The Effects of Caffeine on Hyperactive Children

Philip Firestone, PhD, Hélène Poitras-Wright, BA, and Virginia Douglas, PhD

The voluminous research investigating the effects of stimulant drugs on hyperactive behavior is well known. Subsequent investigations into dietary influences are rapidly increasing in number, one such study to be published in an upcoming issue. This paper examines the effect of caffeine. Were these data to be replicable, avoiding the detrimental side effects of stimulant drugs among some children might be possible through the use of caffeine. — G.M.S.

The effects of a two-week regimen of caffeine on the behavior of hyperactive children were investigated. The double-blind study involved a crossover design and required each subject to be on caffeine and placebo for a period of two weeks. During this time, psychological, physiological, and behavioral observations were made. Caffeine did not significantly improve reaction times and psychological test scores. However, impulsivity and general behavior as measured by parent and teacher rating scales showed some significant improvements due to caffeine.

Hyperactivity is one of the difficult behavior management problems of children that is encountered by clinicians, and it has been estimated that 5% of all elementary-school children display this syndrome. Associated with high activity levels are several other symptoms, which include poor attention, low frustration tolerance, and impulsivity (Douglas 1974).

There is some disagreement as to the etiology of hyperactivity. Several researchers suggest that some type of organic malfunction is responsible (Douglas 1974), while others observe that child-rearing practices and reinforcement histories may also be implicated (Werry & Sprague 1969). Although early investigators speculated that hyperactive children outgrow the disorder, Douglas (1974) suggests that only the most obvious symptom, overactivity, disappears. Attention difficulties and impulse-control deficits, which may be central to the syndrome, seem to persist into adolescence (Weiss, Minde, Werry, Douglas, & Nemeth 1971).

Several investigators have implicated dysfunctions in arousal levels in the etiology of hyperactivity. Some have speculated that hyperactive children are overaroused and that stimulant drugs lower arousal level (Wender 1972), while others have suggested that these children are underaroused (Satterfield & Dawson 1971). Cohen and Douglas (1972) and, more recently, Spring, Greenberg, Scott, and Hopwood (1974) have found no differences between hyperactives and normals on resting skin conductance. To date, there seems to be no direct evidence to support the idea that the arousal level of hyperactives differs from that of normals.

During the last decade stimulant drugs (methylphenidate and the amphetamines) have emerged as the drugs of choice in the treatment of hyperactive children. Clinical studies (Sprague & Sleator 1973, Sroufe 1975) have suggested that the stimulants reduce restlessness, impulsivity, and distractibility and make activity more goal directed. A review of the studies using methylphenidate for hyperactivity reports an improvement in 70% to 90% of the children studied (Whalen & Henker 1976).

In spite of the positive effects of methylphenidate on various behaviors that make up the hyperactive syndrome, it has been estimated that 30% of those taking this medication develop annoying and sometimes serious side effects—these include loss of appetite, sleeplessness (Millichap & Fowler 1967), and depressive withdrawal (Douglas 1974). In addition, there are reports on the possibility of addiction (Sprague & Sleator 1973), potentially dangerous heart-rate changes (Cohen, Douglas, & Morgenstern 1971), and retardation in height and weight gain in children on chronic treatment with stimulants (Safer 1971).

Schnackenberg (1973) has suggested that caffeine may offer an alternative to the other stimulant drugs for some hyperactive children. In his private practice, he took 11 children who were responding with negative side effects off their Ritalin regimen and instructed their parents to substitute two cups of coffee per day. The children drank one cup of percolated or drip coffee in the morning and one at lunchtime. The total amount of caffeine ingested in one day was 250-300mg. Teachers, who reportedly did not know of this change in medication, were asked to fill out a questionnaire during the drug intervention, then while the children were on a medication holiday, then again while the children were receiving caffeine. Schnackenberg's data suggest that the children behaved as well on caffeine as on methylphenidate but that caffeine did not lead to negative side effects that were evident with the methylphenidate. Children behaved poorly when receiving neither of these substances.

Conners (1975)* also studied the effects of approximately 300mg caffeine on hyperactive children. In a double-blind crossover investigation, eight children were administered caffeine and placebo for three weeks each. Although the small number of children made statistical analysis impossible, Conners reports that there was no apparent advantage in favor of caffeine on five dependent measures (parent's observations, teacher's observations, continuous performance task, seat activity, and language test).

