# EFFECTS OF DIETARY CAFFEINE ON COGNITIVE AND MEMORY IMPROVEMENTS IN HUMANS

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Caffeine is generally accepted to be a mild stimulant. It is affordable and easily available throughout the world and found in many products. Caffeine consumption seems effective tool to modulate individual vulnerability to the detrimental effects of sleep deprivation on cognitive performance, and sleep. Caffeine, a well-known antagonist of adenosinergic receptors, can be used effectively to modulate our mental state. Caffeine is found to be beneficial in restoring low levels of wakefulness and to counteract deteriorations in task performance related to sleep deprivation. The efficacy of caffeine to restore mental performance decline in suboptimal conditions seems to be partly due to caffeine expectancy. Caffeine expectancy effects are not limited to cognitive task performance but may be also present in physical task performance.

**Key words**: Caffeine; cognition; mental performance; restoring
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## Introduction

The aim of the present article is to review the effects of caffeine on human behaviour. Caffeine is probably the most frequently ingested pharmacologically active substance in the world. It is found in common beverages (coffee, tea, soft drinks), in products containing cocoa or chocolate, and in medications. Because of its wide consumption at different levels by most segments of the population, the public and the scientific community have expressed interest in the potential for caffeine to produce adverse effects on human health. The main areas of behaviour reviewed are mood, mental performance and sleep. Certain areas, although related to behaviour, such as the underlying CNS mechanisms, are not reviewed in detail. This is because most of the research in this area has involved animal studies.

Caffeine is easily available throughout the world and found in many products. After oral ingestion of caffeine, mostly in the form of coffee or tea, 99%of it is absorbed from the gastrointestinal tract into the bloodstream, peaking 30–60 min after ingestion. Faster absorption of caffeine is found for caffeine-containing chewing gum, with maximum levels reached between 45 and 80 min postadministration, while absorption rate for caffeine-containing capsules lies between 85 and 120 min (Kamimori et al., 2002). The efficacy of caffeine in restoring cognitive processes like emotional perception, judgment, risk-taking, and planning after sleep deprivation was targeted in a series of double-blind studies by Killgore et al. (2009).

**Caffeine**

Caffeine (1,3,7-trimethylxanthine) is a natural alkaloid found in coffee beans, tea leaves, cocoa beans, cola nuts and other plants. It is probably the most frequently ingested pharmacologically active substance in the world, found in common beverages (coffee, tea, soft drinks), products containing cocoa or chocolate, and medications, including headache or pain remedies and over-the-counter stimulants (Carrillo and Benitez 1996).

Smith (2002) noted that the studies reviewed varied substantially in the methodologies used, he drew six conclusions about the effects of caffeine based on his review of the research literature:

- Caffeine exerts a positive effect on alertness and fatigue reduction;
- Caffeine leads to improved performance on tasks that require sustained response and on vigilance tasks;
- The effects of caffeine on complex tasks are more difficult to assess, partially because these effects are likely a result of the interaction of caffeine and other variables, such as personality and time of day;
- Caffeine withdrawal has little or no effect on performance, but may have a negative impact on mood;
- The regular use of caffeine appears to be beneficial, as it leads to higher mental functioning;
- Most individuals are capable of regulating their caffeine intake so as to maximize its positive effects.

**Mechanisms of action in Caffeine**

There is a great deal of evidence to shows that caffeine blocks the effects of the naturally occurring neuromodulator adenosine (Snyder, 1984). This produces a net increase in CNS activity because the inhibitory action of adenosine is blocked. The effects of caffeine on adenosine activity, and the subsequent effects for neurotransmitters such as norepinephrine, occur at concentrations found as a function of dietary intake. Other mechanisms have been demonstrated (e.g. calcium mobilisation, prostaglandin antagonism, phosphodiesterase inhibition), but these only become relevant when caffeine is administered in doses that are at least 20–30 times higher than those found in the diet (Snyder, 1984). In humans peak plasma levels occur 15–45 min after ingestion and its plasma half-life is 5–6 h.

Different mammals use different pathways to metabolise caffeine, and many studies of animal behavior are, therefore, not relevant to its effects on humans. Sensory functions. Lieberman (1992) stated that ‘‘there is no evidence to suggest that moderate doses of caffeine have direct effects on sensory function, although well controlled studies using state-of-the-art methods have not been conducted’’.

## Cognition

Caffeine, personality and time of day research by Revelle and colleagues (Revelle *et al.*, 1987) showed that caffeine facilitated the performance of impulsive individuals and impaired the performance of non-impulsive individuals taking complex cognitive tests in the morning. In the evening, the opposite pattern of results was observed. This has been interpreted in terms of relationships between optimum levels of arousal and complex tasks performance. Such effects do not appear with simple tasks, where even high levels of alertness facilitate performance. Baranski (2007) in his study on confidence in judgment found that one night of sleep deprivation did not result in an impaired assessment of cognitive performance. It should be noted that the overconfidence in caffeine participants might have serious consequences in real-life work environments, like in aviation, because realistic self-perception is highly important in avoiding risks.

## Memory and cognition

While there have been a large number of early studies of effects of caffeine on more complex cognitive processes, it is hard to draw definitive conclusions. If, for example, one considers verbal learning tasks then one finds a large number of studies which have shown no effect of caffeine (Loke *et al.*, 1985). Many of these failures to detect effects on memory were carried out using a methodology that was sensitive enough to detect caffeine effects on psychomotor or sustained attention tasks (Roache and Griffiths, 1987). It would appear from these early studies that the effects of caffeine on cognitive performance are often too small to detect as general groupe ffects. Some positive results have been obtained (Erikson et al., 1985) but only in very specific conditions (when testing was conducted at a slow, not a fast rate). Again, it appears to be little evidence suggesting impairments following consumption of caffeine. However, as Smith (2005) noted, the use of primarily simple, lower-level tasks makes it difficult to generalize these findings with respect to more complex cognitive processes.

In a study conducted by Smit and Rogers (2000) on the effects of low caffeine doses on cognitive performance and mood, the authors divided participants into lower and higher caffeine consumption groups. Low caffeine consumers were defined as consuming less than 100 mg/day, while higher caffeine consumers were defined as consuming more than 200 mg/day (Smit & Rogers, 2000). Smith *et al.* (2005) excluded participants who did not consume any caffeine on a daily basis. Yeomans et al. (2002) studied the effects of caffeine on performance and mood as a function of the level of caffeine abstinence. Individuals were included in the study based on self-reports of daily caffeine intake that indicated daily caffeine usage falling between 195 – 650 mg/day.

Haskell et al. (2005) defined caffeine consumers as those who drank tea and/or coffee, and consumed at least 50 mg of caffeine per day. The range of daily caffeine consumption in this study was 60-800 mg/day, with a mean of 217 mg/day. It is clear from this sampling of caffeine studies that qualifications for typical caffeine consumers vary widely. It also seems that some of the studies (e.g., Haskell et al., 2005; Yeomans *et al.*, 2002) include consumers with an extremely wide range of average daily caffeine consumption.

## Conclusion

The performance effects of caffeine in this study represent a novel and unique finding, one that has been largely missing from prior caffeine research. A finding that caffeine consumption provides only temporary benefits with high future costs in terms of fatigue might cause people to rethink their consumption habits. However, it is unclear that these biomarkers translate into outcomes that are relevant for peoples' daily lives, and further investigation is needed to understand their practical implications.

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