The Effects of Caffeine and Methylphenidate on Hyperactive Children

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Abstract. Twenty-one hyperactive children received in turn 500 mg. caffeine, 300 mg. caffeine, and 20 mg. methylphenidate per day in a double-blind crossover design investigation. Each drug was given for three weeks. Methylphenidate resulted in significantly improved behavior in the children as rated by mothers and teachers, and on tests of impulsivity and motor control. There were no significant improvements in either of the caffeine conditions, although some children showed some slight improvements with caffeine. The negative side effects with both caffeine and methylphenidate were minimal.

A great deal has been written about the problem of hyperactivity which is estimated to affect between 5 to 10% of elementary school children (Firestone et al., 1978b; Heussy, 1967; Stewart et al., 1966). Although hyperactive children are usually described as restless and always on the go, recent research has suggested that more central to the disorder is a limited attention span, difficulty with impulse control, and low frustration tolerance (Douglas, 1972; Dykman et al., 1971).

Stimulant drugs (methylphenidate and the amphetamines) have emerged as the “drugs of choice” in the treatment of hyperactivity, and there is considerable evidence attesting to their effectiveness (Conners, 1974; Gross and Wilson, 1974; Knights and Hinton, 1969; Sprague and Sleator, 1973; Sprague and Werry, 1974). Stephen et al. (1974) report that methylphenidate is the most fre-
sequently prescribed medication because of the reported, but under-
demonstrated, lower frequency of side effects.

Reviews of the clinical studies using methylphenidate for
hyperactivity optimistically report improvement rates of up to 83% (Barkley, 1977; Knights, 1974; Whalen and Henker, 1976).
Laboratory investigations have also demonstrated the positive ef-
effects of methylphenidate. Several researchers have shown that
hyperactives show improved mean reaction times and decreased
response variability (Cohen et al., 1971; Sprague et al., 1970), in-
creased vigilance (Conners et al., 1969; Sykes et al., 1971, 1972),
and improved impulse control (Campbell et al., 1971; Sykes et al.,
1971). Other studies have indicated that methylphenidate can be
instrumental in improving classroom behavior, group participation,
and attitude toward authority in a classroom setting (Conners,
1971; Denhoff et al., 1971).

In spite of the positive effects with the stimulants on various
aspects of the hyperactive syndrome, many of those taking these
drugs develop annoying and sometimes serious side effects. Loss of
appetite and sleeplessness are two well-documented side effects
(Cole, 1975; Millichap and Fowler, 1967). In addition, potentially
dangerous heart-rate changes (Cohen et al., 1971; Knights and
Hinton, 1969; Winsberg et al., 1975) and retardation in height and
weight (Safer, 1971; Safer et al., 1972; Weiss et al., 1975) have
been found in children in chronic treatment with the stimulants.
However, more recent work indicates that there is a considerable
growth rebound following the withdrawal of drugs which leads to
normal growth patterns (Safer et al., 1975).

Recent studies have suggested that caffeine may be an alternative
form of pharmacological treatment for hyperactives that may result
in fewer side effects than methylphenidate. Schnackenberg (1973)
took 11 children from his private practice, who were responding
with negative side effects, off their Ritalin regimen and instructed
their parents to substitute two cups of coffee in the morning and
one at lunchtime. The total amount of caffeine ingested in one day
was 250 to 300 mgs. Teachers, who reportedly were naive to this
change in medication, were asked to fill out a behavior rating scale
(Davids, 1971) during the drug intervention, then while the chil-
dren were on the medication holiday, and again while the children
were receiving caffeine. Schnackenberg’s data suggested that the
children behaved as well on caffeine as on methylphenidate, but
caffeine did not lead to any of the undesirable side effects that had
been evident with the methylphenidate.
Firestone et al. (1978b) expanded the investigation of caffeine in the treatment of hyperactive children and overcame some of the methodological deficits in the Schnackenberg study. Children for the study were defined as hyperactive on the basis of interviews with parents, developmental histories, and rating scales filled out by teachers. The double-blind study involved a crossover design and required each S to be on caffeine and placebo tablets for a period of two weeks each, separated by a one-week "washout" period. The active tablets contained 150 mg. of caffeine and children took one in the morning and one at noon, for a total of 300 mg. Ss were administered various psychological tests, while teachers and parents filled out behavior rating scales, just prior to the study and every seven days during the placebo and caffeine regimen. In addition, on the last day of caffeine and placebo administration, galvanic skin conductance and performance on a reaction-time task sensitive to attentional processes and impulsivity were monitored. The results indicated that although caffeine seemed to improve reaction times and psychological test scores uniformly, these differences were not statistically significant. However, impulsivity as measured by the reaction time as well as general behavior measured by parent and teacher rating scales showed significant improvement due to caffeine. Furthermore, these improvements with caffeine were not accompanied by heightened skin-conductance levels, as has often been the case with stimulant drugs (Satterfield and Dawson, 1971; Cohen et al., 1971).

