionnaire is also able to detect memory deficits in head-injured patients in the same way as objective tests[22] and to detect memory impairment in patients who have undergone temporal lobectomy - including differences in recovery of memory function in those who have undergone right- or left-sided lobectomies.[23] The questionnaire also contains seven items directly relevant to executive function (i.e., short-term retention and manipulation of information or verbal fluency).

The EMQ is shorter than the SMQ and consists of 28 items for which respondents must report how frequently a certain memory lapse occurs. The scale ranges from 'not at all in the last three months' to 'more than once daily'. The questionnaire was developed for use with head-injured patients as an alternative to assessing memory deficits and was based on clinical interview questions. For severely head-injured patients, the questionnaire is more sensitive when completed by relatives than when completed by the patients themselves, possibly due to the more complex structure of the questions or possibly because severely brain-injured patients were unable to recall their memory failures. The EMQ has also been found to correlate strongly with the RBMT with, as expected for a head-injured sample, relatives' ratings showing a higher correlation than patients' self-rating.[24] The EMQ contains four items that could be directly relevant to semantic memory (e.g. concerning the retrieval of general knowledge information) and five items relevant to executive function (i.e. items relating to short-term retention and manipulation of information or comprehension of language). As for the SMQ, items related to semantic memory or executive function were identified, and a score for each type of memory was calculated, which were then subject to separate sub-analyses.

An experimental study by Hogervorst et al.[25] reported different effects of caffeine in different age groups, with 225mg of caffeine improving performance on a verbal memory task with auditory distraction memory scanning task in middle-aged (46-54 years) but not in younger or older participants. Rogers and Dernoncourt[26] were unable to detect any interactions between caffeine and age using a free recall task but were also unable to find any

main effects of caffeine, and this task may be insufficiently sensitive to detect any caffeine effects. The limited data suggest that, although it is unclear whether middle-aged or elderly participants derive more benefit from the caffeine in terms of memory performance, younger people appear to be least affected. The age range of the sample in the present study was sufficient to allow the investigation of this variable, forming a further aim of the study.

In summary, the study had three main objectives. The first objective was to use two validated everyday memory questionnaires to investigate whether the caffeine effects identified in laboratory studies will generally influence real-life memory performance. The study's second objective was to investigate whether caffeine had any specific effects on the real-life use of semantic memory and logical reasoning. The third objective of the study was, if these effects were detectable, to investigate if there was any interaction with age and specifically whether caffeine was more beneficial to older consumers than to younger consumers. A measure of subjective attention was used as a control task as there is considerable evidence that caffeine improves performance on attention tasks.[8;9;10;11;12;13;14]

The following hypotheses were tested:

1. After controlling for demographic, socio-economic and personality variables, higher levels of regular daily caffeine intake will be associated with improved real-life memory performance (especially for tasks involving a high proportion of semantic memory or executive function usage).
2. The association between everyday memory performance and level of caffeine intake will be weaker in younger people than in middle-aged or older people.

2. MATERIALS AND METHODS

The present study was carried out with the approval of the ethics committee, School of Psychology, Cardiff University, and with the informed consent of the participants.

2.1 Participants

The participants were 100 male and female members of the general public recruited from the Centre for Occupational and Health Psychology's participant panel at Cardiff University. Participants were paid £5.00 in return for a completed questionnaire booklet. Members of the database were Cardiff University Cardiff employees recruited by letter and members of the general public in Cardiff who responded to a newspaper advertisement.

2.2 Procedure

Participants were sent a questionnaire booklet, a covering letter and a postage-paid return envelope. Potential volunteers were advised in the covering letter that participation in the study was voluntary but that if they wished to participate, they would have to complete and return the questionnaire booklet and receive a cheque for £5.00 on return of a completed booklet.

2.3 Measures

2.3.1 Demographic details and personality measures

When participants were initially recruited for the panel, they were asked to complete a recruitment questionnaire that recorded demographic details, health-related behaviours, eating and sleeping habits and a profile of personality traits. Personality traits measured included the four dimensions of the Eysenck Personality Inventory[27] and the Spielberger State-Trait Anxiety Inventory.[28] Education was measured on a scale from 0 (no formal schooling) to 8 (PhD or MD or equivalent).

