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Effects of Caffeine Consumption on Cardiovascular Indices, Attention, Task Performance, and Memory Retention in Children

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EFFECTS OF CAFFEINE CONSUMPTION ON CARDIOVASCULAR INDICES, ATTENTION, TASK PERFORMANCE, AND MEMORY RETENTION IN CHILDREN

by

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EFFECTS OF CAFFEINE CONSUMPTION ON CARDIOVASCULAR INDICES, ATTENTION, TASK PERFORMANCE, AND MEMORY RETENTION IN CHILDREN

Suzanne L. Keller, Ph.D.

Western Michigan University, 1994

Caffeine is one of the most commonly used drugs in the western world today. Average intake of caffeine in the United States has been estimated at greater than 200 mg daily per person. Although plagued by inconsistencies, and methodological problems, research suggests that this level of caffeine ingestion may have significant effects on cardiovascular functioning, and behavioral processes such as attention, cognitive processing, memory, and task performance.

Although children consume significant quantities of caffeine, very little research has been done on the effects of caffeine in children. The limited findings suggest that caffeine consumption may affect the cognitive and behavioral skills necessary for success in school. Further research is needed to verify and extend the modest collection of studies with children.

This study evaluated the effects of caffeine on cardiovascular indices, attention, task performance, and memory retention. Eight children, between 6 and 8 years old, completed a series of computer tasks to assess caffeine effects on measures of learning and cognitive processing, using a single-subject, double-blind, alternating treatment design. Children were tested with 0 mg/kg, 2 mg/kg, and 4 mg/kg to determine if different levels of the drug had differential effects.

The results include: (a) statistically significant increases in systolic and diastolic blood pressures across conditions, (b) moderate decreases in heart rate, (c) the

Attention, Performance, and Memory Tasks show biphasic effects, with increased performance levels at the 2 mg/kg level and lower performance levels at 0 mg/kg and 4 mg/kg.

The results of this study suggest that caffeine may have significant effects on the cardiovascular system and dose dependent effects on learning and cognitive performance. These results warrant further caffeine research with children, and suggest the need to monitor caffeine intake and restrict excessive consumption with children.

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I would like to dedicate this dissertation to my parents: Kenneth and Helen Yeakey for always believing that I could achieve. This dedication is also to my husband, Joseph, and son and daughter, Joshua and Rebecca, whose understanding and patience throughout my graduate career have supported me through the long journey.

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Suzanne L. Keller

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CHAPTER I

INTRODUCTION

Caffeine is one of the most commonly used psychotropic drugs in the western world today. It is found in coffee, tea, carbonated beverages, cocoa, and chocolate products. Many non-prescription drugs for pain relief, weight loss, premenstrual cramps, and alertness also contain significant amounts of added caffeine, with little scientific evidence of its effects on the related primary symptoms. The average intake of caffeine in the United States has been estimated at greater than 200 mg daily, per person (Graham, 1978). This amount is equal to the consumption of two or three cups of coffee for every man, woman, and child, each day.

Coffee is the major source of caffeine for adults. Tea, carbonated beverages, and chocolate also provide caffeine for adults, but are consumed on a smaller scale, and typically have lower levels of caffeine per serving than does coffee (Leviton, 1992).

Children also consume significant amounts of caffeine. The ever popular carbonated beverages (e.g., Coca-Cola, Pepsi Cola, Mountain Dew) and chocolate candy are by far, the major source of caffeine for children in the United States. Leviton (1992) estimates that children between the ages of 1 and 5 years, consume an average of 2.1 mg/kg per day; older children (ages 6 to 17) consume an average of 1.4 mg/kg per day. With these averages, a 40 pound, 5 year old consumes an average 60 mg of caffeine daily. A 12 year old, weighing 100 pounds, consumes an average 70 mg of caffeine daily. Leviton's estimates are just averages. It is safe to say that some children consume no caffeine and are caffeine naive; while other children consume significantly more caffeine than adults when considering dosage to overall body weight (Graham 1978).

Because of the ubiquitous use of caffeine, it is essential to determine caffeine's physiological and behavioral effects on humans. Moreover, the importance of determining the effects of caffeine increases, when we consider the powerful effect it may have on the specific population of children, taking into account both acute and long-term physiological and learning effects which may carry over into adult life.

The purpose of this review is to summarize and integrate research on the physiological and behavioral effects of caffeine consumption on humans, specifically children. Among the topics that will be covered are: the physiological effects of caffeine; the relationships between caffeine consumption and health and medical conditions; and the effects on behavioral indices such as attention, performance and memory.

There have been several extensive reviews written, dealing with the varied effects of caffeine on adult populations (e.g., Hull, 1935; Shapiro, Lane, & Henry, 1986; Weiss & Laties, 1962). Because there is not a corresponding wealth of written information about children, this review will focus on the effects of caffeine on children. Along with this review on children, there will be brief comparisons made to the literature on adult populations. There has been some suggestion that children may well process caffeine differently than adults. Yet there have been few studies to refute or dispute these claims. Also, there are several aspects of learning that have only been researched in adult populations, leaving gaps in the literature with children. These neglected learning aspects deserve mention and warrant formulation of future research questions.

The bulk of the literature pertaining to caffeine and children has focused on hyperactive and learning disabled children (e.g., Conners, 1975 and 1979; Harvey &

Marsh, 1978; Leviton, 1992). The methodologies employed in these studies focused on aspects of learning and behavior using children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD). The results of this population focus can not be assumed to be transferrable to the learning capabilities of a normal (non-impaired) child. Many of the studies also compared the effects of caffeine to amphetamines, a common pharmacological agent used in the treatment of ADHD. Again, this is not relevant to children who have no learning problems and are not taking amphetamines to help enhance their performance in a school setting. These studies also, will not be elaborated on.

In summary, the focus of this paper then, is on the physiological and behavioral effects that caffeine may have on the normal child, ingesting caffeine on a daily basis. Ultimately, conclusions will be made as to whether or not caffeine may play a role in the normal child's learning ability.

Caffeine and Medical / Psychiatric Disorders

Researchers have explored many areas of medical disorders, looking for a possible link to caffeine ingestion. These studies have exclusively focused on adult populations. Whether or not one can assume that these medical disorders linked to caffeine ingestion, can be caused by chronic use of caffeine over the years, possibly beginning in early childhood is unclear from the literature.

Caffeine has been linked with disorders in the gastrointestinal system (Curatola & Robertson, 1983). It has been speculated to be a factor in promoting certain types of cancer (Rosenberg, 1985). Several animal studies have indicated a correlation between caffeine ingestion, birth defects, and ongoing learning deficits (Castellano, 1976; Ohnishi, et al., 1986; Watkinson, 1985; Zimmerberg, Carr, Scott, Lee, & Weider, 1991). Other studies link caffeine use to breast disease and cardiac problems

(Rosenberg, 1985). Caffeine has been correlated with essential hypertension (Sutherland, McPherson, Renton, Spencer, & Montague, 1985), a serious medical problem in itself, and a risk factor for other cardiovascular diseases. The studies involving human subjects were either correlational or survey studies because of the ethical nature of administering caffeine to populations at risk. Also, the studies had varying methodologies, with varying acute or chronic caffeine dosages, making it difficult to make comparisons across studies. Although valuable information can be obtained from these works, conclusions must be evaluated carefully because of the methodological variations.

Caffeine has been associated with the Diagnostic and Statistical Manual of Mental Disorders, 3rd edition, revised (DSM-III-R) as a psychiatric disorder: Caffeine Intoxication. This psychiatric diagnostic classification requires: "(a) recent consumption of caffeine, usually in excess of 250 mg; (b) five of the following signs of; restlessness, nervousness, excitement, insomnia, flushed face, diuresis, gastrointestinal disturbance, muscle twitching, rambling flow of thought and speech, tachycardia or arrhythmia, periods of inexhaustibility, and psychomotor agitation; and (c) the condition is not due to any physical or other mental disorder such as an Anxiety Disorder " (The American Psychiatric Association, 1987). The DSM-III-R advises that caffeine intoxication may lead to, or exacerbate the medical conditions previously discussed.

The newly published Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV) incorporated another diagnostic criterion. It requires that the symptoms exhibited must somehow "cause clinically significant distress or impairment in social, occupational, or other important areas of functioning." The DSM-IV has also included two related disorders: (1) Caffeine-Induced Anxiety Disorder; and (2) Caffeine-Induced Sleep Disorder (American Psychiatric Association, 1994). These disorders typically occur only with consumption of large amounts of caffeine (greater than 1 gram), but some symptoms can be exhibited with ingestion of as little as 100 mg of caffeine daily. In most instances, if the person experiencing these symptoms reduces the daily amount of caffeine, the symptoms will decrease or be alleviated.

Although the literature reports varied medical and psychiatric risks with an adult population, there is no evidence that caffeine plays a significant role in medical and psychiatric disorders in children specifically. There is no literature affirming the conclusion that caffeine plays a significant role in childhood medical and psychiatric disorders; nor is there literature denying it. Also, the literature has not addressed the effect of chronic caffeine consumption, beginning in childhood, as playing a possible role in adult medical and psychiatric conditions. These two areas need to be assessed carefully for a more complete examination of caffeine's effect on children. Future research should elaborate on the medical and psychiatric effects of caffeine with child populations as well as delving into the possible long-term effects that caffeine may have on adults who began ingesting caffeine during childhood.

Physiological Effects of Caffeine

Caffeine is a trimethylated xanthine, from the xanthine chemical family that includes theophylline and theobromine. Caffeine's primary physiological effect is stimulation of the central nervous system (CNS) including all portions of the cerebral cortex. This CNS stimulation presumably increases the rapidity and clarity of thought, allowing for a better association of ideas (Pilette, 1983). Sensory stimuli are heightened while enhancing alertness, by allaying drowsiness and fatigue (Greden, 1980). This stimulation also affects the medullary centers of the brain, thus producing anxiety, nervousness, agitation, rapid breathing, and irritability. In addition, the CNS mediated effect of caffeine provokes the heart which can lead to increased heartbeat, palpitations, arrhythmias and increased cardiac output (Rall, 1980).

The literature on the effects of caffeine in children is not as extensive as with adults. In 1987, Baer reported that: "Many American children consume enough caffeine (between 3 mg/kg and 11 mg/kg, per day) to cause central nervous system stimulation." Baer (1987) studied the behavioral effects of caffeine on six 5 year old children in a classroom setting. She did not focus on physiological effects as a dependent variable.

Elkins and associates (1981) studied 19 normal prepubertal boys to determine acute effects of caffeine. Each subject was given one administration of 3 mg/kg, 10 mg/kg and a placebo in a double-blind crossover design. Cardiovasuclar indices and urinary output of catecholamines and metabolites were measured. No significant effect on norepinephrine excretion was found. There was a trend toward an increase in epinephrine excretion. The cardiovascular indices measured during the study were not reported.

In a caffeine challenge study using 38 grade-school children (19 high caffeine consumers, 19 low caffeine consumers) in a crossover design, only the physiological measures of blood pressure (BP) heart rate (HR) and salivary caffeine level were obtained (Rapoport, Berg, Ismond, Zahn, & Neims, 1984). These measures were not obtained at time of consumption, but on a biweekly basis. The researchers reported no changes in any of cardiovascular measures between groups at time of visits.

None of these studies reported acute physiological effects of caffeine. Additionally, these studies used only vague global descriptions of distress related to caffeine ingestion. To be more conclusive, better operationally defined criteria and more extensive measurement and reporting must be implemented in future research to determine the physiological effects of caffeine in children.

If caffeine affects an individual physiologically, withdrawal and tolerance issues should be considered when assessing chronic use. The issue of tolerance has been only marginally researched. As with much of the caffeine literature to date, more studies have been completed with adult populations than with child populations.

Izzo, Ghosal, Kwong, Freeman, and Jaenike (1985) found that adult non-users of caffeine (caffeine-naive) had an accentuated reactivity to caffeine when compared to adult chronic caffeine users. This suggested that tolerance might be an effect of continued caffeine use. Lessening caffeine amounts induced increases in HR and decreases in BP as chronic caffeine users developed tolerance to the drug.

A more recent study in the Netherlands replicated this result and reported only a minor decrease in SBP (1.5 mmHg) and DBP (1.0 mmHg), with a slight increase in HR (1.3 BPM), in habitual coffee drinkers who had replaced their typical caffeinated coffee diet with a decaffeinated coffee diet These results suggest that habitual coffee drinkers, developed a tolerance to caffeine lowering cardiovascular reactivity. Upon caffeine termination, only a minor return to pre-caffeine baseline occurred (van Dusseldorp, Smits, Thien, & Katin, 1989).

Gilbert (1976) observed adult human dependence on caffeine after continued use. By withholding caffeine, various withdrawal symptoms such as anxiety, irritability, fatigue, headache, and depressed mood were created. By ingesting more caffeine these withdrawal symptoms were eliminated.

This finding was in disagreement with the Rapoport, et al. (1984) caffeine study using school age children. The researchers argued that the reported results were independent of withdrawal and tolerance effects in this study. All subjects in this study had been on a baseline caffeine free diet, for two weeks. There were no reported changes in HR and BP between groups in any phase. These results are limited in that individual changes between phases were not reported. More importantly the subjects were only assessed on a biweekly basis. This would not allow for accurate measurement at time of consumption or when possible withdrawal symptoms might be most prevalent. The results are based on self-report indices taken during the biweekly meetings. This time frame might allow for a level of incorrect memory, and distorted self report.

Both withdrawal and tolerance are important concepts to be considered with caffeine use. To date studies evaluating the the effects of caffeine on adults and children have focused more on acute ingestion rather than chronic ingestion. Two very important areas to explore then would be populations of chronic caffeine consumers who abruptly terminate use of caffeine, to measure withdrawal effects, and a comparison between individuals who have a history of chronic ingestion with caffeine-naive individuals, wherein tolerance issues could be addressed. Results from these types of study could determine physiological effects related to withdrawal and tolerance. These studies should be completed with differing age ranges to determine if possible withdrawal and tolerance effects evidenced are consistent across ages.

Effects of Caffeine on Cardiovascular Indices

Caffeine ingestion has been associated specifically with cardiovascular effects in a number of studies leading to speculation about the potential role of caffeine in the etiology and exacerbation of a number of cardiovascular health problems. In an adult population, Whitsettt, Manion and Christensen (1984) found that caffeine altered heart rate (HR), systolic and diastolic blood pressure (SBP and DBP respectively) in caffeine users. This alteration consisted of marked increases in both SBP and DBP along with a maximal decrease in HR from 71 to 46 beats per minute.

Robertson, et al. (1978) studied the effect of a single administration of 250 mg of caffeine and also showed marked changes in the cardiovascular indices. BP increased by 14/10 mmHg along with a marked decrease in HR from baseline levels.

Three separate studies measuring stress and cardiovascular indices reported an additive effect in BP increases and HR decreases when an adult, who had ingested caffeine, was then placed in a stressful situation. These studies were able to separate out the effects of caffeine and stress by measuring each independent variable separately and then in conjunction with each other (Keller, 1988; Lane & Williams, 1985 and 1987).

Research measuring cardiovasuclar indices in children is not plentiful. In one of the few studies using children, there were no significant changes in HR or BP between high and low consumer groups with chronic use of caffeine (Rapoport, et al. 1984). The subjects in this study were normal school age children (mean age 10.3 years) with habitual caffeine consumption histories. Two groups were formed with the high caffeine consumers ingesting a pre-challenge study average of 290 mg/wk and low caffeine consumers ingesting an average of 95 mg/wk. Each group was exposed to two week periods of placebo, no caffeine, and 10 mg/kg per day. BP and HR were not measured at the time of caffeine consumption, in this study but only at screening and on a biweekly basis. Although tolerance issues were addressed, the immediate physiological effects on the cardiovascular indices could not be evaluated. Rapoport reported no significant differences in BP or HR between the groups at any point. It is difficult to extrapolate from this study the exact cardiovascular measurements, as the only reported results were mean averages between groups.

Effects of Caffeine on Attention

In addition to the physiological effects, caffeine has been found to alter attention. Attention is defined as the ability to mentally concentrate, notice and observe (Guralnik, 1984). In order to adequately measure the effects of caffeine on attention, one must be able to measure then, caffeine's effects on concentration and observational capacities (vigilance).

Davidson and Smith (1991), using college students, hypothesized that the CNS arousal associated with caffeine ingestion decreased habituation to a stimulus, allowing for less boredom and greater concentration. Their research confirmed that an acute administration of 300 mg of caffeine produced and maintained increased arousal, reported as increased visual vigilance. The data also suggested that caffeine selectively eliminated habituation under novel conditions (non-repetitive tasks) allowing for maintained attention over a longer period of time.

In another study with adult volunteers, Fagan, Swift, and Tiplady (1988) reported that 200 mg of caffeine sustained the initial level of performance through increased attention over time. This was more evident in the analogue measures of alertness and interest in the second thirty minutes of the one-hour performance test.

Zwyghuizen-Doorenbos, Roehrs, Lipshutz, Timms, and Roth (1990) determined that 250 mg of caffeine increased auditory vigilance performance and decreased mean reaction time in normal sleep-patterned college males. The study determined that caffeine increased daytime alertness.

In a study unrelated to caffeine use, Heinbuck and Hershberger (1989) found that visual attention could be shifted within time spans when testing 5 and 8 year olds. They also found that 5 year olds required more explicit cues provided in advance and more time to shift their visual attention than 8 year olds. A longer latency time for attention shifts in 5 year olds was also recorded in the research. It has been found that children who are easily distracted from learning tasks, learn less than those who pay attention (Kaplan, 1991). Extrapolating from the adult literature, one might be able to argue for potential improved attention in children, with caffeine use.

In a study of hyperactive children treated with 200 mg of caffeinated coffee, Harvey and Marsh (1978) found that most children (mean age 7.26) showed decreased hyperactive behaviors while ingesting coffee, compared to baseline with no coffee intake. This decrease in disruptive behavior allowed for increased attention in learning tasks.

Another study found that 10 mg/kg of caffeine resulted in increased vigilance (sustained attention) for boys (Elkins, et al., 1981). This study incorporated nineteen prepubertal boys that were free of behavior and/or learning problems. Each subject was given a single dose of placebo, 3 mg/kg, and 10 mg/kg of caffeine in a double-blind, crossover study.

In opposition to these findings, Baer's study (1987) did not find significant results with five year old children on sustained attention. She administered up to 2.5 mg/kg of caffeine and measured attention on such tasks as the Paired Associates Learning Test (PAL), and The Continuous Performance Test (CPT).

These studies suggest that caffeine may enhance the ability to mentally concentrate, notice, and observe in children. Problems with the studies to date include; acute caffeine administration only, varied methodologies, and inconsistent measurement devices. To better determine the effects that caffeine may have on attention in children, replications and extensions of previous research should be initiated to verify these results. Care should also be taken to incorporate repeated caffeine administrations into the research which could help determine what role tolerance and withdrawal may play on attention.

Effects of Caffeine on Performance

It seems fairly evident from the research cited above that attention is somewhat increased by caffeine ingestion. Yet, attention alone, does not dictate that performance (the ability to execute an action) improves across all tasks. The existing research suggests that caffeine may have a multi-dimensional effect on performance. That is, caffeine ingestion may enhance performance on some tasks while it decreases the ability to execute an action in other areas (Fagan, Swift, & Tiplady, 1988). This may be related to novelty of the experience, difficulty of the task, or a variety of other variables inherent in the research process.

As reported, caffeine increases sustained vigilance which, in turn, often results in improved performance on a variety of tasks. The arousing properties have been shown to produce faster simple reaction times, and decision times, as well as increased visual vigilance in college students given an acute administration of 300 mg of caffeine. Results of decreased eye-hand coordination and recall performance in adults was also reported (Davidson & Smith, 1991).

Gilliland and Nelson (1939), in an often cited study, reported that caffeine increased adult rate of adding on a mental arithmetic task while decreasing the rate of tapping on a motor coordination task. They summarized that caffeine had a stimulative effect on certain functions; while having a depressive effect on others.

In another study using an adult population and acute administration, Foreman, Barraclough, Moore, Mehta, and Madon (1989) hypothesized that while caffeine decreased reaction time; manual dexterity and hand-eye coordination were adversely effected, creating a null effect on the Stroop Task. They also queried whether the time of day might affect performance and proposed future research in that area.

Baker and Theologus (1972) looked at caffeine's ability to repress the tendency toward response blocking in monotonous tasks. In 100 male subjects, receiving either

200 mg or 400 mg of caffeine, improved vigilance and performance on a simple visual monitoring task were achieved. More importantly, this improvement in performance increased in the latter stages of the four hour test.

In 1988, Landrum, Meliska and Loke failed to find significant effects on reading comprehension, writing rate, tapping rate, reaction time, and serial recall in 44 undergraduate college students who had been given an acute administration of 200 mg of caffeine. These students had been grouped by historical caffeine usage into high and low caffeine user groups.

In most of the adult studies cited above, performance was increased, in conjunction with the aroused attention component in adults. As is the case with attention, it is difficult to conclude caffeine's effect with adults because of the varying methodologies employed, dosage administrations, and lack of discrimination between caffeine-naive and chronic caffeine consumer populations.