Nevertheless, other investigations have not found similar results. Conners (1975) reports that with a series of 8 children caffeine (3 mg/kg b.i.d.) had no significant effects, either positive or negative, on deficits related to hyperactivity.

Huestis et al. (1975) reported that hyperactive children (outpatients in a psychiatry clinic) improved significantly when d-amphetamine or methylphenidate was administered, but the improvement with 300 mg. of caffeine was not statistically reliable. Huestis 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 160 mg. of caffeine and 20 mg. of methylphenidate per day were compared also failed to find a significant clinical effect with caffeine (Garfinkel et al., 1975). The results indicated that methylphenidate was effective in controlling many aspects of the hyperactive syndrome...
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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 (8) and the fact that they were so unmanageable that institutional care was required preclude generalization to hyperactives normally seen in clinics or office practice.

The present study extended the investigation into the clinical use of caffeine with hyperactive children. The purpose was twofold: (1) to evaluate further the effects and possible side effects of 300 mg. and 500 mg. of caffeine per day with hyperactives by using psychological and behavioral assessments that have been well validated with this population, and (2) to compare the effects and side effects of high and low dosages of caffeine with those of methylphenidate used in the normally prescribed fashion.

**Method**

**Subjects**

The subjects were children between 6 and 12 years of age (17 boys and 4 girls) referred by physicians to the Children’s Hospital of Eastern Ontario. The children had as their prime difficulties overactivity, short attention spans, impulsivity, inability to delay gratification, and oppositional behavior. The hyperactivity had to be present since early childhood (noticed onset at 1½ to 2 years of age) and the scores on the hyperactivity factor of Conners (1969) behavior rating scale for teachers had to be at least 1.5. (see table 1 for full description of Ss.) Excluded from the sample were children

<table>
<thead>
<tr>
<th>Table 1</th>
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<tbody>
<tr>
<td>Descriptive Data</td>
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<tr>
<td>X</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>IQ</td>
</tr>
<tr>
<td>SD</td>
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<td></td>
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<thead>
<tr>
<th>Conners Teachers Rating Scale</th>
<th>X</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperactivity</td>
<td>2.64</td>
<td>.68</td>
</tr>
<tr>
<td>Conduct problem</td>
<td>1.07</td>
<td>.81</td>
</tr>
<tr>
<td>Inattentive-passive</td>
<td>1.52</td>
<td>.57</td>
</tr>
<tr>
<td>Tension-anxiety</td>
<td>0.92</td>
<td>.45</td>
</tr>
<tr>
<td>Sociability</td>
<td>0.52</td>
<td>.58</td>
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who had definite signs of epilepsy, psychosis, or brain damage. Furthermore, the children were required to have an IQ score of at least 80 on the Peabody Picture Vocabulary Test.

All children included in the study were required to have a thorough medical examination to attest to absence of illness or other complicating factors. In addition to a physical examination every four weeks during the study, parents were contacted at least twice per week by telephone to monitor for possible side effects or other complications. Parents and teachers were fully informed as to the goals and procedures of the investigation and were free to withdraw at any time.

