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# Effects of caffeine use and ingestion on a protracted visual vigilance task

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**Abstract.** College students (12 female, 12 male) were assigned to either higher caffeine user (HCU) or lower caffeine user (LCU) groups based on a caffeine usage survey. Prior to testing, subjects ingested either placebo or 195 or 325 mg caffeine. They then performed a visual vigilance task measuring response blocks, discrete responses (hits and false alarms), reaction times, and a Mood Check List using a double-blind design. HCU made significantly fewer hits, more false alarms, and also responded faster than LCU. No significant main effects of caffeine administration were found. In the mood analyses, male subjects were more anxious at the end of the experiment. Overall, the user factor (HCU versus LCU) was the most potent experimental variable.

**Key words:** Caffeine ingestion – Caffeine – Vigilance – Mood – Anxiety – Boredom

Considering the general availability and widespread use of caffeine as a mild stimulant in coffee, tea, and cola drinks, few contemporary studies of its effects on human performance have been reported. Caffeine has been reported to enhance human performance in some situations (Baker and Theologus 1972; Franks et al. 1975; Hauty and Payne 1955; Hollingworth 1912; Regina et al. 1974), but not others (Cattell 1930; Cheney 1935, 1936; Weiss and Laties 1962). This variability in outcomes suggests that caffeine effects may be highly 'task-specific' and raises the question of the circumstances under which caffeine produces a facilitory effect.

Past research suggests that caffeine enhances performance in tasks requiring visual vigilance, and seems to be especially effective in situations where vigilance normally becomes degraded due to fatigue and boredom (Baker and Theologus 1972; Hauty and Payne 1955; Regina et al. 1974). The present study was designed to test the effects of caffeine on a simple visual vigilance task under conditions designed to produce boredom and fatigue. Holland (1958) defines a vigilance task as a monotonous perceptual task which involves the monitoring of some infrequent but critical signals. Consequently, long-term performance of such monotonous tasks produces visual or task-induced fatigue. Childs (1978) reported that 'high coffee users' responded significantly faster and more accurately in a visual scanning task than 'low coffee users' when they ingested 400 mg caffeine, but not when placebo or 200 mg caffeine was ingested. In the present study, it was hypothesized that caffeine would significantly increase the number of correct responses while decreasing response times and response blocks (momentary periods of inattention) in subjects performing a vigilance task.

## Materials and methods

Monmouth College undergraduates (12 female, 12 male; 18–20 years of age) were from introductory psychology classes and their participation earned them full credits towards a course requirement. Vision tests (Snellen chart) showed that all had 20/20 or equivalent corrected vision.

A 570 mm Panasonic television was used to display a signal (white circular spot, 5 mm diameter) moving saccadically across the center of the dark gray field (screen). The signal speed was controlled by a timing routine in a microcomputer. The experimental area was semidarkened and the cubicles were partially enclosed to block the view of other subjects while permitting the subject a clear view of the screen. Recording devices placed in an adjacent room measured subjects' responses. An audio generator (RCA model 1421) was used to produce white masking noise.

Throughout the experiment, the signal (spot) swept saccadically across the screen at a standard speed of 29 mm/s. If, on the next trial, the signal's speed remained the same (i.e., 29 mm/s), the signal was called on unchanged stimulus. At random intervals, signal speed changed to 14 mm/s at the beginning of a sweep. This change in speed (29 mm/s to 14 mm/s) was called a changed stimulus. A total of 270 signal sweeps were presented during the 90-min test period. A changed stimulus occurred randomly on 60 (22.2%) of the trials, while the stimulus remained unchanged on the remaining 210 (77.8%) of the trials.