To date, two studies have compared the effects of caffeine and more traditional stimulant medication on the behavior of hyperactive children. Heustis, Arnold, and Smeltzer (1975) reported that hyperactive children (outpatients in a psychiatry clinic) improved significantly when D-amphetamine or methylphenidate was administered, but the improvement with caffeine was not statistically reliable. Eighty-milligram caffeine tablets were administered approximately three

* This paper was not published at the time of the present experiment, which was conducted in the spring of 1973.

times a day for a total of about 300mg per day for one week. Heustis et al. add a cautionary remark in relation to their results by suggesting that their small sample size (18 children) might have precluded the discovery of certain beneficial effects of caffeine. No negative side effects due to caffeine administration are reported.

Another study conducted with hyperactives in which caffeine and methylphenidate were compared also failed to find a significant clinical effect with caffeine (Garfinkel, Webster, & Sloman 1975). Garfinkel et al. compared 20mg methylphenidate and 160mg caffeine per day in their experiment, which had children on each drug for a 10-day period. The results indicated that methylphenidate was effective in controlling many aspects of the hyperactive syndrome but caffeine was not. However, this investigation did not constitute a realistic evaluation of the therapeutic effects of caffeine for several reasons. The small number of children studied (eight) and the fact that they were so unmanageable that hospital day care was required limits the generalization, which may not be useful for hyperactives normally seen in clinics or office practice.

In the present study an attempt was made to investigate more rigorously the effects of caffeine on hyperactivity. A double-blind crossover design was used with well-validated behavior-rating scales as well as psychological, physiological, and motor tests. In addition, a relatively large sample of hyperactives was used.

METHOD

Subjects. Twenty hyperactive male subjects were included, ranging in age from 5 yrs. 7 mos. to 12 yrs. 5 mos., with a mean of 9 yrs. 3 mos. (S D = 1.97). Their IQs ranged from 80 to 129 with a mean of 104.5 (S D = 10.78).

To select the subjects, teachers and principals were given a brief verbal description of the symptomatology characteristic of hyperactive children. This description focused mainly on three traits—overactivity, short attention span, and impulsivity. The teachers were then asked to fill out Conners' (1969) behavior rating scale for teachers. Children whose average score on the hyperactivity factor of the scale was 1.5 or greater were considered as candidates for the study. Further selection was based on parental interviews. For a child to be included, hyperactivity had to be chronic and present since early childhood. Excluded from the sample were children who showed definite signs of brain damage, epilepsy, or psychosis. None of the children were taking psychotropic medication, and all were living at home with at least one parent.

TESTS AND APPARATUS*

Psychological tests. Three psychological tests that have been shown sensitive to the therapeutic effects of amphetamines and methylphenidate were utilized: (1) the Matching Familiar Figures Test (MFF) (Campbell, Douglas, & Morgenstern 1971); (2) the Porteus Mazes Test (Conners, Taylor, Meo, Kurtz, & Fournier 1972), and (3) the Goodenough-Harris Draw-a-Person Test (Sroufe 1975). Conners' 10-point rating scale (Conners et al. 1972) and Davids' 7-point scale (Davids 1971) were filled out by parents and teachers in order to assess children's behavior.

Delayed reaction time apparatus. The delayed reaction time (DRT) apparatus has been used previously and has been shown to discriminate between normal and hyperactive subjects in addition to being sensitive to the

* A more comprehensive version of the tests and apparatus may be found in Firestone and Douglas (1975)

effects of methylphenidate (Cohen, Douglas, & Morgenstern 1971). The DRT apparatus was triggered by auditory stimuli that had been preprogrammed. Onset of the warning signal (WS) marked the beginning of a 10-second preparatory interval after which a reaction signal (RS) was activated, while trials were separated by a 5-second interval.

While performing on the DRT, the subjects were to release the reaction time button only to the RS. However, it soon became evident that they were making three kinds of inappropriate "impulsive" responses. *False starts* refers to those button releases that occurred between the onset of the WS and up to 2.5 seconds following its occurrence. *Interstimulus responses* were those that occurred from 2.5 seconds after the WS up to the onset of the RS. Responses after the button release to the RS occurring before the WS of the next trial were designated *redundant responses*.