**Tests and Apparatus—Standardized Test Materials**

*Matching Familiar Figures Test.* The children’s form of the MFF, a test of impulsivity, consists of 12 standard pictures familiar to children and six variants of each standard. The S must point to that variant which is identical to the standard which remains in view. Two scores are obtained for each S: (1) the mean latency to the first response on each of the 12 items; and (2) the total number of errors on each item.

*The Maze Test* is based on the Porteus Maze Test which measures motor coordination, planning, attention, impulsivity, and general intellectual ability (Porteus, 1968). In the present study an automated version of the maze was used which simplifies data collection by automatically recording the number of contacts a S makes with the side of the maze as well as their duration. The S is required to work his way through the maze with a stylus in the dominant hand. Normative data are presented by Knights and Moule (1968).

*Conners Rating Scale* (CRS). Conners (1969) has developed a widely used rating scale for teachers. This scale of 39 items has been factor analyzed to give 5 factors: (1) hyperactivity, (2) conduct problem, (3) inattentive-passive, (4) tension-anxiety, and (5) sociability. The score for each factor is based upon the mean of the items within the factor (a 4-point scale, 0–3, is used).

*Conners Short Form Rating Scale* (CSS). Conners (1972) shortened his original 39 items rating scale to 10 items. Conners et al. (1972) were able to differentiate between hyperactive subjects receiving dextroamphetamine, magnesium pemoline, and placebo with this scale. Sprague and Sleator (1973) found the CSS sensitive enough to pick up dosage effects in a study using methylphenidate with hyperactive children. In the present study the CSS, which is scored
on a 4-point 0–3 scale, was completed by both parents and teachers. The score for a child is the sum over the 10 items.

Reaction-Time Apparatus. The reaction time has been used previously (Cohen and Douglas, 1972) and has been shown to discriminate between normal and hyperactive Ss in addition to being sensitive to the effects of methylphenidate (Cohen et al., 1971; for a full description see Firestone and Douglas, 1975).

Three measures are available on this task: (1) mean reaction time; (2) the standard deviation of the reaction times; (3) the total number of inappropriate responses to warning signals or responses while the subject was not to respond with the apparatus. These responses are designated "impulsive responses."

Drug Allocation

Caffeine capsules of 75 mgs. and 125 mgs. dosages were used while methylphenidate was prepared in 5 mg. capsules. The capsules were indistinguishable from placebo preparations. In the high caffeine condition children took two 125 mg. capsules in the morning and at noon, while in the low caffeine condition the same procedure was followed with the 75 mg. capsules. In the methylphenidate condition children took a 5 mg. capsule in the morning and one at noon. Increases or decreases in 5 mg. gradations were decided on through telephone interviews. It was predicted that most Ss would respond well to a methylphenidate regime of approximately 20 mg. per day. However, there were some variations. One child was maintained at 30 mg. and two others at 15 mg. per day.

Ss were in each of a high caffeine, low caffeine, methylphenidate, and placebo condition for a three-week period. After each condition a three-day washout period ensued. The study was thus a double-blind crossover, with the order of chemical interventions randomly selected for each S. Each child was tested on the 21st day of drug administration in each condition and ingested his capsules one hour before testing. On the same day rating scales were completed by teachers and each parent independently.

Results

Statistical Analyses

The data were analyzed in terms of four groups. Each group corresponds to a drug or placebo condition. Multivariate analyses of
variance (MANOVA) were performed and following significant effects, univariate analyses of variance were performed on each dependent measure (Hummell and Slago, 1971). When appropriate, Newman-Keuls tests were utilized to compare the effects across treatment groups.

Due to illness, absenteeism, or lack of cooperation by a parent, teacher, or child, and equipment failure, there were missing data. For each analysis if any data were missing the S was dropped from that particular analysis. Thus, only Ss with complete scores were considered in each specific analysis.

