**Effect of Caffeine on Information Processing: Evidence from Stroop Task**

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**ABSTRACT**

**Background:** Caffeine is a psychostimulant present in various beverages and known to alter alertness and performance by acting on the central nervous system. Its effects on central nervous system have been studied using EEG, evoked potentials, fMRI, and neuropsychological tests. The Stroop task is a widely used tool in psychophysiology to understand the attention processes and is based on the principle that processing of two different kinds of information (like the word or colour) is parallel and at different speeds with a common response channel. **Aim:** To study the effect of caffeine on classical color word Stroop task. **Materials and Methods:** This study was conducted on 30 male undergraduate students by performing a test before and 40 minutes after consuming 3 mg/Kg caffeine and evaluating the effect of caffeine on Stroop interference and facilitation. **Results:** The results revealed that practice has no effect on the performance in a Stroop task. However, there was reduction in Stroop interference and increase in facilitation after consumption of caffeine as was evident by changes in the reaction times in response to neutral, incongruent, and congruent stimuli. **Conclusion:** We hypothesize that caffeine led to faster processing of relevant information.

**Key words:** Attention, caffeine, facilitation, interference, stroop

**INTRODUCTION**

Caffeine (1,3,7 trimethylxanthine) is one of the most widely used psychoactive drug in the world and consumed in various forms like tea, coffee, and colas. The half life of caffeine is 3-7 hours and its significant levels can be detected in the brain after 5 minutes of oral intake, with the peak levels reaching in about 30 minutes.¹² Caffeine’s main mechanism of action is by blocking the adenosine receptors and altering the levels of various neurotransmitters like dopamine, adrenaline, serotonin, and acetylcholine.³ Other mechanisms like mobilization of calcium, inhibition of phosphodiesterases, and binding to benzodiazepine receptors have also been postulated.⁴⁻⁶ Studies have been done using questionnaires, electroencephalography, reaction time tests, and evoked potentials to elucidate the effects of caffeine on central nervous system (CNS). Hollingsworth as early as in 1912, reported that consumption of 65-130 mg caffeine increased typing speed, but a dose as high as 390 mg impaired the motor performance.⁷ Lorist et al. demonstrated a decrease in the reaction time and error rate with increase in amplitude of event related evoked potential P3 following intake of caffeine.⁸ Similar results have also been reported by Dixit et al in 2006.⁹ In another study Dixit et al have shown that caffeine intake changes transmission of impulses in the auditory pathway.¹⁰
Besides physiological tests, neuropsychological tests have also been used to understand the influence of caffeine. One such task is the Stroop task, first described by John Ridley Stroop in 1935.[11] The Stroop task is believed to be the “Gold Standard of attentional measures” aimed at studying the interference of a stimulus of one dimension with recognition of stimulus of another dimension.[12] The conventional color word version task consists of words like “Blue”, “Red”, “Green” and “Yellow” written in another color or are incongruent (e.g., Red is written with blue ink) or symbols like “XXX” in different colors or are neutral.[13] The subject has to respond to the color. The time taken to perform the task in the two conditions (incongruent and neutral) is recorded and the difference between the two represents interference. Similarly the time difference between congruent (“Red” written in Red ink) and neutral is an indication of facilitation.

A thorough literature reveals scant work on the effect of caffeine on Stroop task.

Foreman et al in 1989 evaluated the effect of caffeine on numerical version of Stroop task by giving subjects no caffeine or 125 mg or 250 mg caffeine in decaffeinated coffee and found slower responses with a dose of 250 mg.[14] However, there was no significant difference in the error rates of the three groups. The authors hypothesized that caffeine had deleterious effect on tasks that involved conflicting stimuli.

Hasenfratz and Battig studied the effect of nicotine and caffeine on numerical Stroop task and reported an improvement after ingestion of caffeine.[15] But their subjects were in a state of nicotine deprivation (as they were smokers) and hence their results cannot be attributed purely to caffeine.

Edwards et al. studied the effect of 125 mg and 250 mg caffeine on both classical and numerical Stroop task and did not report any significant change in the performance in the two versions of the task.[16] However, there was a difference in the performance due to practice.

Kenemans et al. evaluated the effect of a dose of 250 mg caffeine on Stroop task.[17] They used two versions of the Stroop task: one in which the subjects had to indicate the numerosity of digits and the second was a color-word task. They found a decrease in the error rate in the first task along with a decrease in the reaction time after caffeine consumption. In the color-word task, caffeine reduced the interference.

It is thus clear that there is conflicting evidence with regards to the effect of caffeine on the classical color-word Stroop task. This study evaluated the effect of caffeine on classical color word Stroop task in order to have further insight into attentional processes.

**MATERIALS AND METHODS**

Thirty healthy male medical student volunteers in the age group of 18-25 years (mean age 20.21±1.32 years) were recruited after explaining the procedure and taking written consent. Institute Ethical committee clearance was taken for the study. The subjects were asked to refrain from caffeine or any other stimulant intake for at least 12 hours prior to the study. They were asked to report to the lab at 9 a.m on the day of testing after having proper night sleep. The subjects were given a practice session a day before the day of testing.

The exclusion criterion for subjects were:

- History of medical illness especially neurological diseases
- History of smoking, alcohol or any other drug consumption
- Subjects on any medications during last two weeks.