Skin conductance. A Grass Model 17 polygraph was used to make continuous recordings of skin conductance. Tonic skin conductance readings were taken at 30-second intervals during the last 5 minutes of the 10-minute relaxation period and at the moment of WS onset during the DRT. Skin conductance changes in excess of .30 μmho were counted as phasic responses. A skin conductance orienting response (OR) was scored if it occurred within .5–4.0 seconds of the WS onset. On the same trials skin conductance responses that occurred 2.5 or fewer seconds prior to the RS were considered as anticipatory skin conductance responses (ASR), while a skin conductance response following the RS, from .5–4.0 seconds, was designated as the reaction response (RR).

PROCEDURE

All children included in the caffeine study were given a physical examination by a physician. A double-blind crossover technique was used so that each subject served as his own control. Caffeine and placebo tablets were coded by a psychologist who did none of the testing. The caffeine tablets, which were indistinguishable from the placebos, contained 150mg of caffeine. The order in which active drug and placebo were administered was randomized so that half the subjects were first treated with caffeine, then with placebo; for the other half the reverse order was used. Parents were instructed to give the children one tablet every morning before school as well as on Saturday and Sunday. The children also took a tablet at lunchtime every day. An experimenter telephoned the parents every two days to ensure that the instructions were carried out. For those subjects (about half the sample) who did not go home for lunch, a teacher at each school was in charge of dispensing tablets.

The time covered by the study included a two-week period during which children were on caffeine or placebo, followed by one week when they received no medication and another two-week period during which they received either caffeine or placebo.

General testing procedures. Each child was tested 14 days after starting the caffeine or placebo regimen. On the day of the testing subjects took their tablets exactly one hour before testing began. One experimenter administered the Porteus Mazes, the MFF, and the Draw-a-Person Test and another the DRT. The paper-and-pencil tests were always administered first, in an empty office, and their order of presentation was randomized among subjects. The DRT was administered last. The psychological tests took approximately 25 minutes; the DRT lasted about 20 minutes.

The physical setting for the DRT consisted of a small windowless room isolated in the basement of an elementary school and kept at a temperature of approximately 70° F. The room was divided by a large plywood screen that contained a one-way mirror. The

subject was seated alone on one side of the screen while the polygraph, tape recorder, and programming equipment were operated by the experimenter on the other side.

The subject was seated in a semireclining chair and told that the experimenter was interested in how well he could pay attention to things, and the electrodes were then placed on two fingers of his left hand. He was told that when the experiment started he was to keep the response button down. When he heard a beep through the earphones, it meant he should get ready because the light was going to come on. When the light came on, he was to let go of the button as quickly as possible so we could see how fast he was. Then he was to depress the button again and hold it until the next time a light came on.

Before the experiment started, the subject was put through a 10-minute relaxation period in order that skin conductance might stabilize.

Behavior rating scales. On day 7 and on day 14, the days on which each child was tested, one of the experimenters telephoned the parents and asked the mother to fill out the previously supplied rating scales and return them by mail. On the same day the same experimenter visited the child's teachers and picked up the two rating scales. Behavior ratings were thus collected every seven days during drug or placebo consumption. No ratings were collected during the one-week "off" period, as this was a vacation period at the schools attended by the children.

DATA ANALYSIS

Statistical transformation: autonomic data. In order to account for the nonnormality of the distribution often found in autonomic data and also to account for the Law of Initial Values, it was necessary to perform a transformation on the raw data. Skin conductance values were converted to log scores, and all skin conductance changes were expressed as the difference between the logarithm of the base and peak of the response to stimulation.

Missing data. Due to illness and absenteeism on the part of the teachers and students, there were a few subjects for whom observational data (rating scales) were lacking. If the missing data for a subject covered only one observation, a score was estimated using Winer's (1962, pp. 488-489) estimation procedure; if two observations were missing, the subject was dropped from that analysis. As a result, although there were data for 20 subjects on the DRT and psychological tests, only 14 subjects met the criteria for inclusion in the observational analyses.

RESULTS

All data were analysed by analysis of variance. Significant main effects were followed by the Neuman-Keuls test.

Performance on the Delayed Reaction Time Task

Reaction Times. A two-way analysis of variance was conducted on both mean reaction times and the standard deviation of the reaction times. The two factors were drug (caffeine vs. placebo) and order. There were no significant findings on either (see Table I).