**Behavioral Measures**

These are summarized in table 2. Although CRS was requested from each parent and the teachers, the fathers were most negligent in completing their rating scales. The reasons ranged from forgetfulness to being absent from the home due to work. Thus, only the mothers and teachers scores were subjected to analyses. The results revealed that both mothers $F(3,57) = 8.93$, $p < .001$ and teachers $F(3,39) = 19.92$, $p < .001$ rated children as significantly improved on methylphenidate ($p < .05$), while the other conditions did not differ from each other.

**Delayed Reaction-Time Table**

The mean reaction time, the standard deviations of the reaction times, and impulsive responses on the delayed reaction time were subjected to a MANOVA. The significant multivariate effect $F(6,96) = 2.03$, $p < .05$ was followed by univariate analysis of variance. There were no significant findings with the means or standard deviations.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Placebo</th>
<th>300 mg. Caffeine</th>
<th>500 mg. Caffeine</th>
<th>Methylphenidate</th>
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<tbody>
<tr>
<td>Mothers CRS</td>
<td>17.5 ± 6.9</td>
<td>16.6 ± 8.4</td>
<td>15.3 ± 5.9</td>
<td>10.3 ± 5.9</td>
</tr>
<tr>
<td>Teachers CRS</td>
<td>15.6 ± 7.0</td>
<td>15.4 ± 8.4</td>
<td>13.6 ± 6.1</td>
<td>5.4 ± 4.1</td>
</tr>
<tr>
<td>MFF Latency (sec.)</td>
<td>9.55 ± 8.83</td>
<td>7.28 ± 5.12</td>
<td>8.15 ± 6.56</td>
<td>9.07 ± 7.63</td>
</tr>
<tr>
<td>Error</td>
<td>12.55 ± 6.13</td>
<td>14.90 ± 8.96</td>
<td>13.55 ± 9.93</td>
<td>14.00 ± 10.01</td>
</tr>
<tr>
<td>Maze frequency</td>
<td>17.70 ± 14.43</td>
<td>23.05 ± 18.57</td>
<td>18.10 ± 13.36</td>
<td>13.81 ± 14.66</td>
</tr>
<tr>
<td>Duration</td>
<td>4.40 ± 4.17</td>
<td>4.80 ± 5.10</td>
<td>4.10 ± 4.86</td>
<td>2.75 ± 3.30</td>
</tr>
<tr>
<td>RT $\bar{x}$</td>
<td>.73 ± .22</td>
<td>.66 ± .27</td>
<td>.66 ± .23</td>
<td>.64 ± .28</td>
</tr>
<tr>
<td>SD</td>
<td>.32</td>
<td>.23</td>
<td>.28</td>
<td>.28</td>
</tr>
<tr>
<td>Impulsive responses</td>
<td>20.07 ± 13.87</td>
<td>23.14 ± 19.70</td>
<td>14.00 ± 14.06</td>
<td>11.71 ± 10.1</td>
</tr>
</tbody>
</table>
deviations of the reaction-time data, but the drug effect for impulsive responses was reliable $F(3,39) = 3.11, p < .05$. This revealed that the frequency of impulsive responses in the methylphenidate condition was significantly lower than the other conditions ($p < .05$) which did not differ from each other.

In order to ascertain whether a differential deterioration effect may have been present in the conditions, an analysis of variance was carried out with the means and standard deviations of the first 25 trials and last 25 trials as blocks. These analyses did not achieve statistical significance.

**Psychometric Measures**

The MANOVA on the MFF latency and error scores and the Maze test frequency and duration scores resulted in a significant effect, $F(12,143) = 2.16, p < .02$. Univariate analyses indicated that only the Maze test frequency score $F(3,57) = 4.65, p < .01$ and duration score $F(3,57) = 5.48, p < .005$ were significant. The frequency of contacts was lower in the methylphenidate condition than the low caffeine condition ($p < .05$), but no other conditions differed from each other. The duration of contacts was reliably lower in the methylphenidate condition than the other conditions ($p < .05$), which did not differ from each other.

