# Effect of Caffeine on Cognitive Functions

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## Abstract

*Biocognition is a new and integrated approach to understand the biological basis of high-level functions including comprehension and use of speech, visual perception and construction, calculation ability, attention, memory, and executive functions in human beings. Cognitive functions such as attention and information processing are reported to improve with the intake of Caffeine, which acts as a psychoactive stimulant drug. Therefore, the present study examined the effects of caffeine on attention and information processing in college students in the age group of 18 to 21 years. Twenty one volunteers from undergraduate college were selected for the study. A series of cognitive tests including Two Choice Reaction Time, Ten-Choice Reaction Time, word reaction time, word recognition time, subtraction tests, statement verification tests, Stroop test series and vigilance tests were conducted on all the participants with the help of Cognispeed software. The reaction time for the responses was recorded in millisecond duration. A pretest-posttest design was adopted to examine the effect of caffeine and therefore, seven among the twenty one participants selected on a random basis were administered 100 milligram caffeine orally in a beverage twenty four hours after the establishment of baseline measures. The cognitive tests were repeated after thirty minutes of caffeine intake. The data obtained on cognitive functions was analyzed. The results showed differences in reaction time between the pretest and posttest measures on specific cognitive functions. The results are discussed in the light of biocognitive perspective.*

***Keywords:*** ***Biocognition, Cognitive functions, Caffeine, Attention, Vigilance, Information processing, Cognispeed***

The term 'cognition' refers to the ability to process information and apply knowledge. The high level mechanism of cognitive functions by human brain includes comprehension and use of speech, visual perception and construction, calculation ability, attention, memory, and executive functions such as planning, problem solving, and self-monitoring. The study of the biological basis of cognition and its understanding in organisms is referred to as 'Biocognition'.

The integration between the biological brain, the mind and among different kinds of information processing systems is essential for adequate functioning of cognitive processes. Further, augmentation of cognitive capacities is also possible with a broad range of stimulant drugs like nicotine, cocaine, amphetamines and caffeine. There are research reports on the effects of each of these stimulant drugs amongst which the effect of caffeine has been extensively studied. (Williams, Savory and Leathwood, 1990; Warburton, 1995; Lorist, Snel, Kok and Maulder, 1996; Kenemans and Verbaten, 1998).

In addition to the stimulant drugs, a spectrum of factors such as medical interventions, education and training, gene therapy or neural implants are also reported to influence cognitive functions. These factors are reported to impart specific skills and thus enhance general mental faculties such as concentration, memory and critical thinking. Other forms of mental training, such as yoga, martial arts, meditation, and creativity courses are also in common use for enhancement of cognitive functions (Bostrom and Sandberg, 2009).

Dietary supplements also affect cognition. For maintaining optimal functioning of the brain, continuous supply of glucose is necessary. Increase in glucose availability, from the ingestion of sugars or the release of the acute stress hormone norepinephrine, improves memory with the effects being particularly pronounced on demanding tasks. Creatine, a nutrient that improves energy availability, also appears to benefit overall cognitive performance and reduce mental fatigue. Besides being an energy source,

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food can contribute to cognition by providing amino acids needed in the production of neurotransmitters, which is particularly important during periods of stress or sustained concentration.

**Effects of caffeine on human body**

Among all the above factors, Caffeine is widely used to improve alertness. Caffeine is found in adequate quantity in tea, coffee, chocolate, many soft drinks, and pain relievers. The world's primary source of caffeine is Roasted coffee beans. It is a psychoactive stimulant drug that stimulates the central nervous system at the higher level. It results in increased alertness, faster and clearer flow of thought and better coordination of body movements.