2.3.2 Subjective cognitive performance

The questionnaire booklet contained three questionnaires measuring subjective cognitive performance: the SMQ, the EMQ and the Everyday Attention Questionnaire (EAQ).[29]

SMQ

The SMQ is a subjective measure of everyday memory function consisting of 43 items rated on a 5-point scale ranging from 1 (' very poor') to 5 (' very good'). The maximum score is 215, and the minimum score is 43, where a higher score denotes better memory performance.

EMQ

The EMQ is a measure of self-reported everyday memory function consisting of 28 statements which participants are required to rate for frequency of occurrence from 0 (Not at all in the last three months) to 9 (more than once a day). The possible range of scores is 0-224, where a lower score denotes better memory performance.

EAQ

The EAQ is a four-part questionnaire designed to index everyday attentional performance. The first two parts consist of 6 tasks that participants are asked to rate in terms of distraction when performed in conjunction with an easy or difficult task on a five-point scale from' very

distracting' to' very helpful'. The third and fourth parts of the questionnaire are concerned with carrying out a pair of tasks concurrently and consist of 6 descriptions of pairs of tasks which participants are asked to rate in terms of how well they can do them from' very poor' to' very good'. The minimum score on the EAQ is 18, and the maximum score is 90, with a higher score reflecting better performance.

2.3.3 Beliefs about caffeine

The questionnaire booklet also contained a questionnaire comprising three bipolar scales measuring participants' beliefs about the effects that caffeine had on their own reaction time, concentration and memory.

2.4 Analysis

The analysis of the data was carried out in five stages:

1. Description of the demographic and personality characteristics of the sample
2. Description of the caffeine consumption habits of the sample
3. Investigation of the associations between daily caffeine intake, subjective measures of cognitive performance, beliefs about the cognitive effects of caffeine, demographic factors and personality characteristics.
4. Investigation of subjective semantic memory and executive function performance measures derived from the SMQ and EMQ and the associations with daily caffeine intake.
5. Investigation of the associations between daily caffeine intake and subjective measures of cognitive performance in different age groups

3. RESULTS

3.1 Demographics and personality characteristics of the sample

One hundred and twenty questionnaires were sent to the Centre for Occupational and Health Psychology's participant panel members. Of the 120 questionnaires sent out by post, 108 were returned, a return rate of 90%. Of the questionnaires returned, eight were discarded because they were incompletely filled out.

The demographic and personality details of the remaining 100 participants, 68 females and 32 males, are shown in table 1.

3.2 Caffeine consumption habits of the sample

The pattern of regular caffeine use revealed a wide distribution of daily caffeine consumption, which ranged from 0 mg/24h to 1300 mg/24h. The mean caffeine intake of the sample was 239.20 mg/24h. The consumption profile is shown in Table 2.

The mean daily caffeine consumption of the sample was equivalent to approximately 4 cups of instant coffee or up to 9 cups of tea per day, higher than the UK average of 202 mg per day suggested by Fredholm et al.[30], but lower than the average UK daily caffeine intake of 359 mg suggested by Scott et al.[31] Most participants consumed less than 600 mg/24h, mainly in tea and coffee; two were noted to consume more than 1200 mg/24h and these two participants consumed over 100% more caffeine than the next highest consumer and had a daily caffeine consumption approaching 5 SDs greater than the mean they were considered to be outliers and excluded from the remainder of the analyses.

Table 1: Participant demographics and personality characteristics (n = 100)

Variable	Mean	Minimum	Maximum	SE.
Age (years)	37.60	19	76	1.17
Impulsivity-EPI (0-low to 9-high)	4.39	0	9	0.20
Sociability-EPI (0-low to 12-high)	6.40	0	12	0.31
Extroversion-EPI (0-low to 23-high)	11.41	3	21	0.42
Neuroticism-EPI (0-low to 24-high)	10.59	1	21	0.48
Trait Anxiety-TAQ (25-low to 100-high)	38.95	21	59	0.85

Table 2: Self-administered, daily caffeine consumption, mg/24h (n = 100)

