Psychopharmacology (1998) 140 : 116–119 

RAPID COMMUNICATION

**Paula J. Durlach**

# The effects of a low dose of caffeine on cognitive performance

Received: 16 March 1998 / Final version: 27 July 1998

**Abstract** There is little evidence concerning the effects of caffeine in doses typical of one cup of tea. The present study investigated the effect of 60 mg caffeine, consumed in either tea or hot water, on performance on a subset of the CANTAB test battery. Eight males participated in a practice session and four test sessions. In each test session, the participant consumed a different hot beverage and then, over approximately 90 min, completed nine tests from the CANTAB battery. The four beverages were created by crossing beverage identity (tea or hot water) and caffeine dose (0 or 60 mg). Significant speeding of reaction time by caffeine consumption was found in pattern recognition, delayed match to sample, and match to sample visual search. The effect on reaction time of 60 mg caffeine can be detected, and may be evident within minutes of consumption.

**Key words** Caffeine · Reaction time · Tea · CANTAB · Match to sample

## Introduction

Tea is one of the world's most popular beverages (Stagg and Millin 1975); but there is little evidence on the effect of caffeine doses typical of a single cup of tea, i.e., 40–60 mg (Barone and Roberts 1983). The psychopharmacological literature has tended to use caffeine doses of 100 mg or more (e.g., Lader and Bruce 1989; Rusted 1994), although there are some exceptions (e.g., Kuznicki and Turner 1986; Lieberman et al. 1987; Richardson et al. 1995). In addition, despite subjective reports of immediate beneficial effects of consumption, most research has postponed measurement to coincide with peak plasma caffeine levels (Blanchard and Sawers 1983). The intention of the present study was to investigate the effects of consuming a single cup of tea on a variety of cognitive tests. Testing began immediately after consumption and lasted approximately 80 min.

P.J. Durlach
Unilever Research Colworth Laboratory,
Sharnbrook, Bedford MK44 1LQ, UK
e-mail: Paula.Durlach@Unilever.com

## Materials and methods

### Design

A crossover design was used with four treatment conditions distinguished by two factors, beverage (tea or water) and caffeine dose (0 or 60 mg). Four parallel versions of the test battery (plus a fifth version for the practice session) were used, allowing the same conceptual test to be repeated, using new stimuli each time. A Greaco-Latin square was used to balance order of treatments and test versions.

### Participants

The study was approved by the Unilever Ethics Committee and all participants gave written, informed consent. They were eight nonsmoking males, (mean age 38.1 years), recruited from the Unilever Research Colworth Laboratory staff, who agreed to abstain from caffeine-containing or alcohol-containing products from 9:30 p.m. the evening before each weekly test session.

### Apparatus

The experiment was run using a microcomputer equipped with an integrated capacitive touch sensitive screen (Microtouch). Tests were modifications of the CANTAB Neuropsychological Test Batteries, version 1 (Fray et al. 1996). Responses were made either by touching a particular stimulus displayed on the screen or by operating a response pad, depending on the test. Participants were tested individually, under the supervision of an experimenter, who was blind to the beverage condition.

### Beverage preparation

Drinks (255 ml) were served at 55°C in a white china mug. Tea was made by mixing 0.87 g tea solids, 20 ml semi-skimmed milk, and 235 ml hot mineral water. The tea solids were supplied by T.J. Lipton, Inc. (Englewood Cliffs, N.J., USA), and derived from a single brewing of either caffeinated (T+) or decaffeinated (T−) tea. The T+ contained 60 mg caffeine. W− was heated mineral water and W+ was heated mineral water adulterated with 60 mg caffeine.

### Procedure

Participants were instructed to use their dominant hand, to respond both rapidly and accurately, but to guess if they did not know the correct response. During the first, familiarisation session, no drink was given. For the four test sessions, the timing was roughly as follows:

*Minutes 0–7*: arrival and beverage consumption.

