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Coffee, caffeine and mental performance

Contents

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Coffee, caffeine and mental performance

1. Summary

- It is well recognised that drinking coffee contributes to increased wakefulness and alertness. Most of the work on coffee consumption and mental performance focuses on caffeine.
- There is convincing evidence that moderate caffeine intake helps to improve alertness and concentration.
  - A 75mg serving of caffeine leads to both increased attention and alertness, according to the European Food Safety Authority (EFSA). A typical cup of coffee contains 75–100mg caffeine.
- There is some evidence to suggest potential benefits of coffee and caffeine in situations that require increased alertness e.g. night shifts, long-distance driving, and jet lag.
- Some studies suggest that caffeine abstinence could improve sleep — in context of sleep quality and the time it takes to fall asleep. However, there are large differences between individuals and more research in this area is needed.
- Brain mapping technology indicates that caffeine is not linked to the brain circuit of dependence and therefore does not fulfil the criteria to be described as a drug of dependence.
- Although abrupt cessation of caffeine consumption may induce withdrawal symptoms in a small number of individuals, these are generally not very severe, are of short duration, and can be avoided by gradually reducing caffeine intake.

2. Food and mental performance

It has long been appreciated that certain foods, and the nutrients they contain, can have subtle effects on mood and mental performance. The timing of meals, the type of food eaten and substances contained in those foods have all been, and continue to be, studied in the hope that we can help to improve memory, alertness, mood and counteract drowsiness.

Caffeine is well known for its stimulating effects, which have proven benefits for mental performance. Recently, the European Food Safety Authority (EFSA) evaluated a substantial number of studies on the effects of caffeine and mental performance. It concluded that there is sufficient evidence to support a cause and effect relationship for the effect of caffeine on alertness and attention (concentration)[1].

A 2016 review concluded that caffeine has many positive actions on the brain: it can increase alertness and well-being, help concentration, improve mood, and limit depression. Caffeine may disturb sleep, but only in sensitive individuals, and may raise anxiety in a small subset of particularly sensitive people. Caffeine does not seem to lead to dependence, although a minority of people experience withdrawal symptoms[2].

3. Caffeine and mental alertness — part 1

Caffeine improves visual attention

Numerous studies have investigated the effects of caffeine ingestion on visual attention. EFSA concluded that 75mg of caffeine increases both selective attention (focussing on the relevant stimulus) and sustained attention (maintaining focused attention over an extended period of time)1. This conclusion is further supported by a 2012 review, which suggests that caffeine improves performance in both simple and complex attention tasks, suggesting that the beneficial effects of caffeine consumption are even

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more widespread than previously assumed[3]. Higher caffeine intakes, such as those found in more than 1 or 2 cups of coffee, do not necessarily result in additional increases in alertness[4,5]. A reduction in performance can occur with both under- and over-stimulation[6].

A series of experiments found differences in caffeine's effects on visual attention between non-habitual and habitual caffeine consumers. In non-habitual caffeine consumers, a low dose of only 200mg gave the best results for improvements in visual attention[7]. In habitual caffeine consumers, the dose required to enhance vigilance and visual attention was higher (400mg caffeine)[8]. Similarly, low caffeine consumers were able to detect more errors with 200mg of caffeine, while high caffeine consumers' performance peaked with 400mg[9].

The expectation of having consumed caffeine can also improve attention and psychomotor speed[10]. Although the mechanisms underlying these effects are unclear, these findings are in line with earlier studies, reporting that caffeine and expectation of caffeine activate the same brain areas[11]

Caffeine improves reaction time

The positive effects of caffeine on reaction time have been studied extensively in recent decades[1,12]. However, caffeine appears to have no effect on 'time perception'* or 'time production'**.

* *The sense of time passing in an individual.*
** *The time it takes to produce something following a stimulus.*

Caffeine improves alertness and safety during sleep deprivation

The effects of caffeine on alertness are most marked in situations where an individual's alertness level is reduced, such as when he/she may be suffering from the common cold[13], the post-lunch dip[14], or during night work[15].