Subjects were asked to refrain from ingesting caffeinated beverages for 2 h before the experiment. The 24 subjects were screened from a group of 36 volunteers on the basis of a caffeine consumption survey. The 12 lowest users (six males and six females; mean $44 \pm 28$ mg/day) were designated as the lower caffeine user (LCU) group and the 12 highest users (six males and six females, mean $204 \pm 84$ mg/day) were designated as the higher caffeine user (HCU) group. The designations were intended only in the relative sense for purposes of this study. Rall (1980) reports per capita intake of caffeine in the United States averages 200 mg/day, con-

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sumed mostly as coffee, which is estimated to contain about 85 mg caffeine/cup.

Subjects were randomly assigned to three subgroups (195 mg caffeine, 325 mg caffeine, lactose as placebo). Each subgroup contained two female HCU, two female LCU, two male HCU, and two male LCU. Before vigilance testing, subjects completed a two-page information briefing concerning the effects of caffeine (adapted from Rall 1980; Long 1982; Modell 1978) and the manner in which the study would be conducted, a summarized instruction sheet, and a self-report mood adjective check list (Gough and Heilbrun 1965). Although subjects were informed about the effects of caffeine, they were told only that the drug would be randomly assigned.

After completing the questionnaires, each subject ingested a gelatin capsule containing either caffeine citrate or placebo. Each capsule contained five 65 mg caffeine or placebo tablets (distributed by Eli Lilly, Indianapolis, IN), alone or in combination. To insure that neither the experimenter nor the subjects were aware of the drug administered, capsules were prepared and coded by a third party.

Immediately after ingestion, each subject was assigned to one of three cubicles. Since the screen was placed 3.6 m (12 feet) in front of the middle cubicle, the two subjects sitting on the extreme cubicles were exposed to a perceptual deviation (about 15°) relative to the subject sitting in the middle cubicle and consequently, differences in perceptual judgment of the visual target might exist. To eliminate seating biases, the order of seating was counterbalanced across drug groups. Instructions were reiterated and a 2-min practice run was given. Subjects were instructed to respond by pressing a button that was placed alongside their right forearm whenever they observed a deceleration in the signal's speed. When they observed no change in speed, they were to remain passive. Figure 1 shows organization of the dependent variables. No feedback was provided to the subjects when they responded to any of the signal trials.

The vigilance test consisted of two consecutive 45-min sessions separated by a 2-min break between sessions, during which subjects were allowed to converse and move freely around the testing center. On completing the vigilance test, subjets completed a second Mood Check List. They were also asked to guess the kind of drug (caffeine or placebo) they had consumed.

The following four independent variables were tested: (1) dose level (0, 195, 325 mg); (2) habitual levels of caffeine use (HCU versus LCU); (3) sex (female versus male); (4) testing time since drug administration (0–30, 30–60, 60–90 min). The dependent measures were discrete responses (hits + false alarms), reaction times (hits + misses and false alarms + correct rejections), and response blocks. A response block was defined as any response whose latency was twice the mean duration of the ten shortest response latencies made during the first 30 min of testing (Baker and Theologus 1972) for each subject.

Results of the vigilance test were analyzed using a three-between, one-within (sex × user × dose × trial block) MANOVA and ANOVA (Winer 1971). Significant interactions ($P < 0.05$) were subjected to Newman-Keuls multiple-range tests (Winer 1971). Subjects' responses on the ordinal scale adjectival Mood Check List were analyzed using a three-between, one-within (sex × user × dose × session) ANOVA. Subjects' guesses about the kind of drug they had consumed (caffeine or placebo) were subjected to Fisher's exact probability test (Hayes 1963).