Caffeine can act as a central nervous system stimulant. However, the extent to which it stimulates depends on the dose of caffeine. Caffeine can cause increased neural activity, which can lead to a change in behavior. By conducting scans and tests, researchers have found that caffeine enhances cognitive capabilities by stimulating areas of the brain associated with attention and short-term memory. However, studies also report that people who consume caffeine more regularly are tolerant to many of its effects (Dixit, Vaney and Tandon, 2006). Several studies have reported the positive effects of caffeine consumption on cognitive dimensions which are related to patterns of caffeine consumption in conjugation with socio-demographic variables, educational levels, substance use (Alcohol, Cigarettes, or Tranquilizers), life style, clinical variables etc. Research has shown that consumption of approximately 300 mg caffeine per day results in slower rate of decline of cognitive abilities. Such increased cognitive abilities are reported to be effective for a longer period of time in older Individuals and these beneficial effects also appear to increase with age. However their effects on college students are not investigated in detail (Ritchie, Carriere, de Mendonca, Portet, Dartigues, Rouaud, Barberger-Gateau and Ancelin, 2007).

**Mechanism of caffeine**

Caffeine has a number of effects on the body, but the one that is relevant here is that it blocks adenosine receptors in the brain. These receptors help prepare the body for sleep by curbing the chatter between nerve cells and by widening blood vessels to increase the flow of oxygen. On the surface of brain, the difference between adenosine and caffeine is difficult to assess. But after consumption of caffeine which acts as a stimulant, it attaches itself to the receptors and adenosine is shut out (Figure 1). Thus by blocking adenosine, caffeine enhances memory by increasing the amount of neuron activity or by releasing neuromodulators, facilitating constriction of blood vessels, increase in attention and the synaptic changes that underlie learning.

Studies have shown that, Caffeine mainly acts by blocking adenosine receptors and thus brings about changes in the levels of various neurotransmitters like dopamine, adrenaline and glutamate. The A1 type of adenosine receptors have been linked to dopamine D1 receptors and A2A with dopamine D2 receptors (Lorist and Tops, 2003). The A1 receptors have been found to be associated with regulation of alertness. Mesopontine cholinergic neurons are associated with regulation of arousal level and are under tonic A1 receptor control. Of various dopamine receptors isolated in brain, D1, D2, D4 and D5 have been found in hippocampus. Activation of D1and D2 receptors in hippocampus has been found to improve acquisition and retention of working memory (Packard and White, 1991). Caffeine exercises positive influence on cognitive functions namely, reaction time, vigilance and various other automatic and controlled information processing systems. It has also been shown to improve higher cognitive functions including working memory, selective and divided attention (Koppelstatter, 2005).

**Assessment of cognitive functions**

There are many methods employed for assessment of cognitive functions. The assessment procedures vary from simple observation to questionnaire survey and tests, paper- pencil and motor measures, quantitative electroencephalography (QEEG) and event related potentials or the state-of-the-art technology that uses MRI, fMRI or neuroscan (Deslandes, Veiga, Cagy, Piedade, Pompeu, and Ribeiro, 2005). The most user friendly approach to cognitive assessment is the computer based tests and software that help to measure reaction time on cognitive tests with an accuracy of millisecond duration. One such software that is widely used for cognitive assessment is the 'Cognispeed' (Revonsuo and Portin, 1995).

**Objective of the study**

Intensive research has been carried out on the beneficial effects of Caffeine. However the effect of moderate dosage (100 mg) of caffeine in the un-habituated youngsters especially college students is not very much clear. The objective of the study was to examine the effect of caffeine on certain cognitive functions such as attention, working memory, semantic processing and on