During night work, caffeine has been shown to reduce cognitive failures and accidents by about half in subjects consuming over 200mg caffeine daily[15]. Caffeine also reduces cognitive failures in the non-working population[16].

Caffeine is often consumed just after waking up to increase alertness and fight sleep inertia (reduced motor dexterity and a subjective feeling of grogginess immediately following an abrupt awakening) which may interfere with the ability to perform mental or physical tasks[17].

Finally, the efficacy of drinking coffee versus napping to aid night-time highway driving has been compared. Both drinking a strong coffee (125ml containing 200mg caffeine) and/or taking a short nap (15–30 minutes) are very effective at reducing driving impairment and this improvement is greater when the two are combined[18,19]. Research suggested that subjective driving quality, during a simulated two hour monotonous highway driving test, was significantly improved in the first hour after consuming a single cup of caffeinated coffee containing around 80mg caffeine[20]. Additionally, a 2015 study found that drinking caffeinated coffee (providing 150mg caffeine) can reduce levels of drowsiness in drivers by 25%[21]. Furthermore, a case-control study showed caffeinated beverages, such as coffee, to be associated with a reduced risk of crashing for long-distance commercial motor vehicle drivers[22].

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4. Caffeine and mental alertness — part 2

Caffeine may improve memory

Some studies have shown that caffeine intake can improve working memory. Low doses of caffeine enhance working memory performance, while higher doses were found to decrease it, possibly due to over-stimulation.

In particular, caffeine improves performance in both low-difficulty and low-load memory tasks. In contrast, because high-load and complicated tasks increase arousal, caffeine intake is likely to lead to over-arousal, which suggests that caffeine is particularly effective at improving memory under conditions that might otherwise produce low arousal states, i.e. when performing tedious, repetitive or dull tasks[23].

Caffeine's effects on memory may be linked to personality type[24]. The memory of extroverts has been shown to improve with caffeine consumption, whereas there appears to be no difference in working memory with caffeine consumption in introverts.

Caffeine also appears capable of intensifying the connections between words, thereby improving accurate recall of words in tests[25]. Further research is necessary in this area.

Effect of caffeine heightened with simultaneous glucose intake

When caffeine and glucose are consumed together, they have synergistic beneficial effects on sustained attention and verbal memory[26]. The combined administration of caffeine and glucose may increase the efficiency of the attention system in the brain[27,28]. Further studies are needed to better understand the combined effects of these two substances.

Caffeine may improve mood and reduce the risk of depression

Low to moderate doses of caffeine (up to 5 cups of coffee per day) have been shown to improve ratings of happiness and reduce levels of anxiety. High doses, however, can increase anxiety, nervousness and jitteriness. In addition, the extent to which caffeine improves mood may depend on baseline arousal[23].

A number of factors are believed to impact the mood enhancing effects of caffeine. Age is one, with research suggesting older adults are more sensitive to the mood-enhancing effects of caffeine; these effects also depend on the time of day, with the most significant effects seen in the late morning[29]. Mood is also affected by the expectation of caffeine consumption, with research suggesting that when subjects believe they have consumed caffeine, both their mood and attention improve[10]. Caffeine also appears to be more effective at improving mood in subjects who do not usually consume caffeine[30].

Caffeine has also been associated with a reduced risk of depression. The benefits of caffeine have been demonstrated in a study into the role of caffeine on social support measures. It found that participants who consumed caffeinated coffee sent significantly more 'sadness' messages and required more support during a fictitious game than those drinking decaffeinated coffee. This suggests that caffeinated coffee may help to improve social support and relieve depressive symptoms[31].