	Total caffeine	Caffeine consumed in tea	Caffeine consumed in coffee	Caffeine consumed in soft drinks
Mean	239.20	123.20	104.00	12.00
SE.	20.26	17.53	12.93	4.00
Median	212.50	80.00	0.00	0.00
Range	1300.00	1200.00	390.00	300.00
Minimum	0.00	0.00	0.00	0.00
Maximum	1300.00	1200.00	390.00	300.00
Interquartile range	208.75	160.00	195.00	0.00

3.3 The association between daily caffeine intake, subjective measures of cognitive performance, beliefs about the cognitive effects of caffeine and personality characteristics

Pearson's product-moment correlation coefficients (r) were calculated to determine any associations between daily caffeine intake, subjective measures of cognitive performance and

personality characteristics. For the correlations between daily caffeine intake and personality variables (table 3), there was only one significant effect, a weak association between daily caffeine intake and trait anxiety ($r = 0.228$, $df = 96$, $p < 0.05$) with higher caffeine intake being associated with higher levels of trait anxiety. In terms of the association between daily caffeine intake and subjective measures of cognitive performance, it was found that the only statistically significant association was with the EAQ ($r = 0.210$, $df = 96$, $p < 0.05$), where participants with a higher daily caffeine intake reported higher subjective performance on measures of attention (table 3).

TABLE 3: The associations between daily caffeine intake (mg/24h) and demographic characteristics, personality factors, subjective measures of cognitive performance and beliefs about the cognitive effects of caffeine (Pearson's r, df = 96, two-tailed significance values).

Age	0.062	TAQ	0.228*
Education	-0.006	CPQ1	0.194
Alcohol (units per week)	0.173	CPQ2	0.077
EPI-I	-0.071	CPQ3	0.124
EPI-S	-0.027	EAQ	0.210*
EPI-E	-0.083	SMQ	0.091
EPI-N	0.040	EMQ	0.009

*$p < 0.05$

(**AGE**, age in years; **Education**, education completed; **EPI-I**, impulsivity; **EPI-S**, sociability; **EPI-E**, extroversion; **EPI-N**, neuroticism; **TAQ**, trait anxiety; **CPQ1**, beliefs about caffeine effects on concentration; **CPQ2**, beliefs about caffeine effects on reaction time; **CPQ3**, beliefs about caffeine effects on memory; **EAQ**, Everyday Attention Questionnaire; **SMQ,** Subjective Memory Questionnaire; **EMQ,** Everyday Memory Questionnaire).

Beliefs about the cognitive effects of caffeine on concentration were found to be strongly associated with beliefs about the effect of caffeine on reaction time ($r = 0.749$, $df = 96$, $p < 0.0001$) and memory ($r = 0.616$, $df = 96$, $p < 0.0001$), reinforcing the view that beliefs about the cognitive effects of caffeine can be reduced to a single factor. It is noted that there was also a highly significant negative correlation between SMQ and EMQ score ($r = -0.443$, $df = 98$, $p < 0.0001$). As scoring for the EMQ is reversed, with a lower score indicating better memory performance, the result provides evidence of concurrent validity for the two scales.

The analysis also revealed that demographic and personality factors had statistically significant associations with performance on the subjective measures of memory performance (table 4).

Table 4: The statistically significant associations between measures of subjective memory performance and demographic and personality characteristics (Pearson's r, df = 96, two-tailed significance values).

	SMQ	EMQ
Age	-0.060	**-0.305****
EPI-S	**0.231***	-0.011
TAQ	**- 0.242***	**0.295****
EPI-N	**- 0.251***	**0.257***

*p < 0.05 **p <0.005

(**Age**, age in years; **EPI-S**, sociability; **EPI-N**, neuroticism; **TAQ**, trait anxiety;

SMQ, Subjective Memory Questionnaire; **EMQ** Everyday Memory Questionnaire)

Age was found to be negatively correlated with the EMQ score (r = -0.305, df = 96, p < 0.005), indicating that, for the EMQ only, increasing age is associated with better performance on subjective memory performance. Sociability was positively correlated with the SMQ score, indicating that high sociability is associated with better subjective memory performance as measured by the SMQ (r = 0.231, df = 96, p < 0.05.