Elkins and associates (1981) measured children's performance on the Continuous Performance Test (CPT) and a reaction time test. After acute caffeine administration of 3 mg/kg or 10 mg/kg, the subjects were found to have decreased reaction times compared to placebo. The CPT results showed improved performance and a decreased number of errors of omission and commission across both levels of caffeine. Interstimulus interval was also decreased on the CPT. These results suggest enhanced performance when using caffeine.

Rapoport et al. (1981), in their study comparing acute caffeine effects in normal boys (mean age 10.6 years) and adult males reported no significant differences across conditions on the CPT for adult males or boys. There was no improvement on errors of omission or commission, or interstimulus interval. The researchers did report that the children tended to perform more poorly on the verbal learning task, but with no overall significant results.

In a 1984 study, Rapoport and associates again used the CPT to monitor performance in high and low caffeine consumer groups (mean age 10.3 years). This study employed a chronic administration of 10 mg/kg of caffeine or placebo in two week periods. This study reported no significant effect of caffeine on reaction time, CPT omission or commission errors, or interstimulus interval. There was a trend toward decreased omission errors across groups only.

Baer (1987), in her study utilizing acute caffeine administration on 5 year old students, found no relationship between caffeine intake and the Paired Associates Learning Test (PAL). There was also no relationship between caffeine intake and errors of omission or commission on the CPT. Baer suggested that this lack of results might be due to low dosage administration of caffeine. She suggested that increased dosages might have yielded significant results.

These studies show conflicting results on performance in children. Many of the studies suggest multi-components of performance, but do not elaborate on specific effects except for reaction times. Much more research needs to be done to tease out exactly what effects on performance exist. Studies should incorporate varied tasks (e.g., simple versus complex tasks) to determine if in fact, caffeine does have a multi-dimensional effect on performance. Repeated caffeine trials should be incorporated to tease out the effects of potential caffeine tolerance. Consistent methodologies must be employed to allow for better comparisons. With these suggestions in mind a more complete assessment can be made on the effects of caffeine on children's performance.

Effects of Caffeine on Memory

When reviewing the memory literature, one must distinguish between memory and attention, just as one must distinguish between performance and attention. If attention is not maintained, one will not be able to recall the information. Terry and

Phifer (1986) found that caffeine, even in small amounts (1 cup of coffee) could have adverse effects in adult's memory on the Auditory Verbal Learning Test (AVLT) for memory assessment.

In 1988, Loke determined that caffeine affects memory in a differential way. Caffeine has been shown to enhance low memory load tasks but to decrease performance in high memory load tasks in college graduate students. In earlier research on memory load tasks, Loke, Hinrichs and Ghoneim (1985), found that caffeine showed no significant effects regarding cognitive, learning and memory tasks. With the discrepancies in results reported in studies to date it is more difficult to determine any universal or systematic effect of the drug on an individual's memory, whereas the performance and attention measures, although conflicting, seem to be more concrete.

Perhaps a better operational definition of memory needs to be made. Memory is defined as the power or act of remembering (Guralnik, 1984). Memory span for digits from age five to adulthood doubles, but may be caused by an increase in efficiency of information processing (Engle, Carullo & Collins, 1991). Rehearsal strategies play an important role in memory span tasks and recall. According to Henry (1991) if items are rehearsed quickly, they are retrieved more efficiently. This suggests that the speed of rehearsal is directly related to the number of words that can be retrieved from short term memory.

The primacy and recency effect are directly related to different components of memory. The primacy effect, wherein words or digits that are presented at the beginning of the test are retrieved from memory with greater ease, has been associated with long term memory. This association has been made because it is believed that the words or digits have been converted from short term, working memory into long term memory allowing for better recall (Bourne & Ekstrand, 1985). The recency effect, wherein words and digits that appear at the end of the test are recalled with greater proficiency, has been associated with short term (working) memory. The immediate recall of the information last presented is associated with the recall in short term working memory because the subject can recite accurately the items based upon the order of presentation, not specifically the learned proficiency of the material (American Journal of Psychology, 1989).

Erickson (1985) reported that caffeine impaired adult performance on memory tasks that placed higher demands on the capacity of the working memory. While finding non-significant effects in male subjects, female subjects had significant decreases in serial position, primacy effects, as well as recency effects (working memory). This study discussed the possibility of differences in the way genders process and retain information. A major problem with this study involved the differential amounts of caffeine given in a single session in relation to body weights of males and females. This study also did not take into account individual caffeine histories.

It is important to consider the effects on memory with children, because when asked to learn the information presented to them, the information may have a tendency to be lost or easily forgotten, creating long term problems in learning. Little research has been done with caffeine and its effect on the memory of children. Yet children are asked to use both short term (working) and long term memory on a daily basis.

Rapoport et al. (1981) reported non-significant decreases in memory on a verbal memory test (free recall) across both the 3 mg/kg and 10 mg/kg acute caffeine administration conditions. This study comparing adult males to boys (mean age of 10.6 years) showed no differences in memory across groups.

Elkins and associates (1981), reported very similar results in their study with 19 prepubertal boys. The subjects had fewer total correct answers on two short memory procedures with the 3 mg/kg and 10 mg/kg single dose caffeine administrations. The scores on these memory tests worsened with increased caffeine.

Baer (1987) reported only a slight impairment on the PAL which measured both performance and memory. Again, this study used smaller caffeine dosages which may have been below the impairment threshold.

Much work needs to be done in the area of memory with children. Suggestions for future research include; varied memory tasks (e.g., verbal, visual) to more adequately monitor the different components of memory (i.e., short term, long term), repeated caffeine trials to determine tolerance effects, different dosages to differentiate possible dose dependent effects, and consistent methodologies to allow for a better comparison of results.

Conclusions

The conflicting data collected on caffeine and its effects on adult memory, performance, and attention, allow for no specific conclusions on the effects of the drug. The recorded effects of caffeine on children are even less comprehensive and more conflicting. Inherent problems with existing studies include; varying methodologies and caffeine administrations, inconsistent monitoring of caffeine histories, avoidance of addressing tolerance and withdrawal issues, and lack of comparisons between caffeine naive and chronic consumer populations. With the obvious conflicting, inconclusive results and lack of conclusive evidence on the role caffeine plays on learning and memory in children, it is important to systematically test for an effect either positive or negative.

This study is an assessment of the effects of caffeine on cardiovascular indices, attention, task performance, and memory retention in children. The research compared repeated caffeine and non-caffeine states under a variety of learning conditions much like the work of Baer, 1987, and Rapoport, et al., 1981 and 1984. But this research extended the previous work by incorporating individual subject repeated exposures to each condition, measurement of cardiovascular indices at time of consumption, and controlled tasks through computer implementation. Results of this study could further determine caffeine's role in the way children learn. If in fact caffeine has a detrimental effect on attention, task performance and memory retention in children, then this research could become a powerful tool in the decision to limit or eliminate caffeine consumption in children altogether. If this research showed mixed or no effects, parents could feel safer in allowing their children to consume caffeine in carbonated beverages and chocolate candy with few expected adverse effects.

CHAPTER II

METHODS

Subjects

Four male and four female children, ranging in age from 6 to 8 years (mean age 7 years, 8 months), participated. A flyer recruiting participants for a caffeine consumption study was sent to the parents/guardians of students in the first and second grades of a local school (Appendix A). Parents or guardians of 10 students expressed interest in the study. Only those students meeting the following three inclusion criteria were allowed to participate. A student consumed caffeine with an average daily consumption of less than 300 mg caffeine (less than five, twelve ounce cans of caffeinated soda) as reported on a parent-completed questionnaire (Appendix B). Secondly, students and their parents/guardians agreed that subjects would abstain from caffeine consumption and make no major changes in diet or exercise over the course of the study. Finally, the student's resting blood pressure could not be greater than 140 mmHg SBP and 80 mmHg DBP. Volunteers meeting the above inclusion criteria, their parents/guardians, and the principal and participating teachers were required to sign separate informed consent forms, prepared in accordance with Western Michigan University's human subjects guidelines (Appendix C, D, and J).

Upon completion of the study each subject was paid $20.00 for his/her participation.

Setting

A small utility room within the school setting was equipped with a Macintosh Classic II computer, a table, and two chairs. The station was also equipped with a portable BP/HR monitor. This room was used for all experimental sessions. The subject was seated in front of the computer monitor throughout the session, with the blood pressure monitoring equipment placed as unobtrusively as possible. The experimenter and observer were visible to the subject throughout the session. All other extraneous stimuli were kept to a minimum.

Apparatus/Materials

Physiological Recording

SBP, DBP, and HR were monitored using the Norelco Digital Blood Pressure Pulse Meter, model HC2901. The child-size monitoring cuff was placed about 1-2 cm above the elbow of the left arm for each reading throughout the session. Detection of Korotkoff sound, BP and HR readings, and cuff inflation/deflation were visually displayed digitally following each determination of BP.

Computer Equipment

All tasks were performed on an Apple Corporation, Macintosh Classic II, using a black and white screen and standard keyboard with mouse. All unnecessary keys were covered to reduce extraneous key closures. The program used to create the different tasks was Hypercard 2.1 (Claris Corporation, 1992).

Drug / Vehicle Preparation

Powdered caffeine in three different quantities (0 mg (placebo), 2 mg/kg, and 4 mg/kg) was combined with 55 g of powdered Tang. Powdered Tang had been used previously in caffeine research (Davidson & Smith, 1991). These researchers reported that subjects were unable to differentiate between caffeine and non-caffeine beverages.

Body weight for each of the subjects was obtained at the beginning of the research and three times throughout the study, to determine if any weight changes had occurred. Weight in pounds was then converted to kilograms. Both caffeine and powdered Tang were weighed on a Ainsworth Gamma N IV analytical balance for accuracy. The resulting powdered mixtures (caffeine and Tang) were prepackaged and prepared by a research assistant on each session day. Instructions were included with each package to: (a) mix the packet with six ounces of distilled water; (b) stir the solution until thoroughly dissolved; (c) instruct the subject to completely consume the solution within five minutes, exactly thirty minutes before scheduled appointment; (d) observe the subject complete the ingestion; and (e) return the empty packet with the date and time ingested written on the provided label. The research assistants administered the prepared drink to the subjects each session day at the research site in a randomized double-blind schedule. Neither experimenters nor subjects were aware of the caffeine dosage in the prepared packets.

Questionnaires

A parent or guardian of potential subjects completed a Caffeine Consumption Checklist on which they reported the average weekly consumption of typical caffeinated foods and beverages for their child (Appendix B). Additionally, the parent or guardian also completed a brief medical history for their child indicating any medical or behavioral problems that might be related to caffeine intake (Appendix E). Caffeine abstinence was monitored daily during the study, through self-report measures and a Daily Caffeine Consumption Checklist sent to school with the child (Appendix I).

Construction of Stimuli

The computer program (Potter, 1993) was developed to present seven different tasks in random order. Each task had been designed to measure components of learning. Some tasks measured multiple components. Sample screens of each computer task are represented in Appendix F.

Attention Task

At four random trials (determined by the computer program) within each session, a blank screen would appear. Within this blank screen an object (pig) would then appear. The subject was to place the arrow on the object and click the mouse. The object appeared a total of five times with random varied durations of appearance, and positions on the screen, within each trial. At no time did the Attention Task interrupt another task. There was a total of five possible correct responses in each trial, with twenty possible correct responses in each session. Responses were followed by computer tones differentiating correct and incorrect responses. If no responses were made within a trial, a one minute time out occurred and the program proceeded to the next task. Attention had been previously measured using visual vigilance tasks similar to this task (Davidson & Smith, 1991).

Math Task

In this task, the subject was asked to answer eight addition/subtraction problems of varying difficulty based on the mathematics textbook used within the subject's classroom. The Math Task was composed of single digit addition (e.g., 3 + 2

=, 7 + 2 =), single digit subtraction (e.g., 9 - 1 =, 5 - 4 =), two digit addition (e.g., 8 + 7 =, 9 + 4 =) and two digit subtraction (e.g., 17 - 9 =, 11 - 3 =) problems. Two problems of each level were presented in each session. All problems were novel and randomly generated, with no repetitions throughout the study. The subject was to enter the answer by using the number pad on the standard keyboard, and click on a "Done" box when completed. If the subject did not know the answer, he/she could click on a "Don't Know" box to progress to the next problem. A computer tone differentiated between correct and incorrect responses. If no answer was attempted, the computer screen darkened, a one minute time out occurred, and the program continued.

The Math Task was incorporated to measure performance in the same manner that Gilliland and Nelson (1939) had measured performance in college students. Differing levels of complexity were employed within this task to try and determine if caffeine might have differential effects on more complex problems.

Copy Task

The subject was asked to correctly copy a series of random numbers that was shown on the computer screen. The subject was to copy as many numbers (in order) as possible, in the time provided (two minutes). No computer tones were incorporated into this task. If a subject failed to make a response, the screen darkened and a one minute time out occurred before the program proceeded. As with the Math Task, this task was representative of visual monitoring performance. This task also monitored for eye-hand coordination and motor dexterity.

Long Term Memory Task

This task incorporated free recall of three pictured objects (e.g., cat, flag, cup) presented on the computer screen. At the beginning of each session the subject was shown pictures of three novel objects and instructed to name each object and then click on the computer screen picture. The subject was instructed to remember these objects as he/she would be asked to name the objects later in the session. At the end of each session (approximately 30 minutes later), the subject was then asked, by a research assistant, to recall each object in order. Verbatim subject responses were recorded by the research assistant with no feedback or cues given. The Long Term Memory Task was incorporated to measure memory in a similar manner as previous research (Baer, 1987; Elkins, et al., 1981; Rapoport, et al., 1981). Using three objects to be remembered in this task also explored the primacy and recency effects reported by Bourne and Ekstrand (1985).

Conditional Rule Task

Memory and discrimination were measured by utilizing a task in which the subject was given a digitized audio simulated verbal instruction to click on the black box if in the series of presented letters, the "O" followed an "X". If the "O" preceded an "X" the subject was instructed to click on the white box. After the verbal rule had been presented, ten series of letters of random length and order were presented during the task. Each subject response was followed by a computer tone differentiating between correct and incorrect responses. If the subject did not make a response, the screen darkened, a one minute time out occurred and the program continued. This task required that a subject process and remember a verbal rule, and employ this rule in a series of problems within the task. This type of task has not been reported in the caffeine literature, but is comparable to many of the instructions given in classroom learning situations.

Direction Following (Verbal Instruction) Task

In the Direction Following Task, a digitized audio simulation, verbalized a series of two to five directions to be completed, in order, on the computer, while a screen of several objects was visible. A sample of a verbal direction might be to; (a) place the arrow on the image of the dog and click, (b) type the number 5, and (c) place the arrow in the black box. The subject clicked on a "Done" box when finished. Three, four and five command directions were employed. A series of six direction sets (two at each command level) were presented randomly in each session. If the subject made no response, the screen would darken, and a one minute time out would occur. The subject could not begin the task (mouse was non-functional) until all directions had been given. Directions were not repeated. Varying computer tones occurred throughout this task.

The Direction Following Task simulated a learning situation in which a student would be given a series of directions and be asked to follow them. No caffeine research in either the adult or child populations has used a comparable auditory memory retention task.

Delayed Matching to Sample Task

In the Delayed Matching to Sample Task, the subject was shown a sample stimulus. The sample was erased when the subject clicked on the stimulus. Either a blank screen or a screen incorporating a visual distraction, appeared for a random period of time. The interim screen was then replaced by a screen displaying five comparison stimuli of similar characteristics to the sample stimulus. The subject was to place the arrow on the object believed to be the correct comparison stimulus, and click on the mouse, thus matching to the sample. A total of twelve presentations of varying difficulty and delay between sample and comparison stimuli occurred in each task. Six of the trials incorporated blank screens of either a 2, 6, or 10 second delay, with the other six trials within the task utilizing either a 2, 6, or 10 second distraction delay. Each trial was randomly determined by the computer, with two trials of each component. Each response was followed by a computer tone differentiating between correct and incorrect responses. If the subject made no response to the sample or comparison stimulus choices, the screen darkened, a time out occurred, and the session progressed.

The Delayed Matching to Sample Task was chosen as a measure of working memory and performance because of similarity to the prior research of Lowenkron (1988 and 1989) that reported decreases in correct responses with increased delays. This task also incorporated retroactive distraction delays to determine if caffeine might have differential effects on the working memory under the two delay conditions.

Safeguards

Although the computer tasks were of such a nature as to place minimal stress on the individual, plans were made to terminate a session and implement relaxation techniques and debriefing if BP rose above 160/95 mm Hg or behaviors indicative of distress (i.e., mood changes, excitability, inattentiveness, restlessness, or crying) occurred. Fortunately, there was no reason to implement these safeguards during the study.

Selection and Training of Experimenters

Experimenters were recruited and received initial information about the nature of the study. Two research assistants signed confidentiality forms and were trained in specific session procedures, including drug preparation and administration, BP and HR measurement, and computer protocol.

Dependent Variables

Physiological Responses

BP and HR were recorded four times during each session: (1) immediately prior to ingestion of the drug vehicle; (2) after a thirty minute waiting period, prior to starting the computer tasks; (3) halfway through the computer tasks, during a pause time pre-established by the computer program; and (4) at completion of the session. Research assistants recorded the visually displayed BP and HR readings on the Norelco Digital Blood Pressure Pulse Meter, model HC2901.

Attention

Attention was assessed through use of the Attention Task within each session. Because of the random placement of the four trials within the session, one would be able to determine if attention was consistent throughout each experimental session. Attention was measured by number of errors of omission/commission, reaction time, and total number of correct responses.

Performance

Performance was measured by use of the Math, Copy, and Direction Following Tasks. These tasks identified visual vigilance, performance on addition and subtraction math problems, and performance on tasks initiated with verbal instructions. Performance was measured on these tasks through number of errors of omission/commission, reaction time, total number of correct responses, and total number of in order correct responses.

Memory Retention

Memory retention was assessed using the Long Term Memory, Conditional Rule, Direction Following, and Delayed Matching To Sample Tasks. These tasks were able to monitor short term (working) memory as well as long term memory. These tasks utilized both visual and auditory stimuli. Memory was measured on these tasks through number of errors of omission/commission, reaction time, total number of correct responses, and total number of in order correct responses.

Behavioral Ratings

Both teachers and parents/guardians completed an abbreviated version of the Conners' Rating Scale (Conners, 1980) each session day. The teacher completed the abbreviated teacher version at the end of the school day. The parents/guardians completed the abbreviated parent version just before the subject's bedtime.

Subjective Measures

Subjects were asked to rate how they felt they had done on the computer tasks. They were also asked to determine whether they had been given caffeine, and if in fact, they could determine any drug-related effects. The subjects were given examples of physiological and emotional labels that could be related to caffeine ingestion (e.g., nervous, anxious, drowsy). These questions occurred at the end of each session and responses were recorded by the research assistants.

Procedure

Initial Meeting

At an initial meeting with subject, parents/guardians, and researcher, parents/guardians were given a questionnaire to determine eligibility. Upon acceptance both parents/guardians and subjects were given an informed consent form to sign, shown the computer program, given a chance to ask any questions, and given instructions about experimental procedure. Parents/guardians and teachers were then given a supply of abbreviated Conners Rating Scales (Appendix G and H) to be filled out, per directions, at the end of each session day. Parents/guardians were also given a supply of Daily Caffeine Consumption Checklists (Appendix I) to complete prior to each session. At completion of this meeting a session schedule was set up.

Individual Sessions

At each session the researcher came into the classroom and took the subject to the experimental room. At that time, the caffeine checklist brought from home, was assessed for abstinence, and the subject was asked if he/she had had anything to eat and/or drink with caffeine in it. The subjects were given examples (e.g. "Did you have any pop?") to help them remember. BP and HR were measured, and the drug vehicle was administered. The subject was then returned to his/her regular classroom for the thirty minute waiting period. After thirty minutes elapsed, the subject was brought to the experimental room and BP and HR measured. The subject sat down in front of the computer and began the program. Halfway through the program, BP and HR were measured again. At completion of the computer tasks, BP and HR were measured a final time and subjective measures were taken before the subject was returned to the regular classroom. Total session time, excluding the thirty minute waiting period, never exceeded thirty minutes.

Independent Variables

The independent variable was the ingestion of a beverage (6 ounces) containing three concentrations of caffeine; (a) 0 mg/kg (placebo), (b) 2 mg/kg, and (c) 4 mg/kg. The amounts of caffeine were individually calculated and weighed out, based on the subject's weight. The total amount of caffeine was then added to the pre-measured (55 g) of powdered Tang. The maximum caffeine dosage allowed for any subject was 180 mg of caffeine, due to possible adverse side effects of a greater dosage. The different levels of the independent variable, not to exceed three of any one level, were presented to the subject on a random double-blind schedule as outlined in the Drug/Vehicle Preparation section.