A US study suggested that women who consumed at least 2–3 cups of caffeinated coffee per day were up to 20% less likely to develop depression, compared to those who drank at most one cup of caffeinated coffee per week. The consumption of decaffeinated coffee had no impact on depression risk[32]. Further work in Finnish men reported a significantly lower risk of depression in heavy coffee drinkers (over 813mg caffeine daily). This effect was limited to coffee and was not found either with tea or caffeine alone[33]. Research in Japan and Korea also suggests that drinking coffee may offer protection against depression[34,35]. Furthermore, a meta-analysis suggested that coffee consumption has a protective effect on depression, with a dose-response analysis suggesting a J-shaped curve, with the beneficial effect reported for up to approximately 300mg caffeine per day[36].

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5. Caffeine and dependence

Caffeine is not a drug of dependence

The issue of possible dependence on caffeine has been debated for many years. It is likely that maintenance of coffee consumption is caused by the recognition that it is a stimulant, and not because of any addictive qualities of caffeine[37]. People may also drink coffee from habit: the possible reinforcing effects of coffee may not be due to the caffeine per se, but to the pleasurable aroma and taste of coffee, as well as the social environment that usually accompanies coffee consumption[38].

Drugs such as cocaine, morphine and nicotine activate a dopamine-related brain circuit involved in dependence and reward even at low doses — they are 'addictive'. Studies of rats given caffeine in human doses have failed to find any increase in energy metabolism[39] or dopamine release[40,41] in this circuit.

Further research in humans has also failed to find any activation of the brain circuit of dependence with caffeine intake[42]. This 'brain mapping' approach to the study of dependence in humans shows that caffeine does not fulfil the criteria required to be described as a drug of dependence.

In 1994, the World Health Organization stated that: "there is no evidence whatsoever that caffeine use has even remotely comparable physical and social consequences which are associated with serious drugs of abuse".

Avoiding potential withdrawal symptoms

Another of the characteristics linked with drug dependence is withdrawal. In 2013, the American Psychiatric Association released an updated edition of its Diagnostic and Statistical Manual of Mental Disorders, which included 'caffeine withdrawal' for the first time[43]. They defined it as a 'syndrome' resulting from abrupt cessation or reduction in caffeine following prolonged daily use. Only a small number of coffee/caffeine consumers suffer withdrawal symptoms when they stop drinking coffee (such as headaches, reduced alertness, and drowsiness). These symptoms generally peak 20–48 hours after consumption and can be avoided if caffeine intake is gradually reduced[37].

Consumption of coffee after a period of abstinence has been found to have a greater effect on mood and choice reaction time*. This may be due to an increase in cerebral blood flow with caffeine abstinence reported in some studies[44,45]. However, in some areas related to attention and memory, abstinence from caffeine before the study period does not affect caffeine's positive effect during the experiment, i.e. there is no evidence of withdrawal[3,45].

* *The reaction time for a task in which an individual has to make one of two or more choices.*

6. Caffeine and sleep

Sleep in humans is affected by caffeine intake.

A 2016 systematic review of research on coffee, caffeine and sleep concluded that individuals will respond differently to caffeine based on a variety of factors, including age, sensitivity levels, regular coffee and caffeine intake, time of consumption and genetic variability[46].

There is an association between the daily intake of caffeine, sleep problems and daytime sleepiness[47], including difficulty falling asleep, shorter total sleep time, longer periods of light sleep and shorter periods of deep sleep, as well as more frequent awakenings — even at consumption levels equivalent to those in single cup of coffee. One study suggested that caffeine consumed up to six hours before bedtime can have disruptive effects on sleep[48], and a further paper suggested that drinking coffee disrupts sleep time in physically active males[49].

Sensitivity to the effects of caffeine is variable. For example, the effects of caffeine on sleep are smaller in subjects who usually consume caffeine than they are in occasional coffee drinkers50. In addition, genetic variations may also play a role51-53.

Age may affect sleep quality

Only a few studies have evaluated the age-related effects of caffeine on sleep.

Although the research in this area is quite limited, there is an indication that older adults may be more sensitive to the effects of caffeine. However, caffeine exposure may vary as a function of body weight, so although they may consume the same amount, the effect may be more marked in older adults as they typically weigh less than younger adults. Older adults may also self-limit the amount of caffeine they consume due to perceived sleep problems[46].