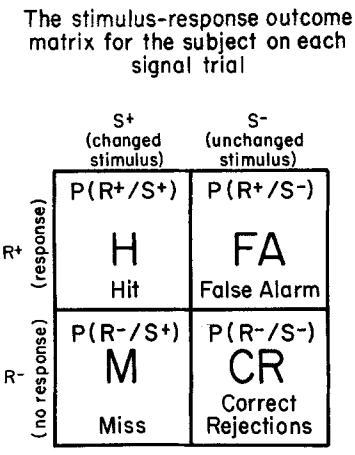


**Fig. 1.** The stimulus-response outcome matrix for the subject on each signal trial

## Results

Overall, subjects made significantly more response blocks during the last two trial blocks, suggesting that performance declined as the duration of the vigilance test increased [$F(2,24) = 3.82$, $P < 0.05$; Table 1]. Contrary to expectation, caffeine ingestion did not significantly affect response blocks, reaction times, or discrete responses. However, some significant differences were found between HCU and LCU. For example, a significant user × trial block interaction [$F(2,24) = 4.42$, $P < 0.05$] was found. Analysis revealed that HCU made fewer hits than LCU, i.e., detected fewer stimulus changes, during the third trial block, 60–90 min after the start of testing, and they also made fewer hits ($P < 0.05$) in their third trial block than in their first (0–30 min). LCU did not decline from trial block 1 to 3 ($P > 0.05$; Fig. 2).

HCU also made nearly three times as many false alarms as the LCU [$F(2,24) = 5.08$, $P < 0.05$]. Overall, subjects improved, making fewer false alarms in the last two trial blocks than in the first [$F(1,12) = 5.37$, $P < 0.05$; Table 1].

Similarly to false alarms, user and trial block effects for the unchanged stimulus were significant [$F(1,12) = 5.45$, $P < 0.05$; $F(2,24) = 5.49$, $P < 0.025$, respectively]. As Table 1 shows, HCU had shorter latencies than LCU, i.e., HCU responded faster than LCU when stimulus speed remained unchanged. Mean response latencies during unchanged stimulus trials were also analyzed. A latency of 18.1 s was scored for each correct rejection, since 18.1 s was the time taken for the unchanged stimulus to traverse the screen. Mean latencies increased in later trial blocks [$F(2,24) = 5.49$, $P < 0.05$; Table 1]. Mean response latencies to the changed stimulus were also analyzed, but no significant effects were found.

Analyses of Mood Check List data showed that neither caffeine nor any of the other variables tested significantly affected either boredom-alertness or anxiety-relaxation scores. However, male subjects reported significantly more anxiety after testing (mean test scores 14.5 before, 24.8 after), while females did not differ before and after testing [mean test scores 14.8 before, 14.7 after; $F(1,12) = 4.86$, $P < 0.05$].

**Table 1.** Caffeine effects on various dependent measures (means)

| | Dose (mg caffeine citrate) | | | User | | Time after ingestion (min) | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 195 | 325 | LCU | HCU | 0–30 | 30–60 | 60–90 |
| Hits (%) | 95.0 | 88.5 | 94.0 | 94.5 | 90.0 | 95.0 | 90.5 | 91.5 |
| False alarms (%) | 1.9 | 3.1 | 3.3 | 1.4 | 4.0[a] | 4.3 | 2.3 | 1.7[a] |
| Response blocks (frequency/h) | 12.6 | 11.8 | 12.0 | 11.2 | 13.2 | 9.0 | 17.6 | 14.0[a] |
| Latency: Changed stimulus (s/trial) | 4.2 | 5.0 | 4.9 | 4.0 | 5.4 | 4.2 | 4.8 | 5.1 |
| Latency: Unchanged stimulus (s/trial) | 17.1 | 16.7 | 16.4 | 17.4 | 16.1[a] | 16.0 | 17.0 | 17.3[a] |
| | | | | | | Before | After | |
| Boredom (test score) | 26.8 | 25.0 | 26.8 | 28.4 | 24.0 | 26.4 | 26.0 | |
| Anxiety (test score) | 17.9 | 16.3 | 17.4 | 16.3 | 18.1 | 14.7 | 19.8 | |