*Minutes 7–11.5*: pattern and spatial recognition. In pattern recognition, a sequence of 12, 100-ms patterns was followed after 5 s by a two-alternative forced choice test. For each pair, the subject had to indicate which pattern was in the previous list. The test was then repeated, but with new patterns. Spatial recognition was identical, except that the stimuli to be remembered were screen locations, indicated by 200-ms squares, and there were four lists of five locations each.

*Minutes 11.5–25*: delayed match to sample. Subjects were shown a complex visual pattern (the sample) and had to decide which of four patterns that appeared below it was identical. On simultaneous trials, the sample remained on the screen while the subject made his choice. On delay trials, the sample disappeared and the choices appeared with a delay of 0, 4, or 12 s. 40 trials were given, ten simultaneous, and ten at each delay.

*Minutes 25–42*: paired associate learning. The subject was required to learn where different patterns appeared on the screen. Three, six, and eight unique patterns were used, on problems 1,2, and 3 respectively. Problems 4–6 used the same eight patterns as problem 3, but in scrambled locations. On each trial, patterns were displayed one at a time for 2200 ms. After all patterns were displayed, each one appeared in the centre of the screen and the subject had to touch the location where that pattern previously occurred.

*Minutes 42–54*: simple and choice reaction time. In simple reaction time (SRT), a white circle remained constantly on the screen. A 250-ms yellow spot appeared inside it, with a variable foreperiod (750–2250 ms). The subject, who otherwise was to depress the response pad, responded by releasing the pad and touching the yellow spot as rapidly as possible. Choice reaction time (CRT) was identical, except that the yellow spot could appear in one of five white circles. Participants were given two blocks of 30 trials each, for both SRT and CRT, preceded by a five-trial warm up on SRT.

*Minutes 54–64*: match to sample visual search. As for the reaction time tests, this test required the subject to depress the response pad when not responding. At 1000 ms after appearance of an abstract pattern in the centre of the screen, a circle of eight boxes appeared around the edge of the screen. Patterns appeared in two, four, or all eight of the boxes, and the participant had to indicate the one that matched the sample in the centre, by releasing the response pad and touching it. Thirty-six trials were given, 12 with two choices, 12 with four choices and 12 with eight choices.

*Minutes 64–74*: rapid visual information processing (RVIP). Participants were required to monitor a stream of 400-ms digits (2–9), and to depress the response pad upon detecting any of the sequences: 3–5–7, 5–7–9, 2–4–6, or 4–6–8. seven hundred numbers were presented, with eight targets for every 100-digit block.

## Results

The Greaco-Latin square design permitted an analysis of variance that could test the effects of session, test version, beverage, caffeine dose, and beverage × caffeine interaction. In addition, for each test, there were specific within-session repeated measures, which could be tested alone and in interaction with the above factors. For example, delay was treated like this for delayed match to sample. The remaining degrees of freedom were allocated to the error term. Unless mentioned, effects failed to be statistically significant ($P < 0.05$); and, for the sake of brevity, the results of tests that were unaffected by drink condition will not be discussed.

### Pattern recognition

The dependent variables analysed were percent correct and mean reaction time for correct responses (rt). Sequence (1–2) was included as a repeated measure in the analysis. rt was significantly faster ($F1,15 = 10.86$; $P = 0.002$) after caffeine (1450.5 ms) than after no caffeine (1566.9 ms). rt was also affected by sequence ($F1,43 = 4.75$; $P = 0.035$), with rt being faster on the second (1470.2 ms) than the first sequence (1547.2 ms).