Impulsive responses. The analysis of variance of the false starts resulted in a significant drug effect ($F = 9.2$, $df = 2/36$, $p < .01$). As Table I indicates, this showed that false starts were more numerous with placebo than with caffeine. Although there appeared to be fewer interstimulus and redundant responses in the caffeine condition, the analyses did not produce significant differences.

Autonomic activity during the DRT. A three-way analysis of variance on tonic skin conductance with drug, order, and condition

TABLE I. Performance on the delayed reaction time task in the caffeine and placebo conditions.

	Caffeine	Placebo
Mean reaction time	38.88	41.36
Standard deviation of reaction time	17.35	19.52
False starts	.70 (1.00)†	1.90* (1.37)
Interstimulus responses	1.65 (2.49)	2.20 (2.52)
Redundant responses	1.25 (2.21)	2.35 (2.24)

* $p < .05$. † Standard deviations are in parentheses.

TABLE II. Effects of caffeine and placebo on psychological test scores.

	Pretest	Caffeine	Placebo
Porteus Mazes Test	108.40 (30.92)*	126.90 (10.36)	123.25 (39.56)
Draw-a-Person Test	85.45 (13.06)	97.05 (18.65)	92.60 (11.62)
Matching Familiar Figures Test			
Latency	7.95 (3.25)	7.00 (2.90)	7.50 (2.65)
Error	15.40 (7.79)	14.30 (6.02)	14.90 (5.53)

* Standard deviations are in parentheses.

(rest or performance phase) as main effects was carried out. The only significant finding ($F = 16.3$, $df = 1/18$, $p < .01$) revealed that tonic skin conductance was lower in the rest condition than while the subjects were performing on the DRT (31.8 μmho vs. 37.1 μmho).

The analyses on the amplitude and frequency of the phasic skin conductance responses yielded no significant effects.

Performance on the Psychological Tests. Performance on the psychological tests (Table II) was evaluated three times: just before the subject began taking caffeine, while they were on caffeine, and in the placebo condition. A two-way analysis of variance of the MFF for both latency and errors yielded no significant effects.

The analysis of the Porteus Mazes scores yielded a significant time effect ($F = 20.8$, $df = 2/36$, $p < .001$). This difference reflects a practice effect only; no treatment effect was evident.

The analysis of variance on the Draw-a-Person Test also revealed a significant time effect ($F = 8.1$, $df = 2/36$, $p < .01$). This indicated that performance in the pretest was reliably poorer than in both the caffeine (Q

= 9.7, $df = 17$, $p < .01$) and placebo trials ($Q = 8.4$, $df = 17$, $p < .05$). No significant treatment differences were found.

Teachers' Ratings

The two-way analysis of variance on the teachers' ratings from the Davids' scale yielded no significant effects (Table III). A similar analysis of the Conners teachers' ratings resulted in a significant drug effect ($F = 5.5$, $df = 4/48$, $p < .01$). Scores on the pretest were reliably higher than on observations in the caffeine 2 condition, but not significantly different from scores in caffeine 1 ($Q = 4.6$, $df = 15$, $p < .05$). In addition, the first and second ratings with caffeine were reliably lower than the first rating in the placebo condition ($Q = 4.6$, $df = 15$, $p < .05$; $Q = 5.22$, $df = 15$, $p < .05$), but not different from the second rating in the placebo condition.

Parents' Rating

The two-way analysis of variance on the Davids' scale (Table III) did not produce any significant findings. The Conners' rating scale showed a significant drug effect ($F = 9.8$, $df = 4/48$, $p < .01$), indicating that pretest scores were higher than scores at the time of both caffeine and the placebo 1 ratings ($Q = 5.66$, $df = 15$, $p < .01$; $Q = 6.14$, $df = 15$, $p < .01$; $Q = 4.88$, $df = 15$, $p < .01$). Both ratings when the subjects were receiving caffeine were significantly lower than those made during the placebo 2 condition ($Q = 4.8$, $df = 15$, $p < .05$; $Q = 5.18$, $df = 15$, $p < .05$).