**Individual Responsivity**

Analyses of group data sometimes mask individual differences in responsivity to drugs. The results of the present study suggest that although methylphenidate led to significant improvement in several areas of functioning and caffeine did not, there were children who seemed to respond to caffeine. These ratings are not subject to statistical analyses, but simply convey clinical impressions and are based on verbal inquiries made by one of the authors (S.P.). A child was considered improved only if substantiated by both mothers and teachers CSS. Using these criteria 77% of the children responded positively to methylphenidate, 29% responded to high caffeine and 14% to low caffeine. Every child that responded positively to low caffeine also responded to the high caffeine regime. In addition, 23% of the children responded positively to both methylphenidate and caffeine, although in each case the improvement with methylphenidate was considerably greater than with caffeine. Only one child did not improve with methylphenidate and did show some marginal improvement with caffeine.
Side Effects

Although no children dropped out of the investigation due to negative side effects, two children did not complete the study. One child required placement in a residential treatment center, and the parents withdrew another child because he responded so well to methylphenidate that the parents refused to allow the child to go through the other conditions. Nevertheless, several children did experience minor discomfort.

Methylphenidate resulted in notable anorexia in five children, insomnia in two children, and stomach cramps with another child. Three children in the 500 mg. caffeine condition had insomnia and one became irritable. One child experienced insomnia in the low caffeine condition.

Discussion

The present findings tend to replicate other investigations comparing the effects of caffeine and methylphenidate (Huestis et al., 1975; Garfinkel et al., 1975). Caffeine did not result in significantly improved performance either at the 300 mg. or 500 mg. per day level. It is interesting to note, however, that slight improvement was in evidence on 50% of the dependent measures in the low caffeine condition and on 75% of these measures in the high caffeine condition (see table 2). The finding of no reliable improvement with caffeine, as compared to placebo, is contrary to a previous study by one of the authors (P.F.). One explanation might be that the children in the two studies differed. Firestone et al. (1978b) solicited subjects from schools, and the majority of those children had never been referred for professional help for behavior problems. The children in the present study had all been referred to the hospital because of their long-standing behavioral difficulties. A comparison of the scores on the five factors of Conners (1969) rating scale for teachers revealed no differences between the children in the two studies, attenuating this hypothesis. An interesting question that arises concerns why some children are referred to hospitals or clinics for their hyperactivity while others are not.

As reported elsewhere (Conners, 1975; Schnackenberg, 1973; Firestone et al., 1978b), caffeine did not have any serious side effects and was well tolerated by all children. In addition, as in other
reports (Conners, 1975; Heustis et al., 1975), several children seemed to show slight improvement while taking caffeine, including one child who reacted poorly to methylphenidate. However, several issues require comment before children are subjected to large amounts of caffeine. Aside from the lack of information concerning appropriate dosages, there is no information available concerning the long-term effects of high dosages of caffeine with children. In addition, caffeine tablets are not commercially available and it is not known whether caffeine ingested in coffee acts similarly to that contained in prepared tablets.

Although not completely consistent with other investigations, methylphenidate has, once again, demonstrated its effectiveness. Unlike in some studies, there were no significant improvements found in reaction time or the Matching Familiar Figures Test measures of vigilance and impulsivity (Sprague et al., 1970; Campbell et al., 1971). However, performance on the Maze test and impulsive responses on the reaction-time apparatus, measures of motor inhibition, did show improvement. This discrepancy is not totally surprising. Knights (1974) points out that sensitivity to stimulant medication on the reaction-time task has been demonstrated in only 50% of published studies and the corresponding rate for the MFF is approximately 31%. Tests of motor inhibition have been sensitive in only 33% of the investigations utilizing these measures.

The home and school behavior of hyperactive children improved dramatically for the majority of the children taking methylphenidate. Several recent reviews (Barkley, 1977; Knights, 1974; Whalen and Henker, 1977) report that approximately 75% of hyperactive children are likely to benefit in the sphere of social functioning with this medication. It seems that these children become less oppositional and more easygoing and are more able to tolerate minimal frustration.

The present findings suggest that caffeine is not a meaningful alternative to methylphenidate for hyperactive children. Rather, other well-known and relatively “safe” medications that are readily available ought to be tried when children require pharmacological intervention.
REFERENCES