Color- Word Stroop task: The Stroop task was administered using Psych/Lab™ for Windows. The task consisted of three blocks given at interval of 5 minutes. Each block had three conditions each of which had 72 trials:

1. Neutral condition- “XXXX” were printed in Red, Green, Blue and Yellow colors
2. Incongruent condition- “Red”, “green”, “blue,” and “yellow” were printed in different ink color
3. Congruent condition- “red”, “green”, “blue,” and “yellow” were printed in same ink color as that indicated by the word

The subjects in all the three conditions had to respond to the color of the text. The response buttons to be pressed for the color were: “z” for Red, “x” for Green, “.’” for blue and “/’” for yellow.

After the first session, the subjects were given caffeine (Caffeine pure from Loba Chemie Pvt. Ltd.) in a dose of 3mg/Kg body weight along with milk powder and sugar in water. The second session of recording was done 40 minutes after caffeine intake.

**Data analysis**

The data obtained was analyzed by 2 within factor repeated measures ANOVA using SPSS 17 followed by Tukey’s test. The level of significance was kept as 0.05.

**RESULTS**

The results obtained are summarized in [Tables 1 and 2].
The analysis of data revealed no significant difference in the reaction time for the three blocks, thereby showing that there was no effect of practice on the Stroop task. Within a block, there was a significant difference between the three conditions (P<0.001) showing the presence of interference and facilitation effects. Also, there was a significant decrease (P<0.001) in the reaction time in all the three conditions after caffeine intake showing that there was modulation of the attentional processes by caffeine.

The number of correct responses failed to show any significant change from one block to another or one condition to another or before and after caffeine intake.

The absolute decrease in interference after caffeine intake was 24.89±8.71 ms and the increase in facilitation was 8.59±4.32 ms.

**DISCUSSION**

The present study evaluated the effect of caffeine, a known CNS stimulant on the color-word Stroop task. There was a decrease in interference with an increase in facilitation as evident by the decrease in the reaction time after caffeine ingestion. However, there was no effect of practice on the performance of Stroop task.

Our findings of no change in performance due to practice were similar to that of Shor et al. and in contrast to that of Edwards et al.,[18,16] Edwards et al. had given only 10 stimuli, whereas in this study an entire block consisting of 72 trials for each condition was given.[16] Hence, it is possible that the subjects had habituated to the stimuli and hence practice had no effect on performance.

There was a clear demonstration of the interference and facilitation in our study. The fact that there was interference suggests that there was conflict in the attentional resources for processing of the two dimensions, i.e., naming of word and naming of color. When the word and the ink color were same (congruent), there was faster processing of the two dimensions, an indication of facilitation. However, studies done by Lyvers et al. and Deslandes et al. did not find any significant effect of caffeine on Stroop task.[19,20] The change in interference in our study was similar to that reported by Hasenfratz and Battig and Kenemans et al.[15,17] Hasenfratz and Battig found an improvement in performance after administration of caffeine.[15] But the difference between their study and ours was that they had smokers as their subjects who were in a state of nicotine deprivation when the testing was done and also they had used numerical stroop task and not the color word task. Nicotine deprivation by itself is known to effect cognitive processes. Hence, their results cannot be attributed to pure caffeine effect.

Kenemans et al in their study performed two experiments to evaluate the effect of caffeine.[17] In the first experiment they reported no consistent effects of caffeine on reaction time along with a significant decrease in error rate following caffeine administration and suggested that caffeine led to suppression of irrelevant information. In their second experiment, they reported a decrease in reaction time with significant decrease in interference effects following caffeine consumption. However, there was no significant reduction in error rates. Based on their experiments, Kenemans et al. postulated that caffeine led to increased sensitivity for relevant responses. Hogervorst et al. in their study found that caffeine’s effect was more on complex task reaction time than on baseline test reaction time.[21]

It has been suggested that subjects tend to develop a strategy for responding when the stimuli are presented in blocks.[17] Kenemans et al. in their study tried to address this issue by using both blocked and mixed
conditions and found no evidence to suggest that the changes in reaction time by caffeine had some contribution from strategy to respond developed by the subjects. We believe that even if the subjects had adopted some strategy for the blocks, the same strategy was being used before and after caffeine intake and thus would have been common to both states. Hence, the effect on interference and facilitation could be attributed to caffeine itself.

Our study found no significant differences in the number of correct responses before and after caffeine consumption. It can be reasonably argued that caffeine was not altering the suppression of irrelevant information, because if that had been the case, the number of correct responses would have changed following caffeine intake. Rather, caffeine, promotes faster processing of relevant information along neuronal pathways as evident from the significant reduction in reaction time in the three conditions. Studies using evoked potentials have reported that caffeine led to faster information processing and increased arousal levels.\cite{22,23}  Shift of EEG towards faster spectral components on caffeine intake also support this finding.\cite{24}

Caffeine at doses comparable to daily consumption acts via blocking adenosine receptors which have widespread distribution in the brain.\cite{25-27} Adenosine is formed by action of AMP selective 5’ nucleotidase and acts as a general CNS depressant. Caffeine by blocking adenosine receptors changes the levels of various neurotransmitters in the brain. Pardo et al. suggested that anterior cingulate gyrus is the main area involved in Stroop interference.\cite{28} Leung et al. demonstrated changes in anterior cingulate, insula, frontal, parietal, and mid temporal regions by incongruent stimuli.\cite{29} Thus, it is evident that a number of networks between various areas of brain are functional in the Stroop task. We hypothesize that caffeine by altering the levels of neurotransmitters leads to processing of relevant information in the classical color word Stroop task.

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