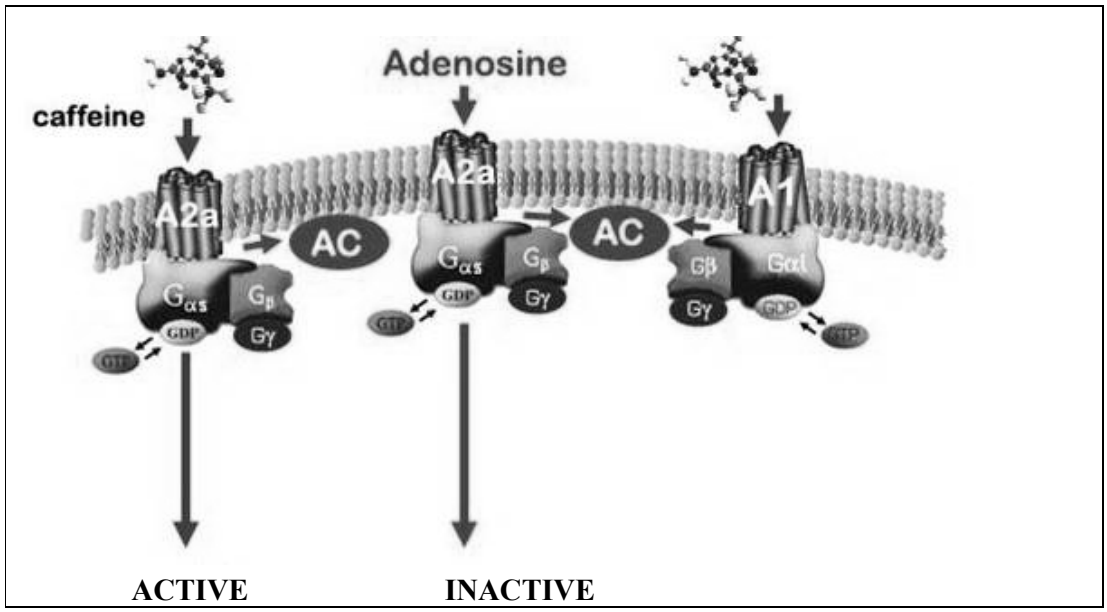


**Figure 1:** Mechanism of caffeine

stroop tasks on college students in the age group of 18-21 years.

## Method

The present study was conducted at the All India Institute of Speech and Hearing, Manasagangothri, Mysore, India. The study group comprised of 21 normal, healthy young undergraduate students in the age group of 18–21 years. The participants had no history of head injury, epilepsy, hearing impairment, migraine, sleeping problems, drug abuse (nicotine, alcohol and opium) and or psychological problems. Written consent was taken from the participants prior to the study.

All the participants were instructed to have adequate sleep and to abstain from caffeine containing substances for at least 48 hours prior to the testing. All the participants were subjected to cognitive assessment by employing Cognispeed software. The details of the tasks for assessment of various cognitive processes in the software are listed below. The performance on the vigilance test, a test that assesses the sustained attention of an individual, is taken as a measure of baseline attention to compare the performance of participants in the posttest under the effect of caffeine on other cognitive tasks that are described below.

### Cognispeed software

The Cognispeed software developed by Revonsuo and Portin (1995) is a software for scientific research work. The software contains several separate tests which can be used to measure reaction time and percent correct responses (accuracy). One of the central ideas in the software is the separation between automatic and controlled information processing. For studying controlled information processing which demands conscious effort, this software offers programs for measuring reaction time for working memory, speed and decision making while the tests for choice reaction time are indicators of attentional functions. The subtraction test involves sustained attention as well as working memory and the statement verification task requires semantic processing in addition to attention and working memory. The Stroop task, on the other hand, requires inhibition and facilitation of attention and semantic processing depending on the specific task. For example, in the color naming test automated meaning processing must be inhibited. Table 1 gives an outline of the tests.

### Design of the study

2 X 2 mixed group design was employed for the purpose of baseline study. Pretest-posttest design was adopted to compare the performance of participants on cognitive tests before and after the consumption of caffeine.

### Procedure

All the participants were tested for vigilance and cognitive skills in a quiet room in the forenoon of a weekend. Participants selected for the posttest were requested to report for the test again the next day. They were informed that caffeine will be given by way of instant coffee and were again instructed not to consume any caffeinated food stuff for another 24 hours. All the participants in the posttest group were administered with 100

milligram of caffeine in the form of a beverage (Nescafe Instant classic), the dose that is considered as moderate, and is known to produce significant effects (Dixit, Vaney, and Tandon, 2006). The test was conducted 30 minutes after the administration of caffeine since the optimum time for the effect of caffeine is reported to be between 15 minutes and 45 minutes after consumption. (Fagan, Swift and & Tiplady, 1988).