### Delayed match to sample

The dependent variables analysed were percent correct and rt. Delay (simultaneous, 0 s, 4 s, or 12 s) was included as a repeated measure in the analysis. Figure 1 illustrates the effects of both caffeine and delay on rt. rt was significantly affected by caffeine ($F1,99 = 14.83$, $P = 0.0002$), by delay ($F3,99 = 11.02$; $P = 0.0001$), and by test version ($F3, 99 = 3.11$; $P = 0.030$). rts for the four

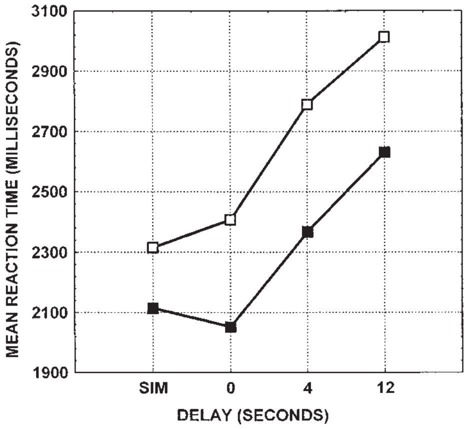


**Fig. 1** Mean reaction time for correct responses on the delayed match to sample test. SIM indicates trials for which the sample and choices were present simultaneously. □ No caffeine, ■ caffeine

test versions were 2273.4, 2473.3, 2443.5, and 2654.2 ms, for versions 1–4, respectively. Pairwise comparisons using *t*-tests indicated that rt on version 1 was significantly faster than on version 4 ($t = 3.05$; $P = 0.003$).

### Simple and choice reaction time

Reaction time was divided into two measures, reaction latency (rl), and movement latency (ml). rl was the time from stimulus onset (the yellow spot) to the release of the response pad. ml was the time from release of the response pad to screen contact. For both SRT and CRT, block (1–2) was included as a repeated measure. No statistically significant effects were found for SRT. For CRT, there was a significant effect of beverage on ml ($F1,43 = 7.27$; $P = 0.01$). ml was faster after tea than after water. Mean ml was 475.4 and 471.4 ms in the T− and T+ conditions, respectively, whereas it was 485.1 and 493.4 ms in the W− and W+ conditions, respectively. rl failed to be affected by caffeine or beverage, but was slower during block 2 (326.6 ms) than block 1 (317.4 ms); ($F1,43 = 7.22$; $P = 0.01$).

### Match to sample visual search

The dependent variables analysed were percent correct, and rt. rt was divided into rl and ml, in a similar manner as for SRT and CRT. Number of choices (2, 4, or 8) was included as a repeated measure.

rl was faster ($F1,71 = 5.92$; $P = 0.018$) after caffeine (1895.9 ms) than after no caffeine (2115.8 ms). Percent correct was 100.0, 97.7, and 93.8 for two, four, and eight choices, respectively. There was a significant effect of number of choices on percent correct ($F2,71 = 11.52$; $P = 0.0001$), rl ($F2,71 = 172.64$; $P = 0.0001$), and ml ($F2,71 = 7.06$; $P = 0.002$). Mean rl was 1007.6, 1948.0, and 3061.8 ms, for two, four, and eight choices, respectively. Mean ml was 540.4, 612.6, and 590.6 for two, four, and eight choices, respectively.

## Discussion

Significant effects of caffeine on response speed were found in three of the tests. rt was reduced by caffeine in the pattern recognition test and delayed match to sample test, and rl (but not ml) was reduced by caffeine in the match to sample visual search test. In contrast, caffeine failed to affect accuracy of performance (e.g., percent correct) on any of the tests. These results are in accord with the literature, which suggests that caffeine most reliably affects alertness and speed of response, and less reliably affects memory, problem solving, or reasoning (James 1991; Rusted 1994).

Performance on SRT and CRT failed to be affected by caffeine. This might be due to the less demanding nature of these tests compared with those involving complex pattern matching. It is worth noting that timing after beverage consumption and the nature of the tests was confounded; therefore, it is difficult to draw firm conclusions about differential sensitivity of the tests to caffeine. Yet caffeine effects were detected in tests that both preceded and followed SRT and CRT. In addition, an effect of beverage was detected in CRT; though it is possible that this small effect (10 ms) was due to chance.