[a] Significant difference among means, $P < 0.05$

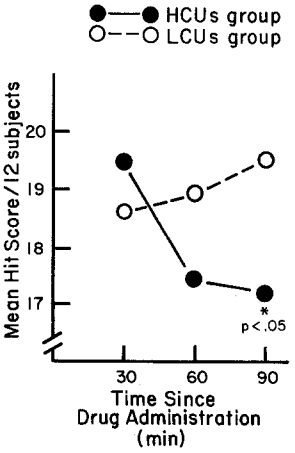


**Fig. 2.** Mean hit scores of higher and lower users during three time intervals after drug administration. * Statistical significance at the 0.05 level between groups on the same time interval

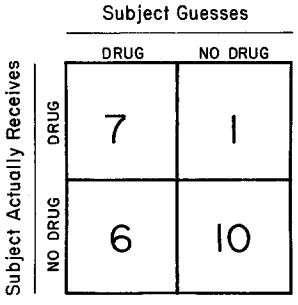


**Fig. 3.** Subjects' guesses and actual drug consumed

Subjects also correctly guessed the kind of drug (either caffeine or placebo) they had consumed at significantly better than chance expectation ($P < 0.027$, Fig. 3).

## Discussion

As expected, performance declined during the 90 min of vigilance testing. Similar results have been reported in past studies (Waag et al. 1973; Thackray et al. 1978). However, contrary to expectation, no improvement was found in vigilance as a result of caffeine ingestion. Thus, caffeine did not reverse a progressively deteriorating performance relative to control.

The nonsignificant effects of the two test doses of caffeine are inconsistent with some past studies (Baker and Theologus 1972; Regina et al. 1974). Differences between the present design and the earlier work may account for the discrepancies in results. In the present task subjects were required to make judgments about the speed of a moving spot; in the Baker and Theologus (1972) study subjects were required to react when the distance between two stationary lights increased; and in the Regina et al. (1974) study subjects were to respond whenever the 'lead car' accelerated, decelerated, or flashed a high-beam signal.

Previous work (Baker and Theologus 1972; Barmack 1940) suggested that caffeine enhances performance by blocking decrements which normally occur when subjects become bored with a task. It was expected that the present task would maximize boredom due to its relative simplicity, repetitiveness, duration (90 min), and the lack of external incentives for good performance. Nevertheless, by their own estimation (Mood Check List), subjects were not significantly more bored at the end of the experiment than at the beginning. Perhaps they were not sufficiently bored for caffeine to produce a significant effect. However, Weiss and Laties (1962) argued that some analeptics (e.g., amphetamine) can enhance performance even in the absence of boredom or fatigue. Some caffeine researchers found little or no change in subjective mood (Bachrach 1966), while others (Costill et al. 1978; Seashore and Ivy 1953) found placebo subjects rated themselves as less excited, exhilarated, talkative, and more fatigued.

A plausible explanation for the lack of increase in perceived boredom may be that the task used allowed subjects to take short rest periods during testing, thereby alleviating boredom. They might have alleviated boredom by attending to the spot as it approached the right side of the screen prior to the its disappearance. The last appearance of the spot provides a cue for the subject to attend or 'get ready' for the next signal trial. Once subjects develop this efficient strategy of vigilance, they may cease to attend to the spot all the time since their attention span is required only at critical periods, i.e., prior to the spot's disappearance and during the brief reemergence of the spot on the left side of the screen.

The strength of the user effect was not anticipated. HCU made more false alarms and fewer hits than the LCU, especially in the 60–90 min interval. White et al. (1980) re-

ported that high caffeine consumers had significantly more muscle tension during caffeine abstinence, and Landgrebe (1960) reported increased flicker-fusion frequency in habitual coffee users, whereas inexperienced users showed decreased frequency.

The present finding that performance by males was not markedly superior to females supports Thackray et al. (1978). In contrast, Waag et al. (1973) found males to be significantly better than females in a simple visual vigilance task. Sex differences in vigilance performance may be minimal when little physical output is required. However, in the present anxiety analysis, male LCU reported greater anxiety after testing while females did not. No plausible interpretation for this interaction effect is found.

The greatest importance must be given to the potent user effect. Future caffeine studies should control for this user effect when investigating other experimental variables.

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