| Sustained attention | Automatic processing | Controlled processing | Tests for Stroop effect Facilitation and interference |
|---|---|---|---|
| Vigilance test | Two-choice reaction<br>Ten-choice reaction<br>Word reaction time | Subtraction<br>Statement verification tests | Word reaction<br>Congruent words<br>Incongruent 1<br>Incongruent 2<br>Automatic semantic processing1<br>Automatic semantic processing2 |

**Table 1:** Tests for cognitive functions

The test was conducted in Language Science Laboratory of the Department of Speech Language Sciences at the All India Institute of Speech and Hearing, Mysore. All the participants were given uniform instructions for each of the tests. Trials with the test stimuli were given for familiarization of the tasks and procedure. The participants were required to press a button on the keyboard of a computer system in response to the target stimulus. Test battery for cognitive assessment included baseline vigilance test, reaction time tests, controlled processing tests and Stroop tests.

The mean scores for reaction time in milliseconds and mean percent correct responses for each of the above tests were obtained for all the participants. The group mean score for reaction time and group mean for percent correct responses for all the tests was also compiled for further statistical analyses. The data was subjected to statistical analyses using SPSS 10 for Windows.

## Results and Discussion

The objective of the study was to examine the effect of caffeine on cognitive function. The data obtained from the participants was analyzed using non-parametric statistics. Analysis was carried out to examine:

a. Between group comparison: Performance of the participants - non caffeine (14 No.) and caffeine group (7 No.) on tests of vigilance and cognitive function.

b. Within group comparison: Performance of the seven participants on tests of cognitive function before and after consumption of caffeine.

Two-independent 't' test was employed to evaluate the performance of the group on tests of vigilance and tests of cognitive function. Results revealed that there was no significant difference between the two groups (P >0.05) on all the above tests. Despite the difference in the number of participants in the two groups, no significant difference was found between the two groups either on vigilance test or on cognitive tests, suggesting that the group was uniform in its characteristics.

Performance of the caffeine group on tests of cognitive function before and after consumption of caffeine was examined by employing 2-related't' test for within group comparison. The results indicated that there was a significant difference on **percent correct response** for specific cognitive tests such as automatic processing (Two choice percent correct) and semantic processing (Statement verification test), while for automatic semantic processing (Stroop interference effect), there was a significant difference for **both mean RT and percent correct response** (P<0.05) (Table 2 and Figure 2).

| Two choice percent correct | Incongruent2 percent correct | Automatic semantic processing mean RT | Statement verification test percent correct |
|---|---|---|---|
| **0.05** | **0.03** | **0.04** | **0.02** |