Research results are variable: in one study, caffeine produced similar effects in young adults (20–30 year-olds) and middle-aged subjects (45–60 year-olds)[54]. In another, middle-aged subjects appeared to be more sensitive to the effects of caffeine than younger subjects[55]. A further study concluded that caffeine increased sleep latency, shortened total sleep duration, and reduced sleep efficiency, and suggested that middle-aged adults are generally more sensitive to the effects of a high dose of caffeine on sleep quantity and quality[56]. Age and caffeine both decrease rapid-eye movement (REM)* sleep. Therefore the combined effects of age and caffeine may further fragment sleeping patterns.

**A stage in the normal sleep cycle during which dreams occur and the body undergoes marked changes, including rapid eye movement, loss of reflexes, and increased pulse rate and brain activity.*

Caffeine abstinence may improve sleep patterns in sensitive people

A review of caffeine abstinence and sleep quality concluded that abstaining from caffeine for a whole day could improve sleep quality[57]. Caffeine abstinence was shown to lengthen sleep duration, improve sleep quality, and make it less difficult to fall asleep.

Caffeine intake and young people

Although caffeine restores wakefulness and counteracts a decline in mental performance caused by lack of sleep, it may produce detrimental effects on subsequent sleep, resulting in daytime sleepiness. This may be a matter of concern, especially in young people[58]. Many teenagers stay awake late at night using multiple forms of technology, and use caffeinated beverages, primarily soft drinks or soda, to help them stay awake.

One study of young people found that sleep was directly related to multi-tasking, with those doing the greatest amount of multi-tasking having the least sleep[59]. Caffeine intake was also found to be 76% higher in those teenagers who fell asleep at school. Authors suggest that those teenagers are not fully functional throughout the day because of excessive daytime sleepiness, and not because of the effects of caffeine intake.

Similarly, another study found that adolescents who drank more caffeinated drinks expected a higher rate of energy enhancement from those drinks. They also got up earlier, reported more daytime sleepiness and drank more caffeine to get through the day[60].

A study in students during an exam period suggested that sleep quality and alcohol consumption significantly decreased, while perceived stress and caffeine consumption significantly increased. However, despite the fact that students shortened their time in bed and showed symptoms of insomnia, the authors concluded that the amounts of alcohol and caffeine consumed had no significant influence on overall sleep quality[61].

Caffeine, jet lag, and shift work

Caffeine may be effective at improving performance of people aged 40 or under, who work shifts, or suffer from jet lag[62]. Further research is required to identify any links in older individuals.

An intervention study suggested that a combination of napping and ingestion of caffeine was best for improving alertness. A decrease in subjective sleepiness was also observed in individuals working a night shift following caffeine consumption[63]. Further work suggests that caffeine increases alertness and clear-headedness after a period of wakefulness, but can also disturb subsequent daytime recovery sleep[64].

Advice for jet lag on short stopovers (1–2 days) is to combine sensible naps with moderate caffeine intake and short-term use of sleeping aids, to help maintain alertness and aid sleep[65].

7. Conclusion

The well-established beneficial effect of caffeinated coffee on mental performance has been confirmed by EFSA, which states that a cause and effect relationship has been established between a 75mg serving of caffeine (the amount in approximately one regular cup of coffee) and both increased attention and alertness, mainly in situations of low arousal or stimulation.

Research also points to positive effects of coffee and caffeine on mood and reaction time.

Brain mapping technology suggests that caffeine use does not lead to dependence, nor does its withdrawal lead to significant negative symptoms. Whilst some individuals may experience caffeine withdrawal, these symptoms are mild, short-lived and can be avoided altogether if caffeine intake is gradually reduced.

Daily caffeine intake does affect sleep patterns; however, these effects depend on the amount of caffeine consumed over the whole day and vary with individuals' genetic backgrounds. Those individuals who do experience sleep problems following consumption of caffeinated coffee may choose, or be advised, to switch to decaffeinated products in the afternoon/evening.

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