Experimental Design

A random alternating treatment design across subjects was utilized. The Tang cocktail was introduced randomly in a double-blind schedule over nine experimental sessions, after three baseline-training (no beverage given) sessions were administered across subjects for control measures and to determine practice effect on the computer. Experimental control was demonstrated to the extent that changes in cardiovascular indices, attention, memory retention, and task performance coincided with the presentation of caffeine in each of the subjects.

CHAPTER III

RESULTS

Physiological Responses

Graphic Analysis

Systolic and Diastolic Blood Pressure

Figure 1 displays mean levels of SBP and DBP across caffeine conditions. The panel in the lower right presents a group average, while the remaining panels present averages for individual subjects. Individual data points on these graphs are an average of three BP readings, in each session, with three sessions at each dosage level. Group data show increases in SBP and in DBP in both 2 mg/kg and 4 mg/kg conditions.

Average SBP for all subjects increased by 5.5 mmHg between the 0 mg/kg and 2 mg/kg condition, with an overall increase of 10.4 mmHg between the 0 mg/kg and 4 mg/kg condition. SBP increased by 4.9 mmHg between the 2 mg/kg and 4 mg/kg condition. Mean SBPs were 101.7 $\pm$ 11.41 mmHg (0 mg/kg), 107.2 $\pm$ 11.27 mmHg (2 mg/kg), and 112.1 $\pm$ 8.32 mmHg (4 mg/kg).

Average DBP for all subjects increased by 4.3 mmHg between the 0 mg/kg and 2 mg/kg condition, with an overall increase of 10.6 mmHg between the 0 mg/kg and 4 mg/kg condition. DBP increased by 6.3 mmHg between the 2 mg/kg and 4 mg/kg condition. Mean DBPs were 77.4 $\pm$ 10.99 mmHg (0 mg/kg), 81.7 $\pm$ 8.26 mmHg (2 mg/kg), and 88.0 $\pm$ 4.83 mmHg (4 mg/kg).

Individual data show considerable between-subject variability. While most subjects showed elevations across increasing dosage conditions, subject 4 showed slight decrements in both the 2 mg/kg and 4 mg/kg conditions. This between-subject variability is probably

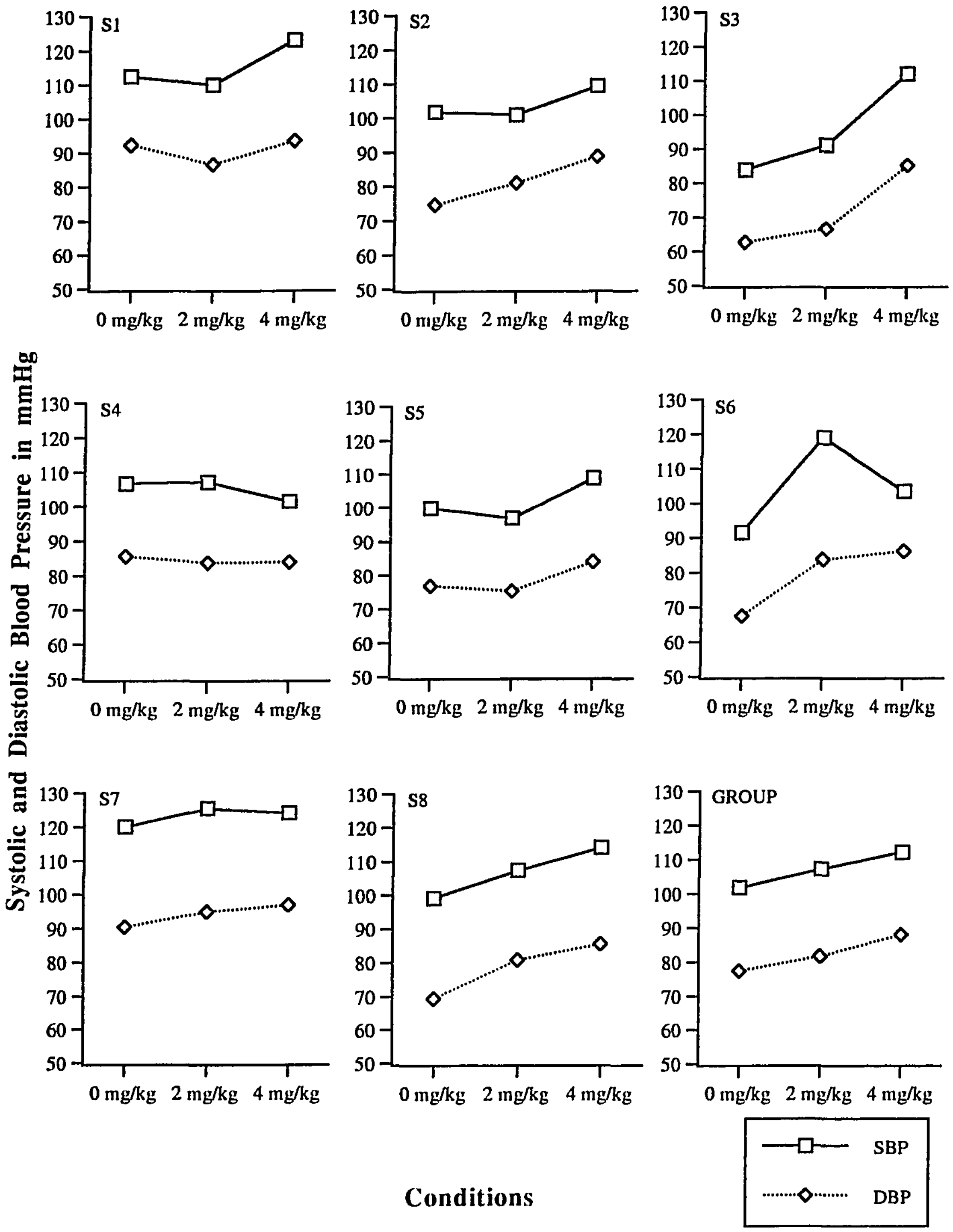


Figure 1. Mean Changes in Systolic and Diastolic Blood Pressures Across Caffeine Conditions by Subject and by Group.

best shown in subject 3 and subject 6. Subject 3 showed marked increases between the 2 mg/kg and 4 mg/kg conditions, while subject 6 had the highest increases in the 2 mg/kg condition.

Heart Rate

Figure 2 displays mean HR levels across caffeine conditions. The lower right panel presents a group average while the remaining panels present averages for individual subjects. Individual data points on these graphs are an average of three HR readings, in each session, with three sessions at each dosage level. Group data show decreases in heart rate at both 2 mg/kg and 4 mg/kg caffeine conditions.

HR was decreased by 2.0 beats per minute (BPM) between the 0 mg/kg and 2 mg/kg condition with an overall decrease of 5.6 BPM between the 0 mg/kg and 4 mg/kg condition. HR decreased by 3.6 BPM between the 2 mg/kg and 4 mg/kg condition. Mean HRs were 90.7 $\pm$ 6.03 BPM (0 mg/kg), 88.7 $\pm$ 8.84 BPM (2 mg/kg), and 85.1 $\pm$ 10.46 BPM (4 mg/kg).

As with both SBP and DBP, individual data show considerable between-subject variability. Subject 4 and subject 7 showed HR increases in the 2 mg/kg caffeine condition. Subject 6 and subject 8 showed HR increases in the 4 mg/kg condition.

Attention

Graphic Analysis

Figure 3 displays the mean percentage of correct answers on the Attention Task across caffeine conditions. The lower right panel presents a group average while the remaining panels present averages for individual subjects. Individual data points on these graphs are a percentage correct average of five stimuli in four trials (20 stimuli total) within a

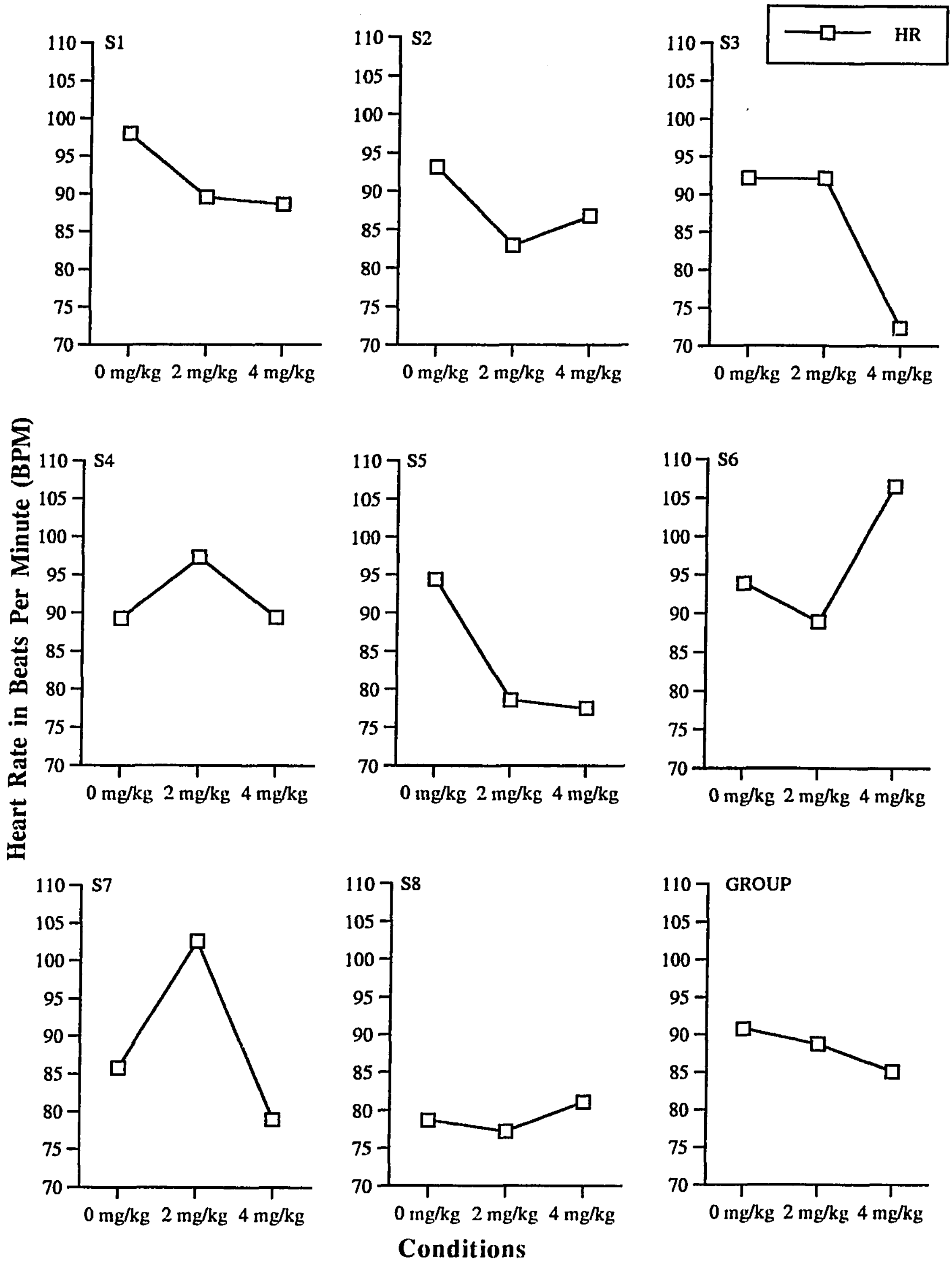


Figure 2. Mean Changes in Heart Rate Across Caffeine Conditions by Subject and by Group.

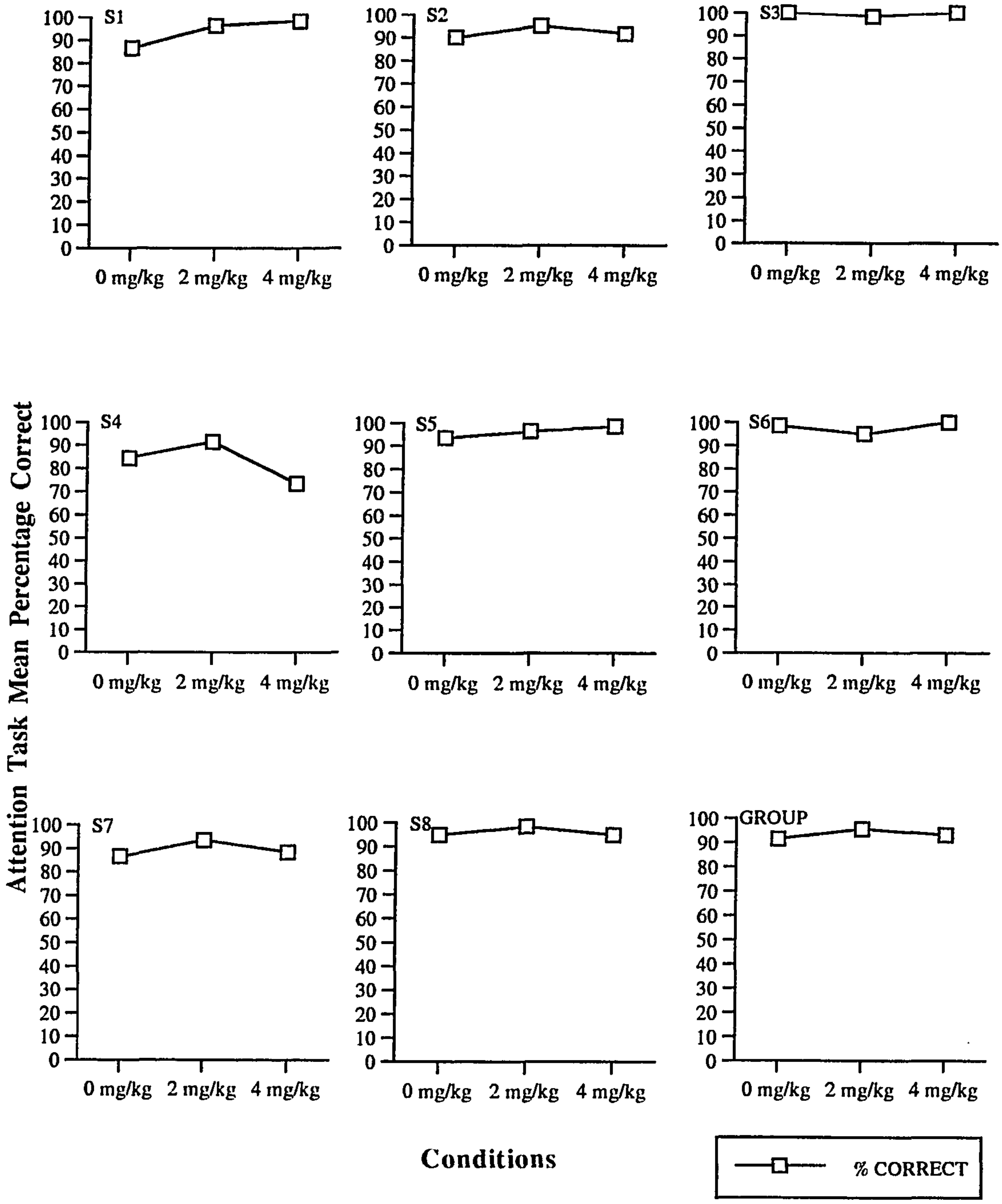


Figure 3. Mean Percentage of Correct Answers on the Attention Task Across Caffeine Conditions by Subject and by Group.

session, with three sessions at each dosage level. Group data show increased percentage correct in both caffeine conditions.

Percentage correct increased by 4% between the 0 mg/kg and 2 mg/kg condition. The percentage correct increased overall only 1.5% with a decrease of 2.5% between the 2 mg/kg and 4 mg/kg caffeine. This might suggest a detrimental effect with higher dosages of caffeine. Mean percentage corrects were 91.5% ($M = 18.3 \pm 1.29$), 95.5% ($M = 19.1 \pm .48$), and 93% ($M = 18.6 \pm 1.80$) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively. At no time did the group mean percentage corrects fall below the 90% range suggesting maintained attention throughout the sessions.

Individual data were more consistent during this task. The lowest percentage correct was found in the 4 mg/kg condition for subject 4, at 73.5%. Overall, only subject 4 and subject 7 fell below 90% correct in any condition.

Performance

Graphic Analysis

Addition Math Task

Figure 4 displays mean percentage of correct answers on the one and two digit Addition Math Task. The panel in the lower right presents a group average while the remaining panels present averages for individual subjects. Individual data points on these graphs are a percentage correct average of two addition problems at each level (one and two digit) within a session, with three sessions at each dosage level. Group data show increases in the mean percentage correct in both the 2 mg/kg and 4 mg/kg conditions.

Percentage of correct one digit addition answers increased 6.2% between the 0 mg/kg and 2 mg/kg condition, with an overall increase of 4.1% from the 0 mg/kg to the 4 mg/kg condition. There was a decrease of 2.1% from the 2 mg/kg to the 4 mg/kg condition. These

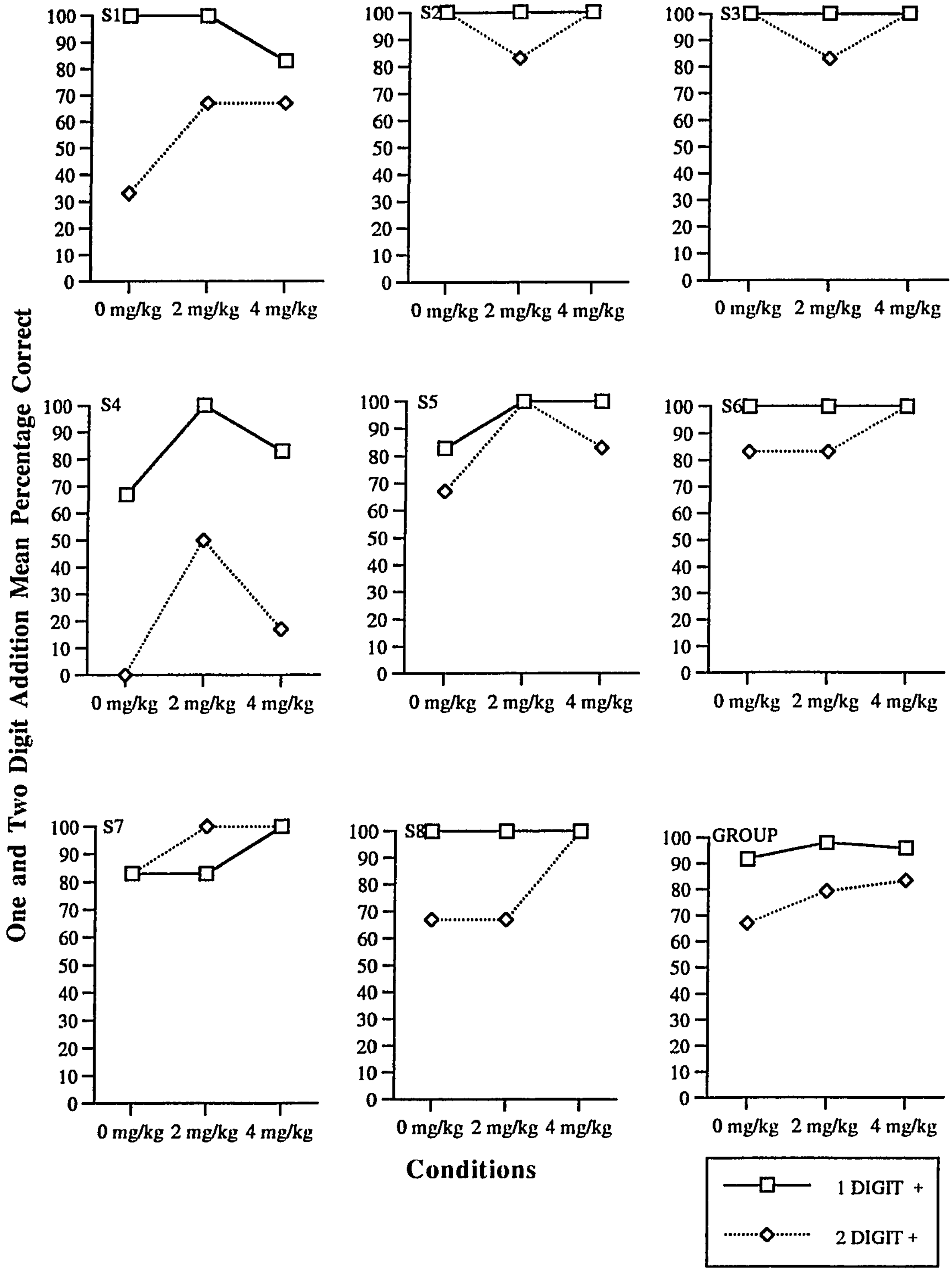


Figure 4. Mean Percentage of One and Two Digit Addition Correct Answers on the Math Task Across Caffeine Conditions by Subject and by Group.

results might suggest that caffeine enhances performance overall, but that more caffeine (i.e., 4 mg/kg) begins to have a negative effect. Mean percentage of correct answers on the one digit addition problems were; (a) 91.7% (M = 1.84 $\pm$ .26), (b) 97.9% (M = 1.96 $\pm$ .11), and (c) 95.8% (M = 1.92 $\pm$ .14) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

Percentage of correct two digit answers increased more consistently. There was a 12.2% increase between the 0 mg/kg and 2 mg/kg condition, with an overall increase of 16.3% from the 0 mg/kg to 4 mg/kg condition. Mean percentage of correct answers increased 4.1% between the 2 mg/kg and 4 mg/kg condition. Although slightly lower, there were increases in both caffeine conditions suggesting that caffeine enhanced performance on the more difficult problems. Mean percentage of correct answers on the two digit addition problems were 67% (M = 1.34 $\pm$ .691), 79.2% (M = 1.6 $\pm$ .36), and 83.3% (M = 1.7 $\pm$ .61) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively. The percentage corrects on the more complicated two digit addition task never reached the level of the one digit addition task, suggesting a level of complexity to challenge this population.