The personality variables most consistently associated with measures of subjective memory performance were neuroticism and trait anxiety. Neuroticism (EPI-N) was found to be negatively associated with the SMQ score (r = -0.251, df = 96, p < 0.05) and positively correlated with the EMQ score (r = 0.257, df = 96, p < 0.05) but as the EMQ has a reversed scale this would indicate in both cases that high neuroticism is associated with poorer measures of subjective memory performance. A similar pattern of correlation was found for trait anxiety with a statistically significant negative association between SMQ and TAQ (r = -0.242, df = 96, p < 0.05) and a positive association with the EMQ (r = 0.295, df = 96, p < 0.005) indicating that participants with higher trait anxiety display poorer subjective memory performance.

Given the consistent association between high neuroticism and trait anxiety and poorer per-performance on subjective measures of memory performance, a further correlation matrix was computed for caffeine intake and subjective measures of cognitive performance

controlling for these factors (table 5). It was found that when neuroticism and trait anxiety were controlled, the pattern of statistically significant correlations did not differ from the initial analysis. The only significant correlation between daily caffeine consumption and subjective cognitive performance involved subjective attention (as measured by the EAQ), and the correlation was marginally higher with neuroticism and trait anxiety controlled (0.258).

Table 5: The association between daily caffeine intake and subjective measures of cognitive performance, controlling for neuroticism and trait anxiety (Pearson's r, df = 94, two-tailed significance values).

	Caffeine (mg/24h)	EAQ	SMQ
EAQ	**0.258***		
SMQ	0.137	**0.335***	
EMQ	-0.051	-0.040	**-0.395*****

*p < 0.05 **p < 0.0001

(EAQ, Everyday Attention Questionnaire; SMQ, Subjective Memory Questionnaire; EMQ Everyday Memory Questionnaire).

3.4 The association between daily caffeine intake and subjective measures of semantic memory and executive function

Previous research found that semantic memory and executive function were the most reliable caffeine effects on memory. Real-life memory relies heavily on these two types of memory, and it was considered possible that purer measures of semantic memory and executive function might be associated with the level of daily caffeine intake even if total SMQ and EMQ scores did not. To provide more specific measures of semantic memory and executive function, items directly relevant to these two types of memory were identified in the SMQ and EMQ. The semantic memory and executive function performance score were calculated for each questionnaire.

The semantic memory performance score for the SMQ was calculated from the sum of 10 items, with the minimum score of 10 indicating poor memory performance and the maximum score of 50 denoting good memory performance. Seven items from the SMQ were directly relevant to executive function performance, with the minimum score of 7 indicating poor performance and the maximum score of 35 indicating good performance. For the EMQ, the semantic memory score was calculated to form 4 items giving possible scores from 4 (good

memory performance) to 36 (poor performance). The executive function score for the EMQ was calculated from 5 items, giving a score of 5 and a worst possible score of 45.

It was found that after controlling for neuroticism and trait anxiety, there were no statistically significant correlations between daily caffeine intake and measures of semantic memory and executive function performance (table 6). It was also found that all the semantic memory and executive function measures were highly intercorrelated. This, unfortunately, suggests that the items that appeared to be conceptually relevant to real-life usage of semantic memory and executive function may have been measuring a common factor as objective measures of these types of memory have previously been found to be unrelated.

Table 6: The association between daily caffeine intake (mg/24h) and subjective measures of semantic memory and executive function performance, controlling for neuroticism and trait anxiety (Pearson's r, df = 94, two-tailed significance values).

	Caffeine (mg/24h)	SMQ-S	SMQ-EF	EMQ-S
SMQ-S	0.119	-	-	-
SMQ-EF	0.200	**0.343****	-	-
EMQ-S	-0.057	**-0.214***	**-0.319****	-
EMQ-EF	-0.064	**-0.242***	**-0.454*****	**0.611****

*p < 0.05 **p < 0.005 ***p < 0.0005

(SMQ-S, Subjective Memory Questionnaire, semantic memory score; SMQ-EF, Subjective Memory Questionnaire, executive function score; EMQ-S Everyday Memory Questionnaire, semantic memory score; EMQ-EF, Subjective Memory Questionnaire, executive function score).