DISCUSSION

Although the findings are not consistent, the change effected by 300mg caffeine per day in the present study is not as dramatic as that reported by Schnackenberg (1975). The means and variability of reaction times on the DRT seemed better in the caffeine than the placebo condition, but the differences were not significant. Baker and Theologus (1972) speculated that caffeine serves to improve performance on attention tasks by retarding deterioration over time. It could be argued that the 15 trials of the DRT in the present study, which took only three to four minutes, might not have been long enough for a significant difference to appear. In those studies that have demonstrated the positive effects of methylphenidate on the delayed reaction time task (Cohen, Douglas, & Morgenstern 1971) and on a vigilance task (Sykes, Douglas, & Morgenstern 1972), subjects were required to participate for a considerably greater length of time.

The effect of caffeine on the ability to inhibit responses remains unclear. Although the frequency of false starts was significantly lower in the caffeine condition, interstimulus, redundant responses and psychological test scores (i.e., MFF, Porteus Mazes, Draw-a-Person) do not support this finding.

Some studies have found heightened skin conductance levels with stimulant drugs (Satterfield & Dawson 1971; Cohen et al. 1971), while others have not (Spring et al. 1974). Spring et al. have suggested that differences in dosage levels may have accounted for the fact that their hyperactive subjects did not show increases in tonic skin conductance while those of Cohen et al. (1971) did. In the present study, caffeine did not appreciably raise tonic levels (32.9 μmho to 35.9 μmho). Whether higher dosages or more prolonged use of caffeine would affect skin conductance remains to be seen. The data raise hope, however, that detrimental autonomic side effects sometimes found with the stimulants (Douglas 1974, Sroufe 1975) may not occur with caffeine. As in the previously reported studies with caffeine, the children in this study did not show any negative side effects, as determined by informal parental reports.

TABLE III. Means and standard deviations of teacher and parent rating scales scores.

		Pre	Caffeine		Placebo	
			1	2	1	2
Teachers						
Davids' rating scale	Mean	24.50	25.14	23.07	25.15	24.93
	SD	11.28	5.01	8.53	8.06	3.64
Conners' short form rating scale	Mean	17.36	12.86°†	12.15°†	17.92	14.22
	SD	8.97	6.67	6.05	6.10	9.94
Parents						
Davids' rating scale	Mean	26.08	21.79	21.22	23.21	26.07
	SD	5.52	6.98	7.89	7.53	3.81
Conners' short form rating scale	Mean	17.07	9.79°†	9.79°‡	11.50°	13.93
	SD	8.65	6.63	8.07	7.05	6.05

* Significantly lower than pre scores.
† Significantly lower than ratings obtained during the first placebo trial.
‡ Significantly lower than ratings obtained during the second placebo trial.

Caffeine induced significant effects on ratings of classroom and home behavior. Conners' 10-point rating scale showed its sensitivity to caffeine as it has to other stimulants (Sprague & Sleator 1973). Both teachers and parents indicated that caffeine may well increase the frequency of desirable behaviors in hyperactive children, although this change, in the present investigation, was inconsistent. Davids' scale did not show any significant changes, though the scores were in the direction of caffeine improving behavior.

Significant effects with caffeine leading to improved performance were found on three measures: false starts, and Conners' rating scale as filled out by parents and by teachers. All other dependent measures utilized showed nonsignificant differences in the same direction (e.g., MFF, Porteus Mazes, Draw-a-Person, reaction time and its variability, Davids' rating scale by teachers and parents). The reasons for this are not clear, but some speculation is warranted. It is possible that the small number of subjects or their variable ages and IQs may have precluded more definite results. In addition, as suggested by Conners (1975), 300mg caffeine may be too conservative a dose for any substantial behavior change. This is supported by the lack of side effects in the children in this study and the Conners study. Furthermore, it is possible that only certain children are caffeine responders, as is the case with other stimulants.

ABOUT THE AUTHORS

Philip Firestone, *educated at McGill University, is with the Psychology Department, Children's Hospital of Eastern Ontario and is associated with the Department of Psychology, Carleton University* **Virginia I. Douglas** *is a professor in the Department of Psychology, McGill University and is a past president of the Canadian Psychological Association* **Hélène Poitras-Wright**, *a graduate from McGill University, is currently completing her MA in clinical psychology at Concordia University*

ACKNOWLEDGMENTS

This study was conducted at McGill University in partial fulfillment of the PhD requirements of Philip Firestone The research was supported by Canada Council Grant number S72-1389 to V.I Douglas, and by a grant from the Social Science Research Fund, McGill University (No. 943-03-69). The caffeine and placebo were supplied by Pharmetics Ltd, Pointe Claire, P Q.

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