**Table 2**: Pre and Post test scores of significance in the Experimental group

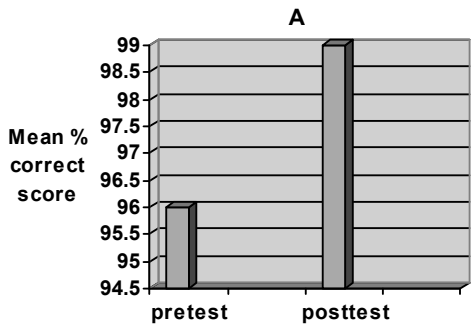


**Figure A:** Mean percent correct score for two-choice reaction task (A)

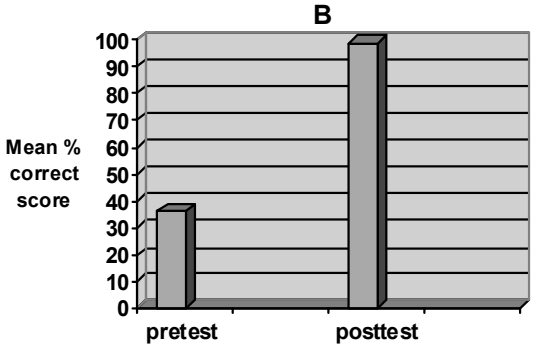


**Figure B:** Mean percent correct score for Incongruent 2 task

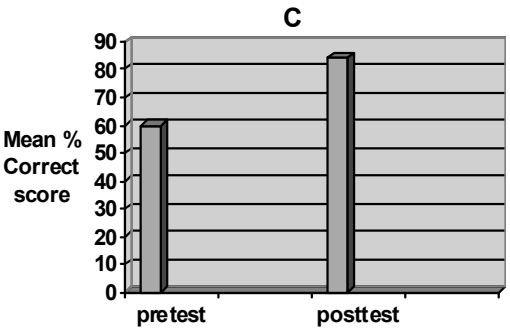


**Figure C:** Mean percent correct score for statement verification task

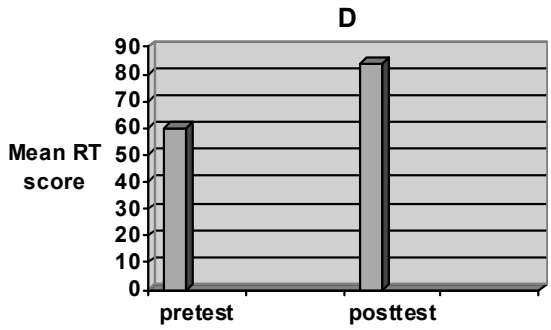


**Figure D:** Mean reaction time for semantic processing tasks

**Figure 2:** Effect of Caffeine on cognitive tasks

Analysis of the results of the study indicates that performance on cognitive tests did show a significant difference before and after consumption of caffeine. Although, the speed with which the tests are performed, i.e., the reaction time (RT) did not show significant difference (except on automatic semantic processing), the accuracy of response was significantly better on test of automatic processing, statement verification and incongruent words. These results are well substantiated by the fact that the participants of the study were equally vigilant even before consumption of caffeine and hence, intake of caffeine did not influence the mean RT or the speed of the test performance. However, the significant difference on percent correct response or accuracy of response on tasks that involve short term memory (also known as working memory) such as statement verification test and colour word incongruent test of Stroop task (Table 2) appear to be the most significant finding of the study. Since the capacity of short term memory depends on the speed of transmission of neurotransmitters, caffeine intake, as explained earlier, appears to have over ruled the adenosine receptor activity, thus enhancing the accuracy of response on tasks that demand short term memory.

In order to confirm the above observation, performance on subtraction test and statement verification test was further compared in both before and after caffeine conditions. Since statement verification involves holding the statement in short term memory before exercising the command, it is quite likely that there could be differences in performance on the above two tests. Therefore, a 2-related't' test was employed on scores of statement verification test and subtraction test in both before and after caffeine condition. The results showed a significant difference in percent correct response ($P < 0.4$) suggesting that the statement verification test which is a task to assess semantic processing, in addition to short term memory showed a significant difference with caffeine consumption.

Majority of the studies reviewed earlier have reported enhancement of cognitive function with intake of caffeine. In the present study which employed Cognispeed to assess general cognitive processes, semantic processes and Stroop effect, it was observed that there was a significant effect of caffeine on the accuracy of response and not on the speed of response; short term memory and not on the general cognitive function. The most interesting finding that emerged out of this small scale study is that there was a striking difference in performance on tasks involving short term memory (also known as working memory) as well as semantic processing. The results indicate that intake of caffeine exercised significant effect on these two specific cognitive functions amongst many other functions under study. The results of the present study are crucial from the perspective of study of biocognition as more studies of similar kind would help in understanding and evolving strategies for enhancement of accuracy of response and short term memory. The results of this study can be meaningfully applied in many fields such as education, IT/BT/Corporate/ Management/defense sectors for specific activities that demand semantic processing and short term memory for efficient work output besides its relevance in the rehabilitation of persons with communication disorders and children with special needs.

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## Acknowledgements

We acknowledge with gratitude the Dr. Vijaylakshmi Basavaraj, Director, AIISH, Mysore for her kind permission to conduct the study at the institute. We thank Ms. Vasantha Lakshmi, lecturer in Biostatistics, Department of Speech Language Pathology for her timely help. We also thank the participants for their cooperation.