3.5 The association between daily caffeine intake and subjective measures of cognitive performance in different age groups

Jarvis[18] reported that the association between high daily caffeine intake and superior memory performance was especially marked in older participants and those participants aged over 55 years. In order to test whether caffeine would have more effect on memory in older participants in the present study, the data were re-analysed using three sub-samples with similar age ranges to those used by Jarvis.[18] The first group comprised participants aged less than 35 years, the second of those aged between 35 and 49 inclusive and the third comprised participants aged 55 years and over. Demographic details and personality characteristics for the sub-samples are shown in table 7.

Table 7: Participant demographics and personality characteristics for groups of different ages (means, SE in parentheses).

	Group 1 (18-34 years) n = 46	Group 2 (35-49 years) n = 37	Group 3 (55 years +) n = 15
Age (years)	27.48 (0.66)	41.70 (0.67)	57.734 (1.74)
Caffeine (mg/24h)	193.80 (19.66)	252.97(22.67)	209.647 (44.39)
Impulsivity-EPI (0 low - 9 high)	4.57 (0.30)	4.03 (0.29)	4.604 (0.65)
Sociability-EPI (0 low - 12 high)	6.91 (0.47)	5.84 (0.47)	7.08 (0.80)
Extroversion-EPI (0 low - 23 high)	11.81 (0.66)	10.65 (0.60)	12.54 (1.27)
Neuroticism-EPI (0 low - 24 high)	10.63 (0.68)	10.03 (0.81)	11.00 (1.39)
Trait Anxiety-TAQ (25 low - 100 high)	40.10 (1.20)	37.43 (1.44)	38.20 (2.18)

When correlations (again controlling for neuroticism and trait anxiety) were computed between daily caffeine intake and total EAQ, SMQ and EMQ scores, it was found that the only statistically significant associations between caffeine intake and measures of cognitive performance were in the older age group (table 8). In this group a high daily caffeine intake was positively associated with higher performance on measures of subjective attention ($r = 0.745$, $df = 13$, $p < 0.005$) and on one measure of subjective memory, the SMQ ($r = 0.800$, $df = 13$, $p < 0.01$). No statistically significant association was recorded between caffeine intake and EMQ, but this measure of subjective memory performance was found previously to be most sensitive when completed by the participant's relatives.[24]

Table 8: The association between daily caffeine intake (mg/24h) and subjective measures of cognitive performance in groups of different ages (Pearson's r, two-tailed significance values).

The measure of subjective cognitive performance	Group 1 (18-34 years) df = 44	Group 2 (35-54 years) df = 35	Group 3 (55 years +) df = 13
EAQ	0.166	0.048	**0.745***
SMQ	0.476	-0.100	**0.800***
EMQ	0.179	-0.170	-0.244

*p < 0.005

(EAQ, Everyday Attention Questionnaire; SMQ, Subjective Memory Questionnaire; EMQ Everyday Memory Questionnaire).

4. DISCUSSION

Previous research has suggested that caffeine ingestion produces reliable short-term improvements in semantic memory and executive function and possibly improves the speed at which relatively complex executive function tasks are learnt. Given the relevance of semantic memory and executive function to everyday use of memory[15; 16; 17], the present study attempted to investigate whether the level of regular caffeine consumption might affect measures of real-life memory performance in the general population.

It was found that the sample ranged in age from 19-76 years and displayed widely varying daily caffeine consumption habits (from 0 mg/24h to 1300 mg/24h), with the majority of participants consuming less than 600 mg of caffeine daily. No association was found between the level of caffeine consumption and the strength of any beliefs about the effects of caffeine on concentration, reaction time or memory, indicating that beliefs about the cognitive effects of caffeine are not associated with an individual's level of caffeine consumption.

Regarding the association between daily caffeine intake and subjective cognitive performance, there were no statistically significant correlations between daily caffeine intake (mg/24h) and either measure of memory performance (the SMQ or EMQ). There was, however, a weak but statistically significant correlation between daily caffeine consumption (mg/24h) and the measure of subjective attention (the EAQ), with, as might be expected, high caffeine consumption being associated with better performance ($r = 0.210$, df $= 96$, $p < 0.05$). This pattern of results appears to mirror the finding of many experimental caffeine studies, which have also found that caffeine is reliably associated with effects on attention but not with effects on memory. Performance on the measures of subjective memory was also found to be associated with trait anxiety and neuroticism (which was found to be highly correlated with trait anxiety). This result is consistent with previous research[32], suggesting that other subjective measures of cognitive performance, such as the Cognitive Failures Questionnaire[33], correlate with trait anxiety. When trait anxiety and neuroticism were partialled out of the correlation, the association profile between subjective cognitive performance measures and daily caffeine consumption was found to be unchanged.