Of the tests that did yield significant caffeine effects, one (pattern recognition) was given immediately post beverage consumption. The observation of a caffeine effect immediately post consumption is a relatively novel finding, and indicates that a caffeinated beverage can produce an effect quite rapidly. A similar conclusion was reached by Quinlan et al. (1998). They found an effect of 100 mg caffeine on skin conductance prior to 30 min. In addition, they found that the immediate rise in skin temperature produced by consumption of a hot beverage (55°C) was modulated by 100 mg caffeine in the drink.

The present research is unable to distinguish whether the observed caffeine effects were due to a performance enhancing, psychostimulant action, or rather to withdrawal-reversal. Participants were between 11.5 and 15.75 h caffeine-deprived, depending on time of testing. Such deprivation in regular caffeine users can produce withdrawal effects, primarily detected in the form of negative mood ratings, and less reliably by decrements in psychomotor performance (Rogers and Dernoncourt 1998). There are few data indicating a psychostimulant action of caffeine in the absence of some performance degrading factor, be it caffeine withdrawal (e.g., Rizzo et al. 1988), task-induced fatigue (e.g., Rogers and Dernoncourt 1998), or drug-induced defecits (e.g., Riedel et al. 1995). Warburton (1995) is a notable exception; however, see objections by James (1997).

**Acknowledgements** This research was supported by the Central Research and Engineering Fund of Unilever Research. The author wishes to thank C. Tomlin and K. Arbuthnott for data collection and K. Moore for design and statistical advice.

## References

Barone JJ, Roberts HR (1983) Biological effects of caffeine. History and use. Food Technol 37a:32–39

Blanchard J, Sawers SJA (1983) The absolute bioavailability of caffeine in man. Eur J Clin Pharmacol 24:93–98

Fray PJ, Robbins TW, Sahakian BJ (1996) Neuropsychiatric applications of CANTAB. Int J Geriatr Psychiatr 11:329–336

James JE (1991) Caffeine and health. Academic Press, London

James JE (1997) Understanding caffeine: a biobehavioural analysis. Sage, Thousand Oaks, Calif.

Kuznicki JT, Turner LS (1986) The effects of caffeine on caffeine users and nonusers. Physiol Behav 37:397–408

Lader MH, Bruce MS (1989) The human psychopharmacology of the methylxanthines. In: Hindmarch I, Stoner PD (eds) Human psychopharmacology: measures and methods, vol 2. Wiley, New York, pp 179–200

Lieberman HR, Wurtman RJ, Emde GG, Roberts C, Coviella ILG (1987) The effects of low doses of caffeine on human performance and mood. Psychopharmacology 92:308–312

Quinlan P, Lane J, Aspinal L (1998) Effects of hot tea, coffee and water ingestion on physiological responses and mood: the role of caffeine, water and beverage type. Psychopharmacology 134:164–173

Richardson NJ, Rogers PJ, Elliman NA, O'Dell RJ (1995) Mood and performance effects of caffeine in relation to acute and chronic caffeine deprivation. Pharmacol Biochem Behav 52: 313–320

Riedel W, Hogervorst E, Leboux R, Verhey F, Van Praag H, Jolles J (1995) Caffeine attenuates scopolamine-induced memory impairment in humans. Psychopharmacology 122: 158–168

Rizzo AA, Stamps LE, Feht LA (1988) Effects of caffeine withdrawal on motor-performance and heart rate changes. Int J Psychopharmacol 6:9–14

Rogers PJ, Dernoncourt C (1998) Regular caffeine consumption: a balance of adverse and beneficial effects for mood and psychomotor performance. Pharmacol Biochem Behav (in press)

Rusted J (1994) Caffeine and cognitive performance: effects on mood or mental processing? Pharmacopsychoecologia 7:49–54

Stagg GV, Millin DJ (1975) The nutritional and therapeutic value of tea – a review. J Sci Food Agric 26:1439–1459

Warburton DM (1995) Effects of caffeine on cognition and mood without caffeine abstinence. Psychopharmacology 119:66–70