Individual data show considerable variability. One must consider the math proficiency of each subject. Subjects 2, 3, 6, and 8 were in the second grade and had had more exposure to addition. For these subjects there may have been a ceiling effect on the one digit addition problems. For the other subjects, two digit addition problems may have been more novel.

Subtraction Math Task

Figure 5 displays mean percentage of correct answers to the one and two digit Subtraction Math Task. The panel in the lower right presents a group average while the remaining panels present averages for individual subjects. Individual data points on these graphs are a percentage correct average of two subtraction problems at each level (one and two digit) within a session, with three sessions at each dosage level. Group data show

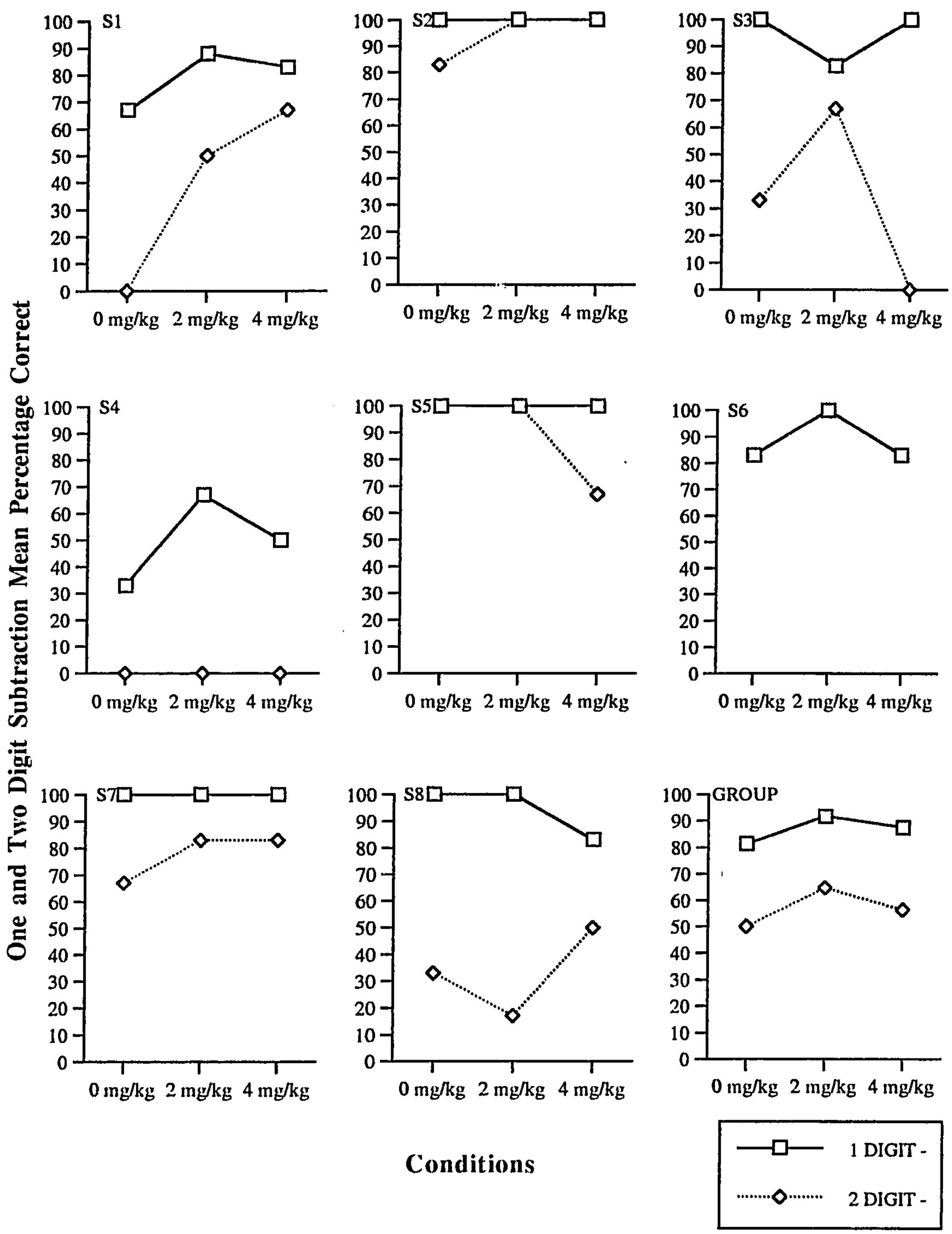


Figure 5. Mean Percentage of One and Two Digit Subtraction Correct Answers on the Math Task Across Caffeine Conditions by Subject and by Group.

increases across both caffeine conditions for percentage of correct answers to subtraction problems.

Percentage of correct one digit subtraction problems increased 10.4% between the 0 mg/kg and 2 mg/kg condition, with an overall increase of 6.2% from the 0 mg/kg to the 4 mg/kg condition. Similar to the one digit addition task, there was a decrease of 4.2% from the 2 mg/kg to the 4 mg/kg condition. This again suggests that caffeine may begin to have a negative effect when increased. Mean percentage of correct answers to the one digit subtraction problems were; (a) 81.3% (M = 1.63 $\pm$ .59), (b) 91.7% (M = 1.83 $\pm$ .26), and (c) 87.5% (M = 1,8 $\pm$ .34) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

Percentage of correct two digit subtraction problems increased by 14.6% between the 0 mg/kg and 2 mg/kg condition, with an overall increase of 6.3% between the 0 mg/kg and 4 mg/kg condition. There was a decrease of 8.3% from the 2 mg/kg to the 4 mg/kg condition. Mean percentage of correct two digit subtraction problems were 50% (M = 1.0 $\pm$ .78), 64.6% (M = 1.3 $\pm$ .79), and 56.3% (M = 1.1 $\pm$ .76) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

Individual data were very variable. There does not appear to be any ceiling effect evidenced in this task. Looking at subjects 1, 4, 5, and 8, who were all first grade students, one can easily say that the two digit subtraction problems might have been quite difficult for them. Even with this level of difficulty, there is a variability in the mean percentage correct, across caffeine conditions, suggesting subjects with individual proficiency levels.

Copy Task

Figure 6 displays the mean percentage of completed and correctly completed numbers on the Copy Task. The panel in the lower right presents a group average while the remaining panels present averages for individual subjects. Individual data points on these graphs are a percentage correct average of a total possible 40 entries within a session, with

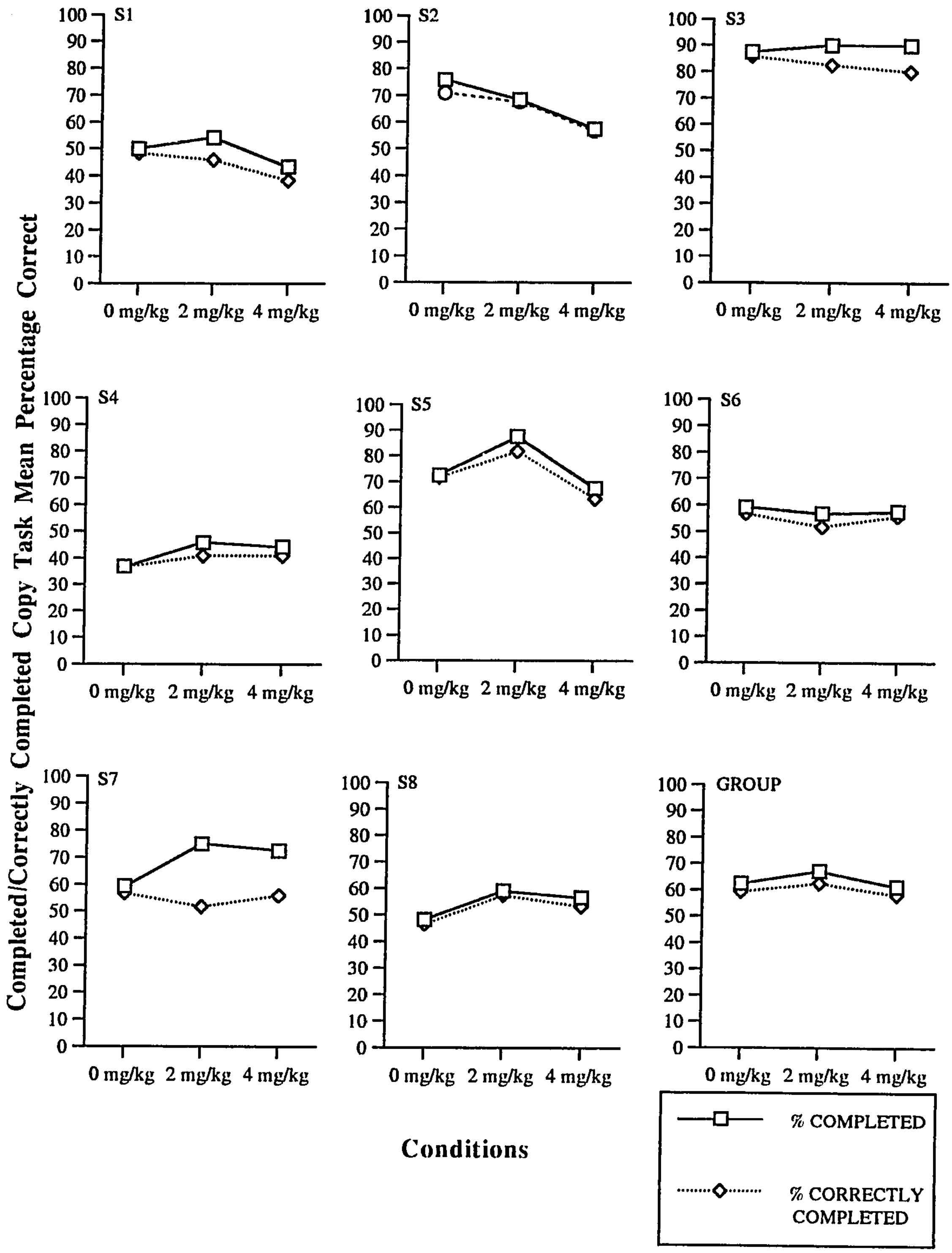


Figure 6. Mean Percentage of Copied and Correctly Copied Numbers on the Copy Task Across Caffeine Conditions by Subject and by Group.

three sessions at each dosage level. Group data show increases in the mean percentage of completed and correctly completed numbers only in the 2 mg/kg condition.

Percentage of of completed numbers increased by 4.8% between the 0 mg/kg and 2 mg/kg condition, with an overall decrease of 1.1% between the 0 mg/kg and the 4 mg/kg condition. There was a decrease of 5.9% between the 2 mg/kg and 4 mg/kg condition. Mean percentage of completed numbers were 62.3% (M = 24.9 $\pm$ 7.16), 67.1% (M = 26.8 $\pm$ 6.40), and 61.2% (M = 24.5 $\pm$ 6.15) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

Percentage of correctly completed numbers shows a similar increase of 3.1% between the 0 mg/kg and 2 mg/kg condition, with an overall decrease of 1.3% between the 0 mg/kg and 4 mg/kg condition. There was a 4.3% decrease between the 2 mg/kg and 4 mg/kg condition. Mean percentage of correctly completed numbers were 59.3% (M = 23.7 $\pm$ 6.39), 62.3% (M = 25.0 $\pm$ 6.37), and 58% (M = 23.2 $\pm$ 6.23) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively. These data suggest that peak performance may be at moderate doses of caffeine with decreased performance at higher levels. The results also depict more modest increases in the percentage of correctly completed numbers suggesting increases in performance as opposed to increases in accuracy.

Individual data again show between-subject variability. Of interest, subject 3 and subject 7 both show increases in mean percentage of completed numbers with decreases in mean percentage of correctly completed numbers. This might suggest an increase in performance with a decrease in overall accuracy. The other subjects display a more parallel balance between performance and accuracy.

Direction Following Task

The Direction Following Task was both a performance and memory task. The results of this task will be described in the Memory Retention section, with graphic analyses in Figures 9 and 10.

Memory Retention

Graphic Analysis

Long Term Memory Task

Figure 7 displays the mean percentage of first, second, and third items correctly recalled on the Long Term Memory Task across caffeine conditions. The panel in the lower right presents a group average while the remaining panels present averages for individual subjects Individual data points on these graphs are a percentage correct average of total recollections (first, second, and third object) within a session, with three sessions at each dosage level. Group data show decreased correct responses in the first and second objects to be recalled across both caffeine conditions. The third item percentage correct is shown to have a slight increase in the 2 mg/kg condition with a decrease in the 4 mg/kg condition.

Percentage of correct first responses decreased by 8.4% between the 0 mg/kg and 2 mg/kg condition, with an overall decrease of 16.7% between the 0 mg/kg and 4 mg/kg condition. There was a decrease of 8.3% from the 2 mg/kg to the 4 mg/kg condition. Mean percentage of correctly recalled first objects were 91.7% ($M = .91 \pm .16$), 83.3% ($M = .83 \pm .18$), and 75% ($M = .75 \pm .39$) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

Percentage of correct second responses decreased by 20.9% between the 0 mg/kg and 2 mg/kg condition. There was no further decrement from the 2 mg/kg to the 4 mg/kg condition for an overall decrease of 20.9% between the 0 mg/kg and 4 mg/kg condition.

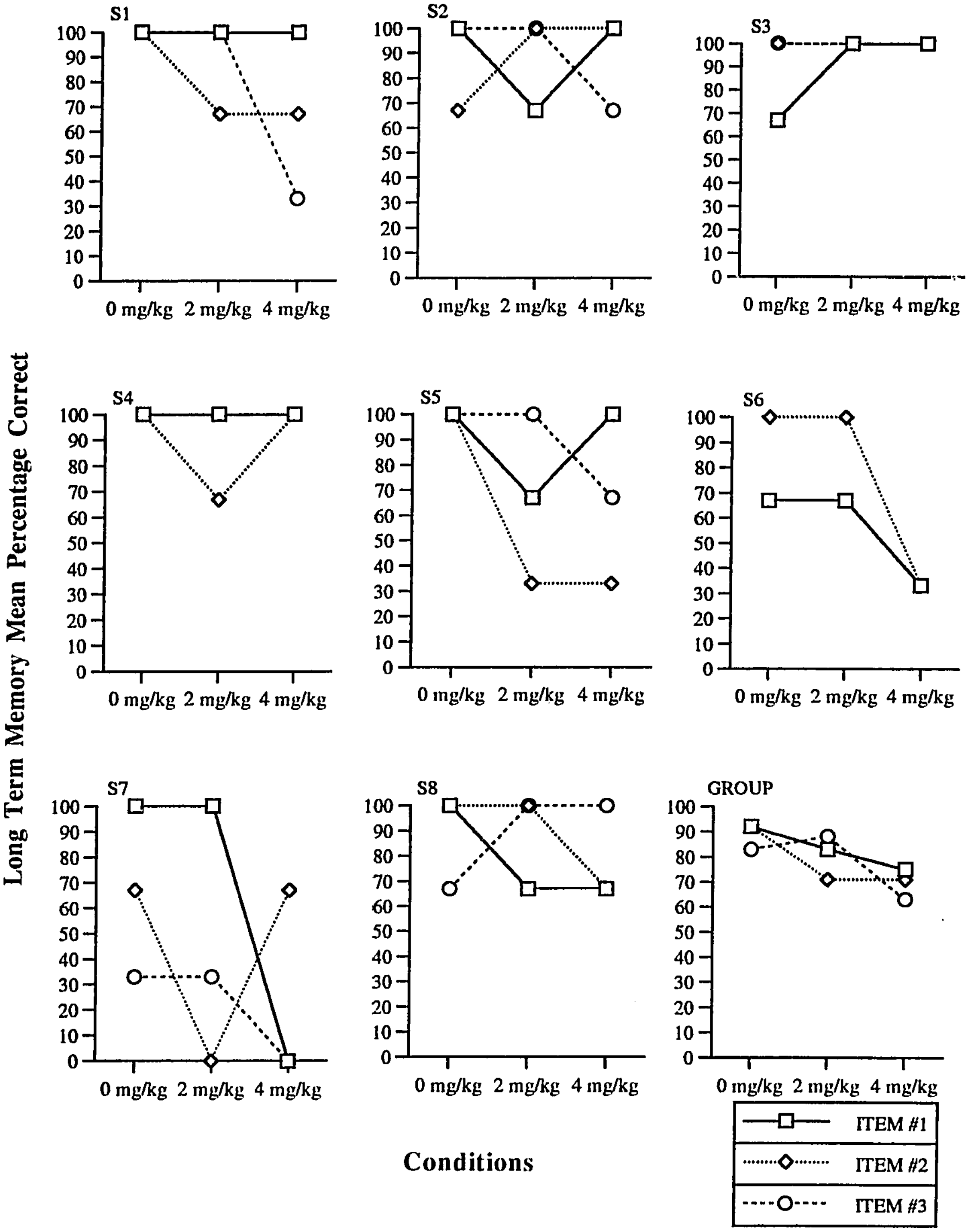


Figure 7. Mean Percentage of First, Second, and Third Correct Items on Long Term Memory Task Across Caffeine Conditions by Subject and by Group.

Mean percentage of correctly recalled second objects were 91.7% (M = .91 ± .16), 70.8% (M = .71 ± ..38), and 70.8% (M = .71 ± .28) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

Percentage of correct third responses increased by 4.2% between the 0 mg/kg and the 2 mg/kg condition, with an overall decrease of 20.8% between the 0 mg/kg and the 4 mg/kg condition. Between the 2 mg/kg and 4 mg/kg condition there was a 25% decrease in correctly recalled third objects. Group mean percentage of correctly recalled third objects were 83.3% (M = .83 ± ..25), 87.5% (M = .88 ± ..25), and 62.5% (M = .63 ± .13) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

These group data suggest a decrement in memory for first objects (primacy effect), second objects, and third objects (recency effect). The group data also show an increased decrement with higher dosages of caffeine.

Individual data show a large amount of between-subject variability. To clarify the individual graphs, subject 3 only showed a decrement in percentage correct in the first recalled response during the 0 mg/kg. Subject 4 and 6 showed identical responses to the first and third responses.

Conditional Rule Task

Figure 8 displays the mean percentage of correct responses on the Conditional Rule Task across caffeine conditions. The panel in the lower right presents a group average, while the remaining panels present averages for individual subjects. Individual data points on these graphs are a percentage correct average of ten trials within a session, with three sessions at each dosage level. Group data show increases in the percentage of correct responses in the 2 mg/kg condition with decreases in percentage of correct responses in the 4 mg/kg condition.