Both the SMQ and EMQ included certain items that were considered to be directly related to semantic memory, and executive function and scores were calculated for these items for both questionnaires to provide purer measures of real-life semantic memory and executive function performance. It was found that the scores were highly intercorrelated, suggesting

that the items which appeared to be conceptually related to semantic memory and executive function may have been measuring a common factor. It is suggested that a more detailed investigation of the association between caffeine intake and real-life semantic memory and executive function in public would require constructing questionnaires designed to precisely measure these specific types of memory or using objective performance tests.

Despite the experimental finding that caffeine improves semantic memory and executive function under experimental conditions, the data appears to provide little evidence that these have any practical implications for everyday memory performance in the general population. It is not suggested that this result contradicts the experimental findings but suggests that, even though everyday memory relies heavily on semantic memory and executive function, caffeine appears to have negligible effects on real-life memory performance. It is acknowledged that the study used subjective reports rather than objective methods, but it is also pointed out that the measure of subjective attention, used as a positive control, did show a significant association with caffeine intake.

Jarvis[18] and Hogervorst et al.[26] have reported that the effects of caffeine on memory performance were more significant in middle-aged or older participants than in younger participants, and the data generated by the present study was analysed further to investigate if the effects of caffeine on everyday memory performance would vary according to age. The analysis of the EAQ and total SMQ and EMQ scores revealed that in younger and middle-aged people, there were no significant associations between daily caffeine consumption and subjective cognitive performance, but in the group aged 55 years and older high daily caffeine consumption was associated with better everyday attention and memory performance (as measured by the EAQ and SMQ). These results would appear to partially support those Jarvis[18] obtained, who also reported a more significant association between caffeine intake and memory performance in older participants than in younger ones.

It is suggested that the effect of caffeine on memory performance in different age groups may warrant further investigation, possibly using an intervention study with objective memory tests. The use of objective memory tests would also enable a distinction between short- and long-term effects to be investigated more thoroughly. There is substantial evidence that caffeine may improve the learning of executive function tasks but no evidence that regular, long-term caffeine intake affects memory performance per se. The samples used in many studies have been student participants who may have been regular consumers of caffeine for

only a few years.   In the present study, the participants who appeared to show an association between caffeine intake and memory were over 55 years old such that they may have been consuming caffeine for tens of years and what is being taken as acute effects related to daily consumption are the results of changes in performance occurring as a result of decades of caffeine consumption. Objective testing using a traditional caffeine challenge paradigm and participants of different ages and differing levels of habitual consumption would enable the distinction between acute effects specific to people over 55 years of age and effects due to chronic consumption to be investigated more thoroughly. Generally, the results also suggested that the SMQ appears more sensitive in terms of caffeine effects than the EMQ, as no statistically significant associations were found between caffeine intake and any dimension of the EMQ. This result may not be surprising as Schwartz and McMillan[24] have also reported that the EMQ is less sensitive than the SQM and may be most useful when given to participants' relatives rather than the participants themselves.

5. CONCLUSIONS

In summary, although laboratory studies have generally produced reliable experimental evidence of improved semantic memory and executive function performance after ingestion of caffeine, there is little evidence that the level of daily caffeine consumption is associated with everyday memory performance. The only exception to this finding was in a sub-group of participants aged 55 years and over, where a higher regular caffeine intake was associated with better memory performance as measured by the SMQ. The present study has been a preliminary investigation into the effects of caffeine on real-life memory performance, which might have been expected to follow from reliable effects on semantic memory and executive function. It is suggested that the effects of caffeine on memory in older participants may warrant further investigation, possibly using objective memory tests that would also enable acute, specific to certain age groups to be separated from long-term effects

Author Contributions

Both authors were involved in the study's design and the final manuscript's preparation. D-N-V-T collected the data and performed the analyses.

Competing Interests

The authors have declared that no competing interests exist.

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