Group mean percentage of correct responses increased by 1.2% between the 0 mg/kg

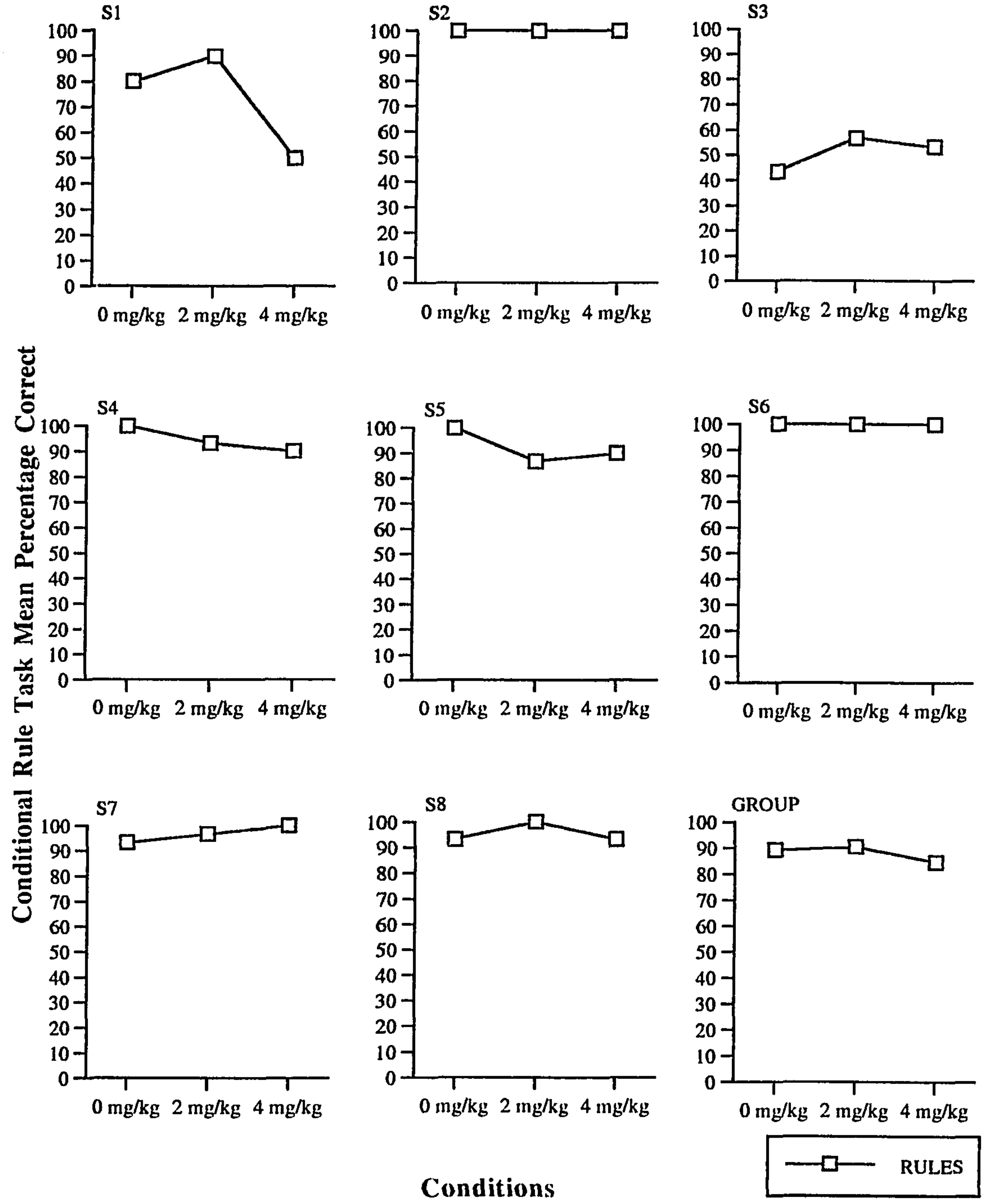


Figure 8. Mean Percentage of Correct Responses on the Conditional Rule Task Across Caffeine Conditions by Subject and by Group.

and 2 mg/kg condition, with an overall decrease of 4.6% from the 0 mg/kg to the 4 mg/kg condition. There was a correct response percentage decrease of 5.8% between the 2 mg/kg and 4 mg/kg condition. Group mean percentages of correct responses were 89.2% (M = 8.9 $\pm$ 1.96), 90.4% (M = 9.0 $\pm$ 1.44), and 84.6% (M = 8.5 $\pm$ 2.08) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively. Although nominal, the group data show peak performance being achieved in the 2 mg/kg condition with decreases becoming evident as the caffeine is increased. These results coincide with the Attention, Math, and Copy Task results reported above.

Individual data, although variable is more consistent in this task. Subjects 2 and 6 showed no variation across condition. Only subject 7 showed an increase in percentage of correct responses in the 4 mg/kg condition. Subject 3 showed decreased performance in all conditions.

Direction Following Task

Figure 9 displays the mean percentage of correct 3 command, 4 command, and 5 command responses on the Direction Following Task across caffeine conditions. The panel in the lower right presents a group average while the remaining panels present averages for individual subjects. Individual data points on these graphs are a percentage correct average of two trials (3, 4, and 5 command) within a session, with three sessions at each dosage level. Group data show mixed results. There are increases across caffeine conditions for the 3 command and 5 command tasks, with slight decreases across conditions for the 4 command task.

Mean percentage of correct 3 command responses remained constant between the 0 mg/kg and 2 mg/kg condition, with an overall increase of 2.2% between the 2 mg/kg and 4 mg/kg condition. Group mean percentage of correct 3 command responses were 93.6% (M

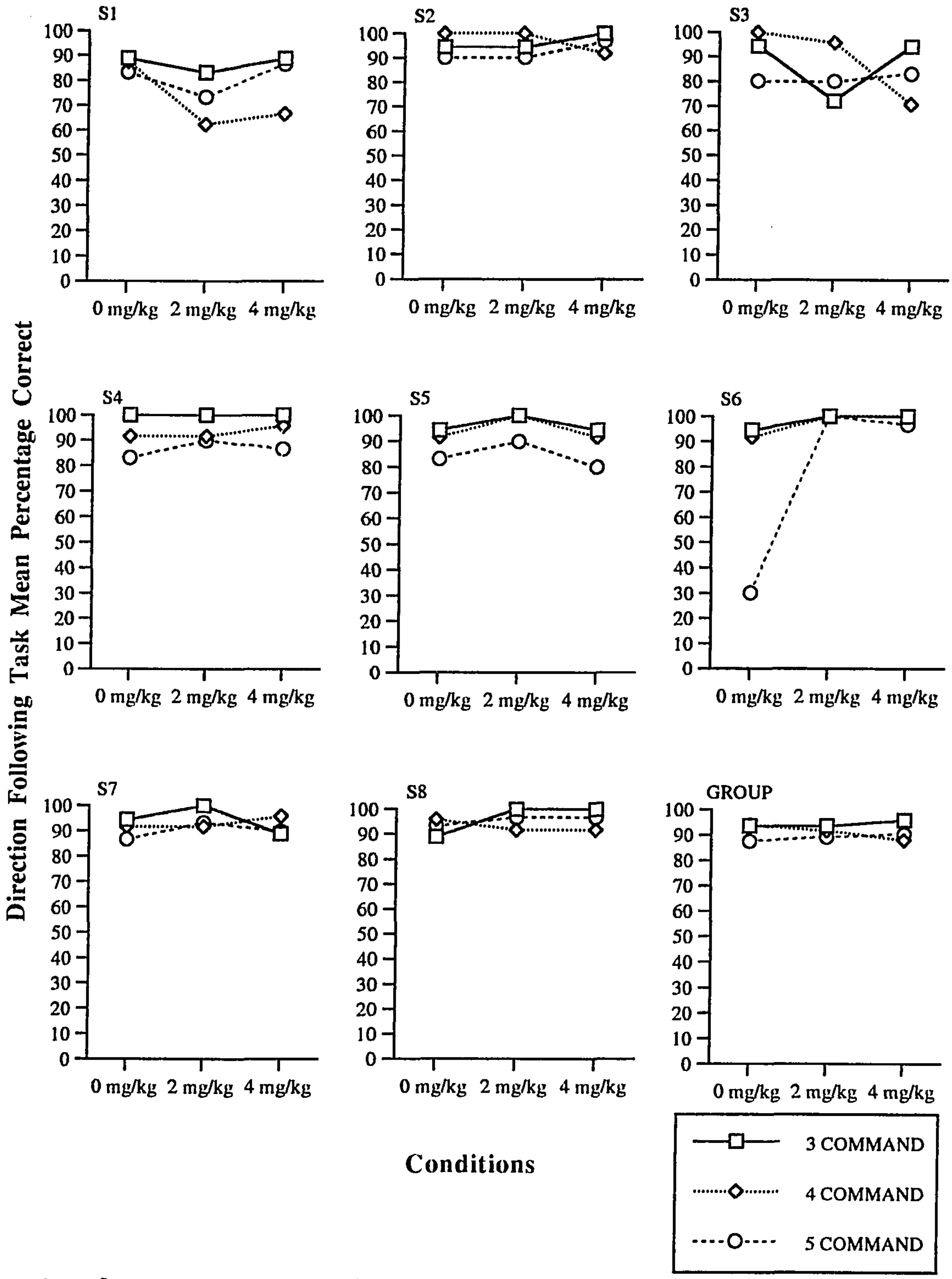


Figure 9. Mean Percentage of Correct Responses on the Direction Following Task Across Caffeine Conditions by Subject and by Group.

= 2.8 ± .29), 93.6% (M = 2.8 ± .31),.and 95.8% (M = 2.9 ± .14) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

Mean percentage of correct 4 command responses decreased by 2.1% between the 0 mg/kg and 4 mg/kg condition, with an overall decrease of 5.8% between the 0 mg/kg and 4 mg/kg condition. There was a 3.7% decrease in percentage of correct 4 command responses between the 2 mg/kg and 4 mg/kg condition. Group mean percentage of correct 4 command responses were 93.8% (M = 3.8 ± .17), 91.7% (M = 3.7 ± .50), and 88% (M = 3.5 ± .49) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

Mean percentage of correct 5 command responses increased by 1.7% between the 0 mg/kg and 2 mg/kg condition, with an overall increase of 2.9% between the 0 mg/kg and 4 mg/kg condition. There was a 1.2% increase in percentage of correct 5 command responses between the 2 mg/kg and 4 mg/kg condition. Group mean percentage of correct 5 command responses were 87.5% (M = 4.4 ± .33), 89.2% (M = 4.5 ± .42), and 90.4% (M = 4.5 ± .26) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

These group data are somewhat confusing in that one could hypothesize that the more difficult the memory task the more likely one would see decrements in performance with increased caffeine. This is only true for the 4 command Direction Following Task. Both the 3 and 5 command tasks showed improved performance with increased caffeine dosages.

Individual graphs, as with most of the tasks reported above, show great between-subject variability. This variability might suggest a unique way in which the subjects processed the verbal information.

Direction Following In Order Task

Figure 10 displays the mean percentage of 3 command, 4 command, and 5 command in order correct, responses on the Verbal Instruction Task. The panel in the lower right presents a group average, while the remaining panels present averages for individual

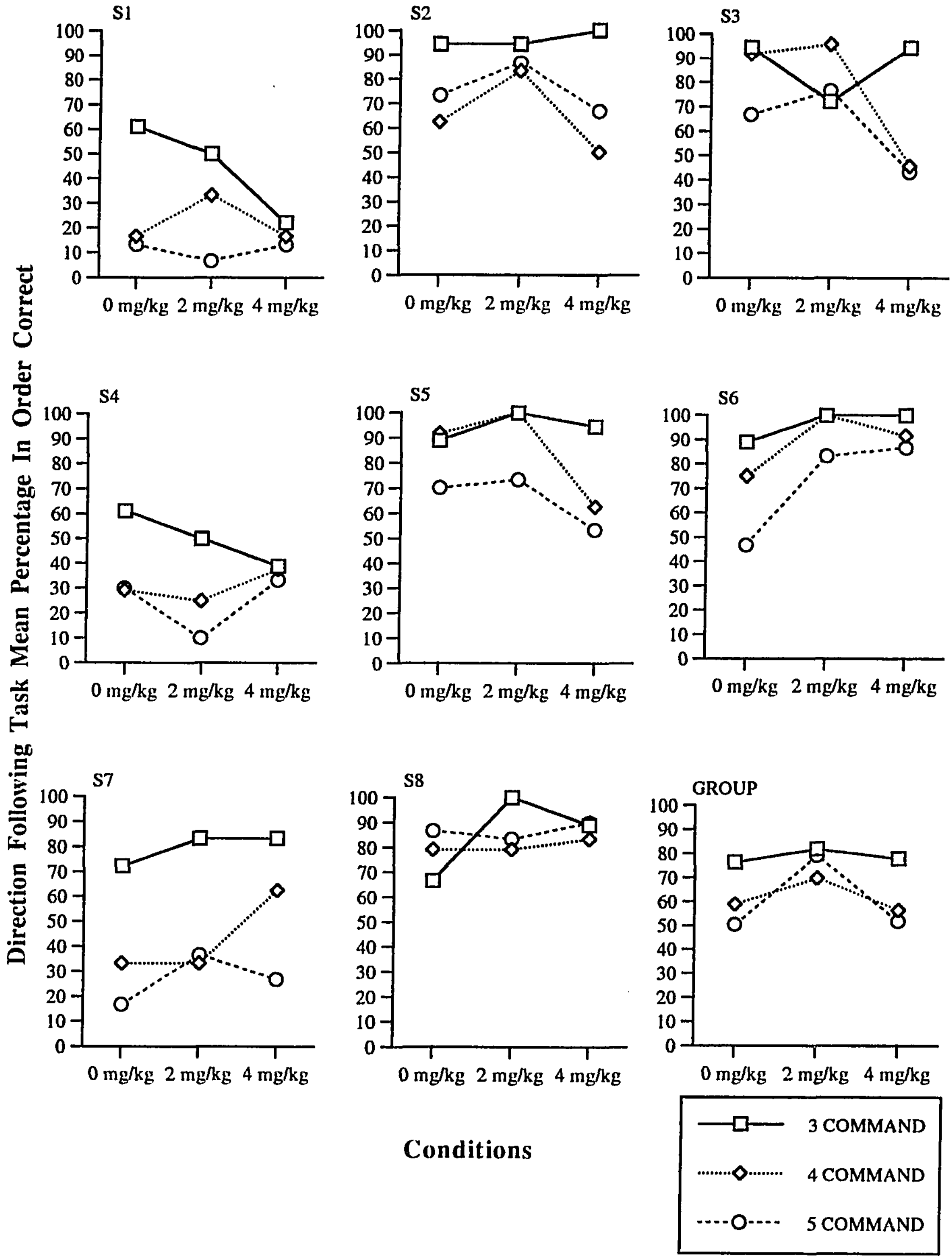


Figure 10. Mean Percentage of In Order Correct Responses on the Direction Following Task Across Caffeine Conditions by Subject and by Group.

subjects. Individual data points on these graphs are a percentage in order correct average of two trials (3, 4, and 5 command) within a session, with three sessions at each dosage level. Unlike the group data for the Direction Following Task, these group data show the more typical performance pattern with increases across all command tasks in the 2 mg/kg condition, and decreases in the 4 mg/kg condition.

Group mean percentage of in order, correct 3 command responses increased 5.5% between the 0 mg/kg and 2 mg/kg condition, with only an overall increase of 1.4% between the 0 mg/kg and 4 mg/kg condition. There was a 4.1% decrease from the 2 mg/kg to the 4 mg/kg condition. Group mean percentage of in order, correct 3 command responses were 76.4% ($M = 2.4 \pm .45$), 81.9% ($M = 2.5 \pm .69$), and 77.8% ($M = 2.3 \pm .79$) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

Mean percentage of in order, correct 4 command responses increased 10.9% between the 0 mg/kg and 2 mg/kg condition, with an overall decrease of 2.6% from the 0 mg/kg to 4 mg/kg condition. There was a 13.5% decrease in mean percentage of in order, correct 4 command responses between the 2 mg/kg and 4 mg/kg condition. Group mean percentage of in order 4 command, correct responses were 58.9% ($M = 2.4 \pm 1.14$), 69.8% ($M = 2.7 \pm 1.31$), and 56.3% ($M = 2.3 \pm .97$) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

Mean percentage of in order, correct 5 command responses increased 28.8% between the 0 mg/kg and 2 mg/kg condition, with a slight overall increase of 1.3% from the 0 mg/kg to the 4 mg/kg condition. There was a 27.5% decrease between the 2 mg/kg and 4 mg/kg condition. Group mean percentage of in order, correct 5 command responses were 50.4% ($M = 2.5 \pm 1.39$), 79.2% ($M = 2.8 \pm 1.69$), and 51.7% ($M = 2.6 \pm 1.38$) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

These group data show more consistent findings with the other tasks. The percentage increases in the 2 mg/kg condition, become more pronounced with increased number of commands. As with the other results these data suggest improved performance with 2 mg/kg of caffeine, as well as definite decrements in performance at 4 mg/kg.

Two Second Delayed Matching to Sample Task

Figure 11 displays mean percentage of correct responses on the Two Second Delayed Matching to Sample (DMTS) Task across caffeine conditions. The panel in the lower right presents a group average while the remaining panels present averages for individual subjects. Individual data points on these graphs are a percentage correct average of four trials (2 second with and without interference delay) within a session, with three sessions at each dosage level. Group data show decreases in correct responses with the no interference two second delay and slight increases in correct responses with the two second interference delay across caffeine conditions. The percentage of correct responses decreased, in the two second with no interference task, 4.1% between the 0 mg/kg and 2 mg/kg condition. There was an overall decrease of 8.3% from the 0 mg/kg to the 4 mg/kg condition. Percentage of correct responses decreased 4.2% between the 2 mg/kg and 4 mg/kg condition. Group mean percentage of correct responses for the Two Second (with no interference) DMTS task were 97.9% ($M = 1.96 \pm .35$), 93.8% ($M = 1.88 \pm 1.06$), and 89.6% ($M = 1.79 \pm .32$) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

The mean percentage of correct responses to the Two Second (with interference) DMTS Task remained constant between the 0 mg/kg and 2 mg/kg condition, with an overall increase of 4.2% from the 0 mg/kg to the 4 mg/kg condition. Group mean percentage of correct responses to the Two Second (with interference) DMTS task were 83.3% ($M = 1.67 \pm 1.07$) for the 0 mg/kg and 2 mg/kg condition, and 87.5% ($M = 1.75 \pm 1.39$), for the 4 mg/kg condition.

Individual data were variable across subjects. Subjects 5 and 6 showed no variation in responses across conditions or interference components. Subject 7 showed large

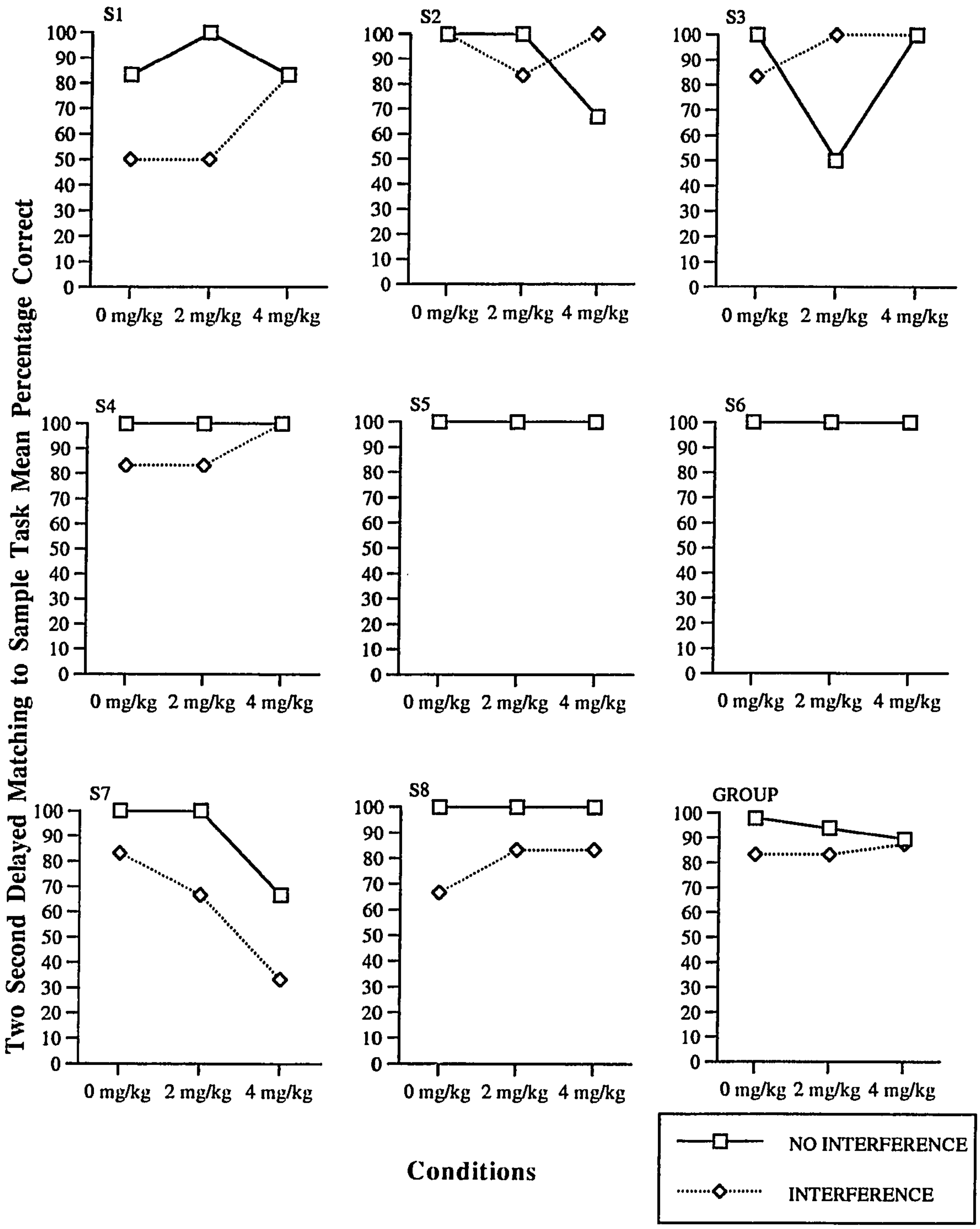


Figure 11. Mean Percentage of Correct Responses on the Two Second Delayed Matching to Sample Task Across Caffeine Conditions by Subject and by Group.

decrements in percentage of correct responses for both interference components in the 4 mg/kg condition. As with the Math Task (one digit addition), reported above, this task may have been too simple suggesting a ceiling effect for some of the subjects.

Six Second Delayed Matching to Sample Task

Figure 12 displays the mean percentage of correct responses on the Six Second DMTS Task across caffeine conditions. The panel in the lower right presents a group average, while the remaining panels present averages for individual subjects. Individual data points on these graphs are a percentage correct average of four trials (6 second with and without interference delay) within a session, with three sessions at each dosage level. Group data show increases in the mean percentage of correct responses on the Six Second (with no interference) Task across caffeine conditions. The data also show the dose dependent increases in percentage of correct responses in the 2 mg/kg condition with decreases in the percentages in the 4 mg/kg condition on the Six Second (with interference) DMTS task.

The mean percentage of correct responses to the Six second (with no interference) DMTS Task increased 6.3% from the 0 mg/kg to the 2 mg/kg condition, with an overall increase of 10.5% between the 0 mg/kg and 4 mg/kg condition. Group mean percentage of correct responses to the Six Second (with no interference) DMTS Task were 83.3% (M = 1.75 $\pm$ .93), 89.6% (M = 1.79 $\pm$ .74), and 93.8% (M = 1.88 $\pm$ .52) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

The mean percentage of correct responses to the Six Second (with interference) DMTS Task increased 14.5% from the 0 mg/kg to the 2 mg/kg condition, with an overall increase of 8.3% from the 0 mg/kg to the 4 mg/kg condition. There was a 6.2% decrease between the 2 mg/kg and 4 mg/kg condition. The group mean percentage of correct responses to the Six Second (with interference) DMTS Task were 83.3% (M = 1.63 $\pm$ 1.25), 95.8% (M = 1.92 $\pm$ .46), and 89.6% (M = 1.79 $\pm$ .74) for the 0 mg/kg, 2 mg/kg,

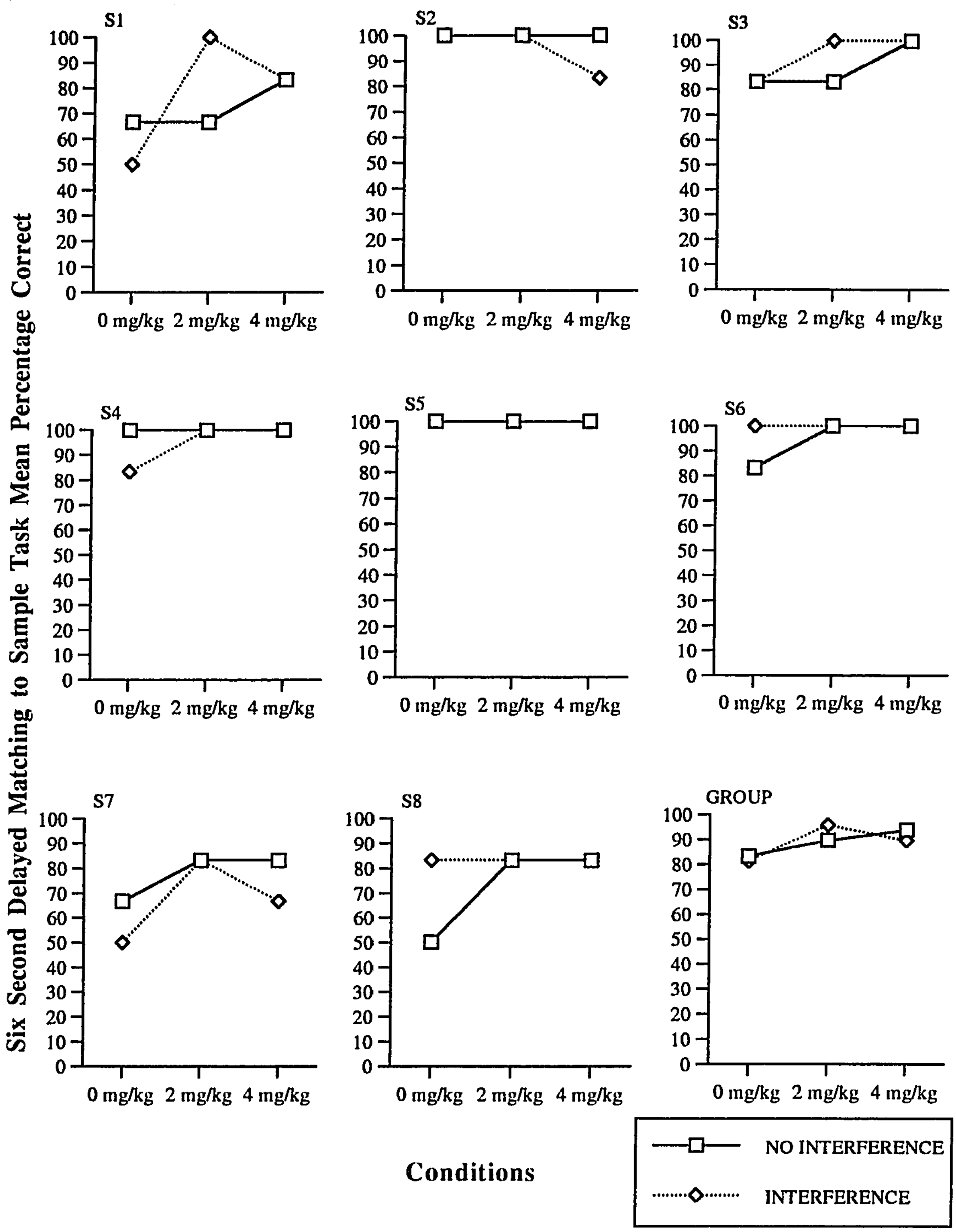


Figure 12. Mean Percentage of Correct Responses on the Six Second Delayed Matching to Sample Task Across Caffeine Conditions by Subject and by Group.

and 4 mg/kg conditions respectively.

The group data show improvement in percentage of correct responses with 2 mg/kg of caffeine in both interference components and with 4 mg/kg of caffeine in only the with interference component.

Individual data are very similar to the individual data in the Two Second DMTS Task. As before, subject 5 showed no variability in any responses across caffeine condition, nor interference component. There did not seem to be as much variation across the interference components for individual subjects.

Ten Second Delayed Matching to Sample Task

Figure 13 displays the mean percentage of correct responses to the Ten Second DMTS Task across caffeine conditions. The panel in the lower right presents a group average, while the remaining panels present averages for individual subjects. Individual data points on these graphs are a percentage correct average of four trials (10 second with and without interference delay) within a session, with three sessions at each dosage level. Group data show very minor changes across caffeine conditions.

The mean percentage of correct responses in the Ten Second (with no interference) DMTS Task increased 8.3% from the 0 mg/kg to the 2 mg/kg condition, with an overall increase of 4.2% between the 0 mg/kg and 4 mg/kg condition. There was a 4.1% decrease in correct responses between the 2 mg/kg and 4 mg/kg condition. Group mean percentage of correct responses in the Ten Second (with no interference) DMTS Task were 87.5% (M = 1.82 $\pm$ .89), 95.8% (M = 1.92 $\pm$ .46), and 91.7% (M = 1.79 $\pm$ .76) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

The mean percentage of correct responses in the Ten Second (with no interference) DMTS Task remained constant between the 0 mg/kg and 2 mg/kg condition, with an overall correct response increase of 2.1% from the 0 mg/kg to the 4 mg/kg condition. Group mean

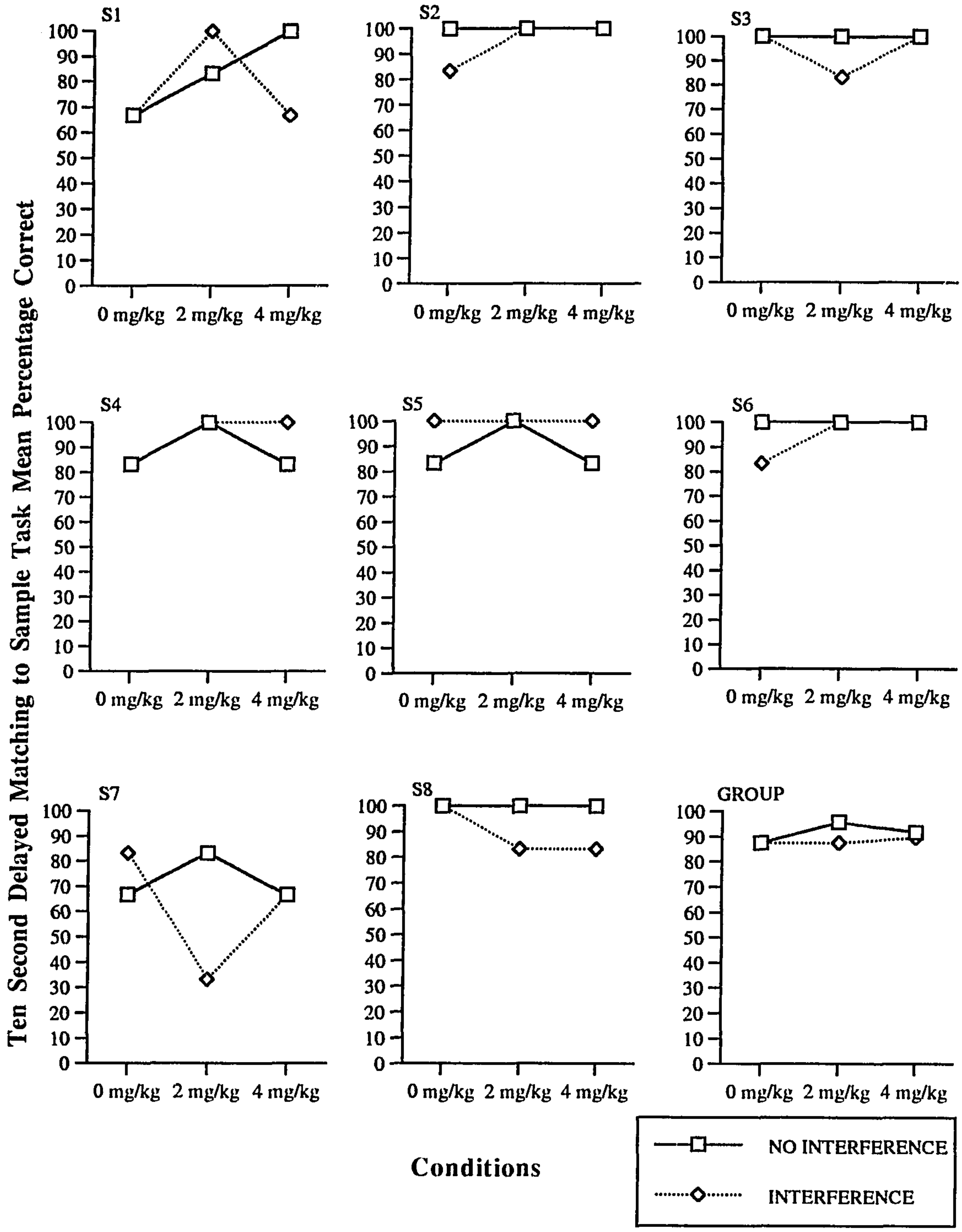


Figure 13. Mean Percentage of Correct Responses on the Ten Second Delayed Matching to Sample Task Across Caffeine Conditions by Subject and by Group.

percentage of correct responses in the Ten Second (with interference) DMTS Task were 87.5% ($M = 1.75 \pm .71$), 87.5% ($M = 1.75 \pm 1.39$), and 89.6% ($M = 1.79 \pm .76$) for the 0 mg/kg, 2 mg/kg, and 4 mg/kg conditions respectively.

Group data showed the dose dependent increases in the Ten Second (with no interference) Task to the 2 mg/kg of caffeine, with the coinciding decrements to the 4 mg/kg caffeine. The interference component showed only slight increases of correct responses in the 4 mg/kg condition. These findings are somewhat puzzling and need to be analyzed further.

Individual data was consistent with the other tasks in amount of between subject variability. Unlike the two second and Six Second DMTS Task, subject 5 showed decrements in number of correct responses in both the 0 mg/kg and 4 mg/kg condition for the no interference component. This was the only variability seen in that subject's performance.

Statistical Analysis

Table 1 shows a summary of One Factor Analysis of Variance (ANOVA) -- Repeated Measures for the dependent variables. Statistical analysis was conducted on all dependent variables within the study. But possibly because of small sample size and high between-subject variability, only four variables reached statistical significance at the $p < .05$ level. Only the results showing statistical significance are listed in Table 1 for brevity.
The One Factor Analysis Variance of Variance -- Repeated Measures allowed for more power with the limited number of subjects included. After the initial statistical analysis was completed, those variables obtaining statistical significance ($p < .05$) were then tested using the Fisher PLSD post-hoc multi-comparison procedure. Statistical significance was obtained in SBP between the 0 mg/kg and 4 mg/kg condition only, and in DBP and Long Term Memory between all compared conditions (0 mg/kg and 2 mg/kg, 2 mg/kg and 4 mg/kg, 0

mg/kg and 4 mg/kg). The 3 Command Direction Following Task Mean Time of Completion obtained statistical significance between 0 mg/kg and 2 mg/kg, and between 2 mg/kg and 4 mg/kg. All Fisher PLSD were significant at 95%.

Table 1

Summary of One Factor Analysis of Variance -- Repeated Measures

Source	Mean	SD	df	MS	F	p
Systolic Blood Pressure (mmHg)						
	0=101.7	11.4				
	2=107.2	11.3				
	4=112.1	8.3	2	73.5	3.77	.0490
Diastolic Blood Pressure (mmHg)						
	0=77.4	11.0				
	2=81.7	8.3				
	4=88.0	4.8	2	51.4	8.58	.0037
Long Term Memory Task						
	0= 8.0	1.1				
	2= 7.3	1.6				
	4= 6.3	2.6	2	2.0	4.54	.0301
3 Command Direction Following Task Mean Time of Completion (seconds)						
	0= 7.1	1.3				
	2= 5.9	1.0				
	4= 6.7	1.2	2	0.87	5.05	.0223

0 = 0 mg/kg
2 = 2 mg/kg
4 = 4 mg/kg

Miscellaneous Analysis

Task Errors by Omission

Table 2 displays the summary of individual task errors by omission, as well as total errors of omission, and total errors of omission by category. Errors of omission are errors made by not making a response. These data are broken down into time out errors, when no response was made before time ran out and responses that were not made in the sequence of instructions.

Table 2

Summary of Task Errors by Omission

Category	Task	0 mg/kg	2 mg/kg	4 mg/kg
Attention Task				
	Pig Time Outs	25	11	26
Total Attention		25	11	26
Performance Task				
	Math Time Outs	1	1	1
Total Performance		1	1	1
Memory Tasks				
	Long Term Memory - no response	8	14	20
	Conditional Time Outs	2	2	2
	3 Command Instruction - no response	9	9	6
	4 Command Instruction - no response	12	10	16
	5 Command Instruction - no response	30	26	21
	DMTS Time Outs	4	2	2
Total Memory Retention		65	63	67
TOTAL ERRORS OF OMISSION		91	75	94

As with earlier results there is a biphasic effect on errors of omission across task, and in total numbers. Subjects made fewer errors of omission in the 2 mg/kg condition, with comparably higher errors in both the 0 mg/kg and 4 mg/kg condition. This would further the hypothesis that when ingesting more caffeine performance accuracy decreases.

Task Errors by Commission

Table 3 displays the summary of individual task errors by commission. Errors of commission are errors made by making an incorrect response. The Table also displays total errors of commission and total errors of commission by category. These errors are broken down into extra click errors, delete errors, or incorrect answers.

The errors of commission results are consistent with the errors of omission results across task, and in total numbers. The same dose dependent results occur. Subjects made fewer errors of commission in the 2 mg/kg condition with significantly more errors in both the 0 mg/kg and 4 mg/kg conditions. Of interest are the Attention Task, extra clicks. The large increase in extra mouse clicks in the 4 mg/kg condition may well be a result of higher caffeine dosage. The subjects also enjoyed using the mouse across the blank field, and may well have had decreased motor coordination in this higher caffeine condition.

Table 3

Summary of Task Errors by Commission

Category	Task	0 mg/kg	2 mg/kg	4 mg/kg
Attention Task				
	Pig - incorrect answers	14	10	10
	Pig Extra Clicks	86	74	113
Total Attention		100	84	122

Table 3--Continued

Category	Task	0 mg/kg	2 mg/kg	4 mg/kg
Performance Task				
	Math Deletes	25	11	22
	Math - incorrect answers	44	28	36
	Copy Deletes	52	11	43
	Copy - incorrect answers	30	46	30
Total Performance		151	96	131
Memory Tasks				
	Conditional Extra Clicks	22	28	20
	Conditional - incorrect answers	25	26	39
	DMTS Extra Clicks	38	27	27
	DMTS - incorrect answers	32	27	27
	3 Command Instruction - incorrects	29	11	12
	4 Command Instruction - incorrects	34	30	38
	5 Command Instruction - incorrects	49	37	38
Total Memory Retention		229	186	201
TOTAL ERRORS OF COMMISSION		480	366	454

Task Reaction Time (Latency)

Table 4 displays the summary of mean task reaction times across tasks and total mean task reaction times for session. Not all tasks utilized reaction times. The following table represents those tasks in which latency was a factor.

The latencies displayed, although not comprehensive of all tasks, show a dose dependent effect across caffeine conditions. Responses were made more quickly in the 2 mg/kg condition than in either the 0 mg/kg or the 4 mg/kg condition. The 4 mg/kg condition showed the longest reaction times of all three conditions. This could have to do with the decreased motor coordination associated with higher dosages of caffeine. As with the errors of omission and commission, 2 mg/kg of caffeine had enhancing effects, with decreased accuracy and performance being seen with the larger amounts of caffeine.

Table 4

Summary of Mean Task Reaction Times

Category	Task	0 mg/kg	2 mg/kg	4 mg/kg
Performance Tasks				
	Math Task (all levels)	5.55	6.17	6.65
Memory Tasks				
	Conditional Task	3.00	2.55	3.00
	3 Command Instruction Task	7.05	5.88	6.72
	4 Command Instruction Task	9.06	8.63	9.46
	5 Command Instruction Task	11.20	11.13	10.83
	DMTS Task	2.85	2.63	2.71
Total Task Latency		38.71	36.99	39.37

<u>Behavioral Ratings</u>

Several behavioral measures were collected from both parents and teachers throughout the study. Both teachers and parents had been coached as to the possible effects of caffeine and were to fill out either the Abbreviated Teacher Rating Scale (Appendix H), or the Abbreviated Parent Rating Scale (Appendix G) which gave specific examples of behaviors that could be associated with caffeine usage. No one reported any observations of behaviors typically correlated with caffeine consumption, such as irritability, tearfulness, nausea, or nervousness. All students returned these behavioral measures each session, which suggests that the adults did observe their children/students. The lack of observations would suggest that there were no behavioral side effects witnessed.

When the subjects were asked how they felt, at the end of each session, there were no reports of any of the above side effects. The most common response was of "tiredness", or of "not having done as well as they would have liked to". The subjects were prompted by the experimenters on types of feelings possible. This prompting did not increase reported side effects. Again, as with the parent and teacher behavioral observations, this would suggest no behavioral side effects having been experienced.

Subjective Measures

At the end of each experimental session the subjects were asked to determine if they had ingested caffeine or not. The subjects were scored for the accuracy of their estimates.

Table 5

Summary of Caffeine Ingestion Estimates

Subject	Correct Detections	Correct Rejections	Percentage Correct
#1	3	1	44%
#2	5	1	67%
#3	4	3	78%
#4	1	2	33%
#5	0	1	11%
#6	2	2	44%
#7	0	3	33%
#8	0	2	22%
Mean Percentage of Correct Determination			42%

Table 5 displays the summary of correct detections and rejections of caffeine administrations, by the subjects, and subject's percentage correct.

The majority of correct responses occurred in the reporting of a no caffeine condition. This occurred because many of the subjects reported no caffeine for every session. Out of 72 ingestions of the Tang beverage, only 30 were correctly identified as to whether or not they contained caffeine. The fact that this identification accuracy is below chance responding (32% - 50%) suggests that the beverage vehicle was adequate to mask caffeine.

Baseline Measures

One could argue that the ingestion of the beverage itself (without caffeine) may have had effects on the subjects. Table 6 depicts the group differences between the last baseline data point and the first 0 mg/kg beverage administration data point. These data are not consistent in that due to the random presentation of the different levels of the drug vehicle, not all subjects progressed from a no beverage to a 0 mg/kg beverage. Only 2 subjects received a placebo beverage in the first experimental session.

These data show no consistent differences between baseline (no beverage) and placebo (beverage without caffeine) for any of the dependent variables. These results are somewhat complicated because of the lack of consistency in independent variable presentation. Because the subjects may have participated in up to six experimental sessions with caffeinated beverages before the placebo presentations, no direct comparisons can be made. Possible methodological changes in future research could correct this lack of consistency to allow for a more direct comparison between baseline (no beverage) and placebo (beverage without caffeine) conditions.

Table 6

Summary of Baseline and First Placebo Comparisons

Category	Task	Baseline (No Beverage)	Placebo (0 mg/kg)
Cardiovascular Indices			
	SBP	102.0 mmHg	100.6 mmHg
	DBP	78.2 mmHg	76.6 mmHg
	HR	90.1 BPM	91.5 BPM
Attention Task			
	Percentage correct	88%	90%
Performance			
	Math Task % Correct	80%	74%
	Copy Task		
	% Correct	65%	63%
	In Order % Correct	61%	61%
Memory Retention			
	Long Term Memory Task		
	Total % Correct	70%	81%
	Conditional Rule Task		
	Total % Correct	68%	71%
	Direction Following Task		
	3 Command % Correct	96%	94%
	4 Command % Correct	97%	90%
	5 Command % Correct	86%	92%
	DMTS Task		
	Total % Correct	95%	93%

CHAPTER IV

DISCUSSION

This study assessed the effects of caffeine consumption on cardiovascular indices, attention, task performance, and memory retention in children. All components play a role in the way a child learns and performs in school and in everyday life. There has been a paucity of research done in these areas of learning with children and caffeine.

Cardiovascular Indices

Caffeine ingestion produced significant increases in SBP and DBP relative to placebo condition. SBP increased an average of 5.5 mmHg in the 2 mg/kg condition and 10.4 mmHg in the 4 mg/kg condition. DBP increased an average of 4.3 mmHg in the 2 mg/kg condition and 10.6 mmHg in the 4 mg/kg condition. This strongly suggests that caffeine increases both SBP and DBP when ingested. It further suggests that higher caffeine dosages create corresponding increases in both SBP and DBP.

These results replicate the findings of Keller (1988), Robertson et al. (1978), and Whitsett, Manion and Christensen (1984), in adult populations. The first two studies reported average SBP and DBP increases of 14/10 mmHg, 30 minutes after acute ingestion of caffeine. In both the Robertson and Whitsett studies caffeine dosages varied, in that the subjects were given single doses of 250 mg of caffeine. Neither of these researchers controlled dosage to weight. Keller (1988) administered 2 mg/kg of caffeine with average SBP and DBP increases of 5/6 mmHg. This study's results more closely replicate Keller's results with the comparable methodologies and caffeine dosages administered.

Robertson, et al. (1978) reported decreased elevations in both SBP and DBP to an insignificant level, 180 minutes after ingestion. He also reported that chronic caffeine administration decreased reactivity levels. His results suggest that caffeine has the greatest effect on BP in the first two hours after administration, with diminishing effects thereafter. His results also suggest that chronic caffeine use attenuated BP reactivity. This study did not assess peak reactivity duration or chronic use issues.

Caffeine ingestion also produced decreases in HR relative to placebo conditions. Although not statistically significant, HR decreased an average of 2.0 BPM in the 2 mg/kg condition, and 5.6 BPM in the 4 mg/kg condition. As with SBP and DBP results, the HR results replicate the findings of Keller (1988), Robertson, et al. (1978), and Whitsett, Manion and Christensen (1984), in adult populations. Whitsett reported a maximal decrease 25 BPM with 250 mg of acute caffeine ingestion. Keller reported a more modest HR decrease of 1.5 BPM with acute 2 mg/kg caffeine administration in the rest (non-stressor) phase of her study.

This study's results must be interpreted cautiously. Although individual and group data show increases in SBP and DBP and decreases in HR in response to caffeine ingestion, one must consider the small subject sample and high individual variability. The variability may be indicative of inherent individual reactivity to caffeine or differing caffeine histories. With additional subjects and more stringent methodological controls (i.e., comparing caffeine-naive individuals with chronic caffeine consumers), greater generalizability might be possible.

There are no definitive studies with children, with which to compare this study's results. It is unclear whether the immediate effects of caffeine reported with adult populations can be directly compared to this study. One of the few studies done with children measured only cardiovascular indices on a biweekly basis and not at time of caffeine consumption (Rapoport, et al., 1984). Thus, no direct comparison can be made.

Another problem with comparison to previous research is associated with the few studies using differing levels of caffeine. It is unclear whether the linear effects reported in this study with increased dosages would be replicated with caffeine administrations at greater than 4 mg/kg. Future research with children should incorporate multiple levels of caffeine administration to verify the linear effect on BP and HR, and determine at what point a maximum effect occurs, and at what dosage.

This study averaged BP and HR measurements of individual subjects three times across each experimental session. It did not compare measurements between at rest and on task performance. Variability in cardiovascular reactivity to specific tasks was also not monitored. Future research must monitor cardiovascular measurements at rest, as well as when a subject is performing specific tasks, to determine if there are additive effects under different conditions.

Cardiovascular measurements over a longer period of time (greater than 60 minutes) would determine peak cardiovascular reactivity to caffeine. Comparing caffeine-naive and chronic caffeine consumer samples under similar conditions would differentiate tolerance effects

With added research, a more definitive conclusion on the cardiovascular effects of caffeine can be determined The significance of caffeine ingestion related to medical disorders then could be more systematically addressed This study reported acute cardiovascular effects to caffeine ingestion. Future research must look at what role these acute effects have on immediate health and on potential long term health issues.

Attention

The Attention Task data measuring visual vigilance (indicative of sustained attention), show increased performance on measurements of attention at the 2 mg/kg condition, but decreased performance at the 4 mg/kg condition. Because of high between subject variability these results did not achieve statistical significance. The average percentage of correct responses suggest that sustained attention was increased with 2 mg/kg of caffeine, but began to decrease with added caffeine, creating a biphasic drug effect, depicted in Figure 3.

These results replicate and extend Elkins, et al. (1981) research on the effects of caffeine on children's sustained attention . Baer (1987) did not report significant increases in children's attention , therefore placing that study in disagreement with these results. Both Elkins and Baer used the Continuous Performance Test (CPT) to measure sustained attention. The CPT is a computer software application in which the subject must press the space bar when observing a blue square. This task is a widely accepted measure of sustained attention/vigilance and impulsivity. The Attention Task in this study utilized similar visual stimuli presented randomly on the computer screen.

Comparisons can be made to the previous studies because of consistent methodologies employed. Elkins, et al. (1981) administered a single caffeine dose of 3 mg/kg and 10 mg/kg in his study. Although the dosages differed, he reported significant increases in sustained attention at the high dose measured by both a decreased median reaction time and a decrease in errors. Baer (1987) only employed the CPT for a 5 minute duration in each experimental session, not allowing for a direct comparison to this study. She also used lower dosages of caffeine and reported that the dosage may have been too small to determine clear effects.

Caution must again be exercised when reviewing these results on the effects of caffeine on measurements of attention. The lack of statistical significance must be considered. The novelty of the computer task is another factor that must be considered. The subjects enjoyed working on the computer. They also enjoyed finding the picture of the pig on the Attention Task. It is unclear whether similar levels of caffeine would produce similar effects on attention to tasks that differed markedly from those used in this study. For example, future research could focus on the the performance on tasks that were repetitive or less enjoyable and compare the measurements to performance on tasks that were novel and entertaining.

The one important factor to be considered with these Attention Task results employed in this study, is the consideration that attention was maintained at a fairly high group average rate of greater than 90% correct responses throughout the sessions. This would lend credibility to the conclusion that changes in performance and memory were not correlated to a lack of attention by the subjects.

Performance

Performance was measured by three individual tasks: Math Task, Copy Task, and Direction Following Task. These tasks were chosen to measure different types of performance. The Math Task measured performance at two levels of complexity, in the same manner as measured by Gilliland and Nelson (1939), and Lane and Williams (1985). They had employed addition and subtraction problems as a measure of performance in adult populations. The Copy Task, measured monotonous performance, much like Baker and Theologus (1972), and Landrum, Meliska and Loke (1988). Both previous studies employed a monotonous letter copying task to measure performance in adult populations. The Direction Following Task incorporated verbal instructions to measure both overall performance, and auditory memory of instructions. This task was created to be more representative of a classroom situation and will be discussed under the Memory Retention section.

The Math Task was broken down into four components; one and two digit addition tasks, and one and two digit subtraction tasks. These components were created to measure differing levels of complexity for the subject. All components except for the two digit addition task showed a biphasic caffeine effect, with increases in performance at the 2 mg/kg condition and decreases in performance evidenced at the 4 mg/kg condition. There were increases in performance at both caffeine conditions in the two digit addition task. It is unclear why this inconsistency occurred. A possible explanation would be the individual mathematical proficiencies of the subjects. Four subjects were in the first grade with the remaining four students in the second grade. The different skill levels may have played a role in these results.

The results depicted in Figures 4 and 5 suggest increased performance with caffeine ingestion. But as with the reported results on the Attention Task, higher levels of caffeine seem to have a detrimental effect on performance.

Possible problems with using the Math Task as a measure of performance include: (a) limited sample problems, (b) complexity of problems, and (c) performance levels of the subjects. Only two examples of each component were administered per session for a total of eight math problems. It is unclear whether a greater number of math problems administered each session, would have altered the results. The problems, although chosen from the textbook used in the classrooms, may not have been at an appropriate level for all subjects. The one digit addition tasks were very simple for most subjects and tended to show a ceiling effect on performance. This ceiling effect created a situation in which only performance decrement could be observed. The two digit subtraction problems may well have been too difficult for some subjects. The first grade subjects had not had as much exposure to two digit subtraction. Just as the one digit addition problems could not appropriately measure for performance enhancement, the two digit subtraction had limited ability to measure for performance decrement. The "Don't Know" option may have created an escape for the subjects, allowing for limited contact with the problem. The 4 first grade subjects all used the "Don't Know" response across experimental sessions. The variability of skills shown by the subjects make it difficult to make a between-subject comparison on the effect of caffeine on math performance. If a study utilizing math problems to assess performance was to be implemented in the future, researchers must take into consideration the above factors to better control variability.

The results of caffeine's effects on performance using the Copy Task are consistent with the other results discussed above. There seems to be a biphasic caffeine effect on performance with increases in average total completed percentages (4.8%), and average total correctly completed percentages (3.1%) in the 2 mg/kg condition. Overall there was a very slight decrease in performance in the 4 mg/kg conditions as depicted in Figures 6 and 7.

As with the other results reported, there was great between-subject variability with no clear explanation as to why that variability occurred. Secondly, performance in the different conditions did not achieve statistical significance suggesting the possibility of chance in the measurement differences. Lastly, one must look at the confounding variables of decreased motor dexterity, and hand-eye coordination previously reported by Foreman, et al. (1989) that may have affected the percentage of correct responses. Although hand-eye coordination and motor dexterity are measures of performance, one would be measuring a different aspect of performance. To replicate this study a more concrete way of measuring performance must be attained. One possible solution for differentiation between aspects of performance would be to incorporate valid measures of motor dexterity and hand-eye coordination skills (e.g., finger tapping rates, key pressing rates). By implementing these additional tasks, more definitive discrimination between the ability to copy numbers and the motor dexterity needed to accomplish the task could be made.

In summary, there appears to be a biphasic effect of caffeine on children's mathematical and monotonous task performance . It is unclear what role the small subject sample, the high between-subject variability, and the lack of statistical significance attained plays on these effects. The area of task performance as a measure of overall learning needs further research to tease out all of these elements. This study is a good beginning in determining how performance may be affected by caffeine ingestion, and should lead to further experimental questions to be tested. Types of questions that could assess the effects of caffeine on performance in the future include; comparisons of performance between monotonous tasks and novel tasks, performance on tasks requiring differing levels of physical dexterity, and performance on tasks that are valid indicators of different types of performance.

Memory Retention

Because memory is a covert behavior with no precise measurements, the varied tasks employed in this study measured memory in much the same way as memory retention had been researched before. This study also extended the previous measurements by employing verbal instructions in two of the tasks to simulate classroom learning environments.

Memory retention was measured by four individual tasks; Long Term Memory, Conditional Rule, Direction Following, and Delayed Match-to-Sample Tasks. As with the performance tasks, these tasks were chosen to measure different aspects of memory retention. The Long Term Memory Task measured memory of items over an extended period of time. This task also looked at the primacy and recency effects previously researched by Bourne and Ekstrand (1985) and Hitch , Halliday, Dodd, and Littler (1989),. Both of these studies had used adult populations. The Conditional Rule Task measured both verbal memory and discrimination abilities, much like the early research of Hull (1935), and later animal research of Castellano (1976). This type of memory retention is very important in applying rules to novel learning problems across time. The Direction Following Task measured memory much like the Conditional Rule Task, with the added component of multiple verbal instructions. This task required that the subject : (a) listen to the complete set of instructions, (b) complete the commands in order, and (c) indicate when finished. This task again measured a type of memory that is common in a school learning situation. The concepts of primacy and recency effects could also be measured on this task (Bourne & Ekstrand, 1985). The DMTS Task measured short-term visual memory, employing an interference in a proportion of the sample items. This type of task was employed to determine if interference would limit recall of the sample stimulus. This type of task has been researched in children, without caffeine, by Lowenkron (1989), and Marschalek, (1988). No research reported in the literature to date, has measured memory in this manner with children and caffeine.

The Long Term Memory Task data show decrements across all caffeine conditions in each of the three pictured objects except for the final object. The third or most recent object presented showed a biphasic drug effect on average percentage of correct responses. The Long Term Memory Task performance measures reached statistical significance suggesting that caffeine does in fact have a detrimental effect on long term memory. Overall memory retention of the each of the three pictured objects decreased with caffeine ingestion as compared to placebo.

These data would strongly suggest an adverse effect on memory. It is unclear if the effect sizes are meaningful to extrapolate to overall memory or to classroom learning. To further substantiate and extend these results, further research should be initiated; using differing time frames (greater than 30 minutes), employing verbal as well as visual stimuli to be recalled, and increasing the number of sample pictured objects to more adequately measure the primacy and recency effects on memory. Long term memory should be measured in simulations as much like classroom learning as possible to allow for a valid comparison to real life situations.

The Conditional Rule Task data measuring verbal recall of an applied rule show increased performance on measurements of memory at the 2 mg/kg condition, but decreased performance at the 4 mg/kg condition. Because of high between subject variability these results did not achieve statistical significance. The average percentage of correct responses suggest that verbal recall of a conditional rule was increased with 2 mg/kg of caffeine, but began to decrease with added caffeine creating a biphasic drug effect, depicted in Figure 8.

This is a very important area of memory that warrants further research to determine the effects on caffeine on discrimination and memory. Although there was individual variability suggesting that caffeine may be processed differently by individuals, the results should be considered as a warning to the potential adverse effects in learning situations. Suggestions for future research in this area of discrimination and memory would include; the use of a larger subject sample, a greater sample of tasks, and more varied tasks to discriminate between, to more adequately measure caffeine effects.

The Direction Following Task results are somewhat confusing. One would expect to find consistent results between average percentage of correct responses and average percentage of in order-correct responses. This is not the case. The Direction Following Task measuring verbal recall and performance on following directions show an overall increased performance on measurements of following directions, while showing a biphasic drug effect on the measurement of in order responses depicted in Figures 9 and 10. The discrepancy in the results may well be due to the design of this task. The subjects would often, if they did not remember the instructions, randomly click on all of the objects displayed on the screen. This random clicking would create false correct responses. The in order, correct response percentage corrected for this random responding. In the second component of the Direction Following Task, subjects performance was measured on the ability to follow the directions in order, with random clicking counting as an error of commission. Table 2 and 3 depict the average number of errors of omission and commission on this task.

One should cautiously summarize the caffeine's effects on memory and performance measured by the Direction Following Task. Individual variability was high. The measurements of performance and memory did not achieve statistical significance. The task design allowed for random performance inflating the measurement of responses.

As with the other tasks measuring performance and memory retention, this task could be improved and used in future studies. The task has the potential to measure memory, taking into account both primacy and recency effects, as well as measuring performance. Ways to improve this assessment device to more adequately measure memory retention and performance would include; using an increased sample item size, employing more refined criteria for correct responses to avoid random responding, and requiring responses with a higher response cost or response effort. Similar to previous suggestions, increasing the subject sample and discriminating between caffeine-naive and chronic caffeine consumer populations could also extend the results.

The DMTS Task results are very mixed. Statistical significance was not achieved for any component of this task. It would be safe to say that this task, showed no conclusive evidence of caffeine's effects on memory and performance. There was great between subject variability, and conflicting results between the interference and non-interference components.

This task needs to be replicated with greater care taken to more adequately measure the effect of caffeine on working memory utilizing a DMTS task . Possible alternate methods might employ more complex sample stimuli to control for ceiling effect. Longer delays might be utilized to more carefully measure the memory component. Different forms of interference (e.g., visual, auditory) should also be employed. As with the other tasks, a larger subject sample and more sample DMTS items could be employed to discriminate what effects caffeine has on DMTS performance.

Behavioral Ratings

Throughout the study, subjects returned Abbreviated Parent Rating Scales from home. Teachers also returned Abbreviated Teacher Rating Scales from each session day. The subject's parents/guardians were to fill them out each session day at bedtime, while teachers were to fill out the forms at the end of the school day. None of the returned rating scales (100% returned) reported any behavioral changes related to caffeine. This is puzzling in light of reports of behavioral changes (e.g., nervousness, stomach ache, head ache, restlessness) from previous research (Elkins et al, 1981). Several hypotheses can be made. Parents/guardians and teachers may have completed the forms without adequately monitoring behavior. When filling out each form, they may not have been fully aware of behavioral changes because the observed changes were minimal. Because of the subject's caffeine consumption histories, only minimal or no changes in behavior may have occurred. The instructions required monitoring at the end of the school day or at bedtime, which may have allowed for inaccurate recall of behaviors occurring earlier in the day.

Future research must employ more stringent behavioral observations over time to more adequately measure the behavioral effect of caffeine. This could be accomplished by an observer, remaining in the classroom, each experimental session day to monitor behavior. Phone calls to the subject's home could be made each evening, to query about behaviors, utilizing specific questions to aid in monitoring for targeted behaviors. More thorough observational training of parent/guardians and teachers could be employed to add assurance that the targeted behaviors were being identified. With these suggestions implemented, more comprehensive behavioral observations could be obtained to more adequately make conclusions of caffeine's behavioral effects.

Subjective Observations

The subjects in this study were unable to systematically determine whether the ingested beverage contained caffeine or not. The subjects were asked at the end of each session to determine this. It is unclear whether asking the children at the time of consumption, instead of at the end of each experimental session (60 minutes later), might have allowed for more accurate responses. It is equally unclear whether another beverage would have masked the taste of the powdered caffeine more adequately for the subjects.

At no time during the study, did the subjects report that they could determine that they had had caffeine because of the way they felt. They also did not report that their performance was altered because they thought they had consumed caffeine. It is unclear whether their performance was altered because of their perception of having ingested caffeine or not. This study's conclusions can only be based on the self-report of the subjects and the direct observation of the research assistants.

Future research could employ more experimental sessions without any beverage being consumed to discriminate expectancy effects that might be related to ingestion of a beverage. Training the subjects to be more aware of sensations within their bodies, and how to describe those sensations, might allow for better subjective observation of possible changes. Asking the subjects whether they had ingested a beverage containing caffeine or not immediately following ingestion might help determine whether Tang adequately masked the caffeine. These types of controls in future research could begin to assess the covert effects that caffeine may have on children. It could also monitor perceptions to disprove misperceived effects if no caffeine had been given.

Conclusions

There have been few studies that have assessed the effect of caffeine on children. Yet children consume varying amounts of caffeine on a daily level. Caffeine may well have an acute and possible chronic effect on children's learning ability. This study serves as a good introductory study on the effects of caffeine related to cardiovascular indices, attention, task performance, and memory retention in children.

Much more needs to be done in the future, to experimentally determine caffeine's effects on children's attention performance and memory retention.

A larger subject sample would be beneficial in future studies to more accurately detect if statistically significance differences. Along with more subjects, future research should look at varied age levels, more heterogeneous populations, and child populations with special needs. Research could also discriminate between genders, cultures and special populations to more adequately determine specific effects, caffeine may have on learning.

More experimental sessions at each caffeine condition would more accurately determine caffeine effects. This study incorporated three sessions at each level of caffeine. More sessions at each caffeine condition over greater periods of time, could more carefully look at issues of caffeine tolerance, habituation to the task, and possible caffeine withdrawal effects.

This study used three levels of the independent variable; 0 mg/kg, 2 mg/kg, and 4 mg/kg. Possible administration of higher dosages of caffeine could verify more conclusively the dose dependent, biphasic effects witnessed in this study. Higher dosages of caffeine might alter performance more drastically or level off with a certain undetermined dosage. Along with this recommendation, one must caution on administration of higher dosages of caffeine. Previous research (Elkins, et al. 1981) administering 10 mg/kg of caffeine, reported subjective reports of distress (e.g., nervousness, anxiety, crying, jitteriness) in children. If future research assesses the effects of caffeine on learning, at higher dosages, safeguards must be taken to insure that harmful consequences do not occur.

Safeguarding against possible abuse of too much time away from the classroom, a limited number of samples in each task were utilized to measure the effects of caffeine on learning in this study. Increasing the number of samples would have made the duration of each experimental session problematic for the subject and the classroom teacher. Research employing measures of performance on each of the tasks separately (i.e., attention, task performance, memory retention), with many more sample items in each task, per session could discriminate learning effects more conclusively without infringing on the subjects classroom time. A measure of repeated acquisition was not utilized in this study. This type of assessment measure could have determined the effects of caffeine on another component of learning. Future research should focus on each of the tasks in this study, as well as a task assessing repeated acquisition to more definitively determine the validity of the effect of caffeine on learning.

Improvements could be made on the timing of cardiovascular indices measurements. BP and HR were measured at a half way point in each session, at a computer designated time. This did not allow the researchers to measure changes in BP and HR after specific tasks, due to the computer generated randomization of tasks. It might well be that certain tasks were more autonomically arousing than others. This should be determined in future research. This study also averaged the three cardiovascular measures across each experimental session. This type of measurement did not allow for the possible additive effects of caffeine and the stressful nature of some tasks. In the future, research should take care in measuring cardiovascular indices both at rest and in each performance component to more adequately discriminate the effects of caffeine.

Events occurring in the classroom, before each session were not monitored. There may well have been variables that altered the initial BP and HR measurements (e.g., gym class, rest period). Although the subjects were taken out of the classroom at approximately the same time, each morning, the classroom schedule varied from day to day. A more careful monitoring of antecedent classroom events would clarify the effects of caffeine on cardiovascular changes.

The subjects were taken out of the classroom for each experimental session, creating a somewhat artificial setting for learning. To more adequately measure classroom performance, a study measuring performance within the classroom, similar to Baer's study (1987), should be performed.

Caffeine abstinence was measured by self-report and parental/guardian self-report only. To more conclusively measure for abstinence, urine or blood tests measuring for caffeine metabolites could be initiated.

In summary, the results of this study although mixed, and without statistical significance are important for several reasons. First, very few studies have measured the effects of caffeine on children. This study replicates and extends the literature on the effects of caffeine on children. Second, much of the previous caffeine research did not utilize strict measurement criteria. By employing a standardized computer program and collecting data in a computerized manner, the measurement of attention, performance, and memory retention has been improved. Third, by measuring several areas of learning, numerous research questions have been formulated that can be further researched. Fourth, statistically significant effects of caffeine on cardiovascular indices at time of caffeine consumption and Long Term Memory have been obtained in this study to be able to more effectively correlate the findings with adult research in this area.

To determine caffeine's role on cardiovascular indices, attention, task performance, and memory retention, one must continue to manipulate environmental variables that best exemplify naturalistic learning situations, with strict data measurement criteria. Tolerance and withdrawal issues must be addressed more carefully. Both historical and current individual variables must be taken into account to help improve on internal validity.

The effects of caffeine on children should be monitored and evaluated both from a physiological and performance perspective. Caffeine is a drug that can be effectively dealt with when its effects become empirically known.

Appendix A

Subject Recruitment Letter

Dear Parents and Guardians of 1st and 2nd grade children:

As you probably already know children consume varying amounts of caffeine in carbonated beverages daily. We are not sure how caffeine affects your child's learning and performance. We would like to find out more about caffeine's effects. We are writing to recruit your child's participation in a research project that will provide information for a doctoral dissertation and an undergraduate Senior Individualized Project at Western Michigan University and Kalamazoo College respectively. This study should be an enjoyable experience for your child and provide useful information regarding the effects of caffeine on learning. It has been estimated that the average intake of caffeine, is greater than 200 mg. per day. This amount is equal to two to three cups of coffee, or three to four cans of caffeinated soda for every man, woman, and child. Because caffeinated beverages are universally available and widely consumed, it is important to understand the effects it has on the human body, physiologically and psychologically. We are specifically interested in the effects of caffeine consumption on heart rate and blood pressure, attention, task performance, and memory retention in children ages 6-8 years old.

We are recruiting 12 children between the ages of 6-8 years old, who will be willing to refrain from caffeine, other than our administration, for a period of approximately 5 weeks. During this time your child will participate in 12 sessions. Caffeine will be administered in a Tang drink mixture at three levels: 0 mg/kg, 2 mg/kg, and 4 mg/kg. At 4 mg/kg for a 60 pound child, the caffeine ingested would be 110 mg. This amount of caffeine is equivalent to one cup of coffee, or a 16 oz. bottle of caffeinated soda (e.g. Pepsi, Mountain Dew, Coke). The maximum dosage any child will receive is 180 mg. of caffeine. Your child will then be asked to perform a series of potentially enjoyable computer tasks to test their memory abilities, performance capabilities, and attention span. These tasks are entertaining and do not require prior knowledge of computers, as we will teach your child all the skills necessary to use the computer. Because learning is such an important part of life, we hope that you will allow your child to participate in this project to determine if caffeine is inhibiting or facilitating the learning process.

Parent's permission and cooperation must be obtained as well as the permission of the child and teacher. Testing will occur in school, for approximately 30 minutes every other day, between 9 and 11 am during independent study. It will not disrupt your child's schedule, nor will they miss out on any learning taking place in the classroom. Parents and teachers will also be asked to rate the child's behavior using a brief, standardized checklist. This provides us with more accurate information on the lasting results of caffeine. Once testing is complete the child will receive $20.00 for his/her participation. At completion, parents/guardians will also receive a report outlining the individual child's results, as well as compiled results of the study. Please consider having your child participate, and discuss the possibility with him/her. A planned informational meeting in which you will get more details about the benefits of participating in the study will be scheduled, once we receive word from those interested in participating. If you and your child are interested please contact Suzanne Keller at 387-4464, or Meredith Bigelow at 383-6363. If you have further questions or or want more information about this study please contact us at the numbers listed above.

Thank you for your time and consideration in this important endeavor,
Suzanne L. Keller, Meredith K. Bigelow & R. Wayne Fuqua, Ph.D.

Appendix B

Caffeine Consumption Checklist

CAFFEINE CONSUMPTION CHECKLIST

Please list the items and the amounts of each item that contained caffeine that your child consumes in a typical week. Be specific on the amounts.

1. Amount of coffee consumed:

   Instant regular ____________
   Instant decaf ____________
   Instant freed dried ____________
   Percolated regular ____________
   Percolated decaf. ____________
   Dripolated regular ____________
   Dripolated decaf. ____________

2. How many ounces were in each cup of coffee? ____________
   (An average teacup contains six ounces and an average mug contains 8 ounces)

3. How much tea was consumed:

   Regular tea, bagged
   brewed 1 minute ____________
   brewed 3 minutes ____________
   brewed 5 minutes ____________
   Instant iced tea ____________
   Herb tea ____________

4. What brand of tea was consumed? ____________

5. How many ounces were in each cup/glass of tea? ____________
   (An average teacup contains six ounces and an average glass contains 10 ounces)

6. How many bottles/cans (or portions of bottles/cans) of soft drinks were consumed:

   Cola drinks ____________
   Diet cola drinks ____________
   Cola drinks (decaffeinated) ____________
   Diet cola drinks (decaffeinated) ____________
   Jolt Cola ____________
   Mountain Dew ____________
   Diet Mountain Dew ____________
   Mello Yellow ____________
   Sunkist Orange ____________
   Others: ____________
   ____
   ____
   ____

7. How many total ounces of soft drinks were consumed? ____________
   (An average can contains 12 ounces and an average bottle contains 16 ounces)

8. How much chocolate was consumed:

   Hot chocolate _______________
   Chocolate milk _______________
   Milk chocolate _______________
   Baking chocolate _______________

9. Are there any other foods/drinks consumed that contained chocolate? _____ If so, what were they?

   ____
   ____
   ____

10. How much chocolate was consumed in total? _______________

11. Were any non-prescription drugs ingested that contain caffeine:

    No Doz _______________
    Vivarin _______________
    Anacin _______________
    Midol _______________
    Dristan _______________
    Sinarest _______________
    Coryban-D _______________
    Caffedrine _______________
    Other: _______________
    ____
    ____

12. How many pills/capsules were ingested? _______________

13. Are there any other items consumed that you know contain caffeine. Please list the item and the approximate amount below.

    _______________ _______________
    _______________ _______________
    _______________ _______________
    _______________ _______________

To the best of my knowledge the above is an accurate accounting of the items and amounts of caffeine that your child has consumed in a typical week.

______________________________ __________________
Signature Date

Appendix C

Informed Parent/Guardian Consent

Informed Parent/Guardian Consent for Participation in an Investigation

Western Michigan University

Department of Psychology

Your son/daughter is invited to participate in a research study, that will provide information for a doctoral dissertation, on the effects of caffeine on blood pressure, heart rate, attention, task performance, and memory retention. We hope to learn if caffeine ingestion alters the way a child learns and remembers in a classroom-like situation.

As a participant, you and your child will first be asked to complete two questionnaires concerning your child's medical history and typical caffeine ingestion. We will then ask you to help monitor your child's caffeine abstinence throughout the study and have them maintain an unchanged diet and exercise regime. The study will last approximately five weeks with sessions at school, every other day during the school day. These sessions will only take place while a school nurse is on school premises. In the case that the school does not have a trained nurse on staff, the sessions will only be conducted when an authorized school employee, trained in emergency medical first aid is on premises. In each of these sessions your child will be out of classroom for approximately 30 minutes. Thirty minutes prior to each session we will have your child drink a 6 ounce glass of Tang which may or may not contain caffeine. Then, your child will work on computer tasks in a private room while we measure heart rate and blood pressure. The equipment used to perform these measurements is non-invasive and painless. Your child does not need any previous computer skills to participate in this study. At the end of the study your son/daughter will be paid $20.00 for his/her participation. At completion, you will also receive a report outlining your individual child's results, as well as compiled results of the study.

The research involves minimal risk for your child. The highest dosage of caffeine given will be limited to 4 mg/kg. At 4 mg/kg for a 60 pound child, the caffeine ingested would be 110 mg. This amount of caffeine is equivalent to one cup of coffee, or a 16 oz. bottle of caffeinated soda. The maximum dosage any child will receive is 180 mg. of caffeine. The computer tasks your child will be working on are not difficult and similar to situations that they would experience in a normal classroom setting. In the unlikely event that your child would become stressed, the tasks will be immediately terminated and relaxation exercises commenced. In addition to payment, you and your child may experience the added benefit of increased knowledge as to how your child reacts to caffeine consumption, along dimensions relevant to learning. If interest warrants, we will make available a program to help decrease caffeine consumption at the conclusion of the investigation.

Information obtained in this study will be confidential, with access restricted to experimenters. All identifying information will be removed and data will be stored in a locked file cabinet within the Behavioral Medicine Laboratory, Western Michigan University for a period of seven years. By signing this Informed Consent document, you give permission for the data to be used in scientific presentations and publications.

By signing this document, you also state that you have never been told that your child needs to avoid caffeine for medical reasons and also that s/he has no known history of cardiovascular disease.

Participation is voluntary; your decision will not in any way prejudice relations with Western Michigan University. Although we strongly recommend that you and your child's commitment be for the full length of the study for maximum benefit to all involved, you will be free to have your child discontinue participation at any time without prejudice.

This study has been approved by a university panel (Human Subjects Institutional Review Board) assigned to protect subject's rights. Questions or complaints regarding this research or your rights may be directed to Suzanne L. Keller at 387-4464 or Dr. R. Wayne Fuqua at 387-4474.

Your signature below indicates that you have read and understood the above information and decided to allow your child to participate in the study.
You will be given a copy of this form to keep.

_______________________________ _______________

Signature Date

Appendix D

Informed Subject Consent

Informed Subject Consent
for Participation in an Investigation

Western Michigan University
Department of Psychology

We would like you to participate in a study to see what caffeine does to your body and the way you work on computer problems. We hope to see if drinking caffeine changes the way you normally work.

If you want to participate, we are going to ask you not to drink or eat anything that has caffeine in it. Your parents/guardians will help you to do this. We also don't want you to change anything you normally eat or do. During school time, we will come in 12 different times and have you drink a glass of Tang. It may or may not have caffeine in it. After 30 minutes we will take you out of your class to work some problems on a computer. We will also be putting a band around your arm so that we can see what is going on inside of your body. It won't hurt. At the end of the computer program, we will take you back to your classroom. If the problems get too hard or if you feel uncomfortable we will immediately stop the study. If you complete this study you will receive $20.00.

By signing this, you let us write about what we find out. We will never use your name when we do this.

You don't have to do this, only if you want to. If you decide at any time that you don't want to do this anymore that is alright. We do hope that you want to finish though, because it would help us the most.

If you have any questions or problems with this study, you can tell your parents/guardians and they will call either Suzanne L. Keller at 387-4464, or Dr. R. Wayne Fuqua at 387-4474.

Your signature below means that we have explained this paper to you and that you understand what we want you to do for this study.
You will be given a copy of this form to keep.

______________________________ ______________
Signature Date

______________________________ ______________
Witness Signature Date

Appendix E

Participant Participation Form

PARTICIPANT PARTICIPATION FORM

We are asking that your child abstain from caffeine throughout the course of this study. We also ask that your child continue his/her typical diet and exercise patterns. The reason we are requesting these things is that any changes may affect the measures we are taking. If your child makes any lifestyle changes, becomes ill or is given any medication, please notify the experimenters at once. Additionally please complete the attached questionnaire concerning your child's medical history. Information that you provide on this form will be held in the strictest of confidence. The identity of individual participants will be completely protected in any publications or presentations emanating from this research.

Child's Name: ____________________ Date of Birth: ____________

Address: ____________________ Phone: ________________

Physician's Name: ____

1. Have you ever been told that your child's blood pressure was high?

   Yes _____ No _____. If yes, how long ago? ____________

2. Has your child ever taken medication for high blood pressure?

   Yes _____ No _____. If yes, what and how often? ____________

3. Has your child ever taken medication for Attention Deficit Hyperactivity Disorder?

   Yes _____ No _____. If yes, what and how often? ____________

4. Is your child currently taking medication for Attention Deficit Hyperactivity Disorder?

   Yes _____ No _____. If yes, what and how often? ____________

5. Does your child have difficulty concentrating or staying on task at school or at home?

   Yes _____ No _____. If yes, at what and how often? ____________

6. Have you ever been told that your child has a learning disability?

   Yes _____ No _____. If yes, what type? ____________

7. How many cups of coffee, tea, or ounces of caffeine containing sodas (e.g. Coke, Pepsi) does your child consume per day?

Amount: ____________ What are they? _________________________

8. What is your child's present height? _______________

9. What is your child's present weight? _______________

Please read and sign the following statement: I understand that systematic alterations in my child's diet, medication, exercise, body weight and levels of caffeine consumption may obscure the results of this experiment. I agree to hold these factors constant, through monitoring, to the best of my ability and notify the experimenters should unavoidable changes occur.

______________________________ __________________

Parent/Guardian Signature Date

Appendix F

Sample Screens of Computer Tasks

Sample Screens of Computer Tasks

The following pages are sample screens of the computer tasks that subjects will complete during each session. These tasks will be randomly generated through the Hypercard 2.1 program (Claris Corporation, 1992).

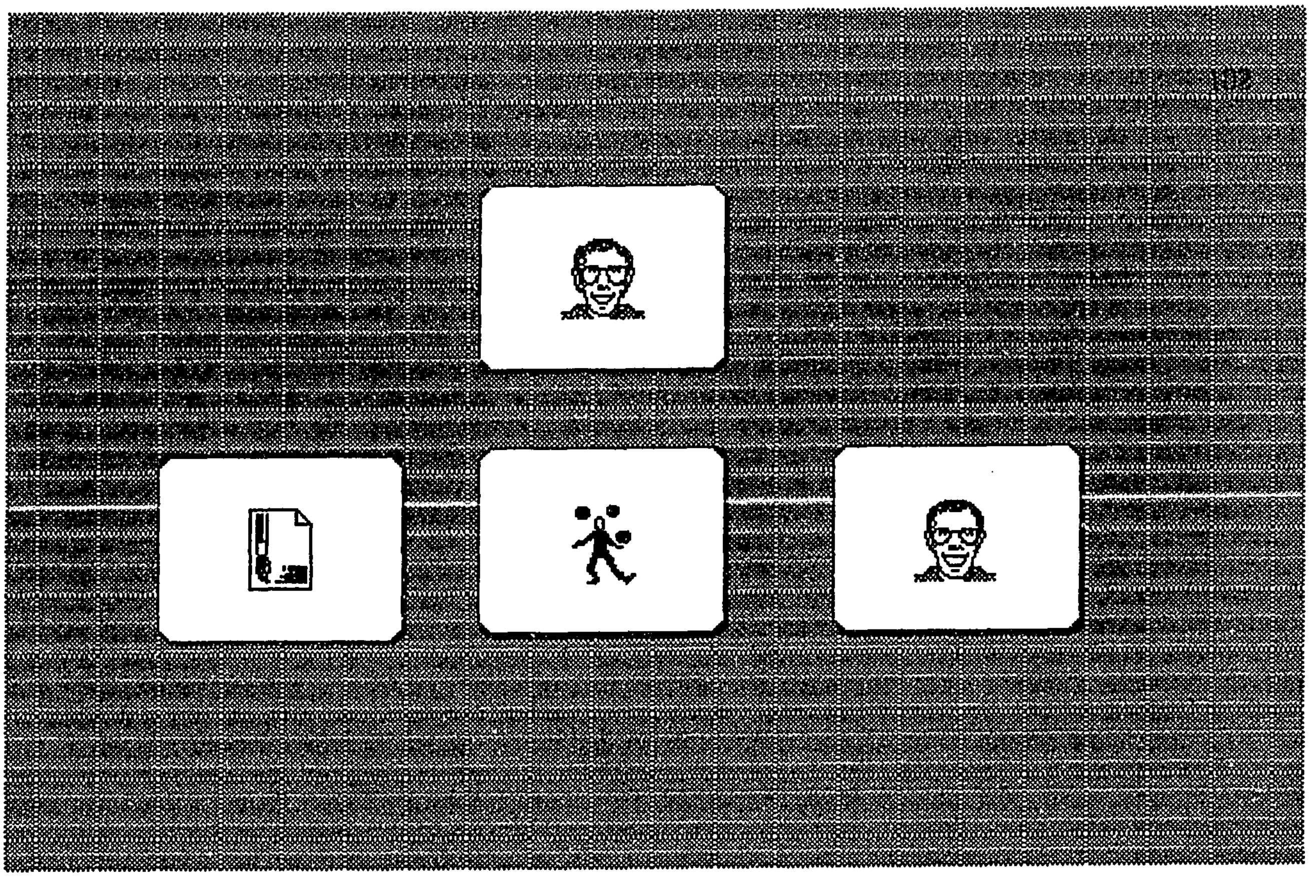
1. Math Task
2. Delayed Matching To Sample Task
3. Direction Following Task
4. Copy Task
5. Attention Task
6. Long Term Memory Task
7. Conditional Rule Task

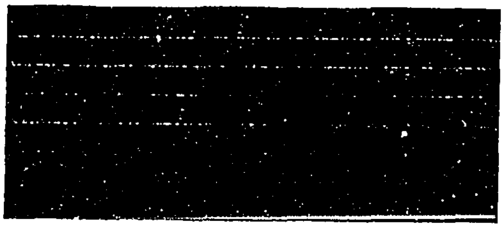
$$\begin{array}{r} 8 \\ \underline{+7} \end{array}$$

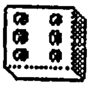
Type your answer in this box $\boxed{}$

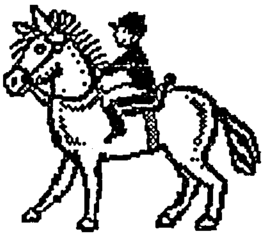
DONE

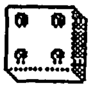
DON'T KNOW











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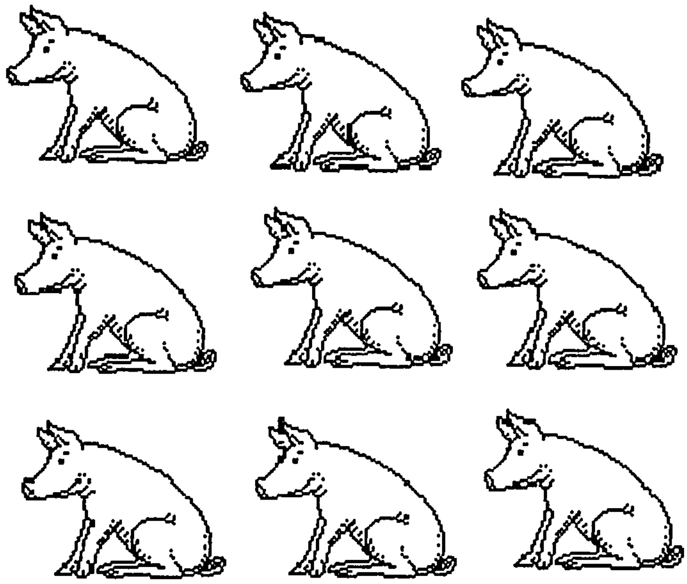
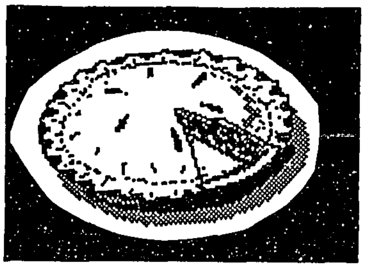
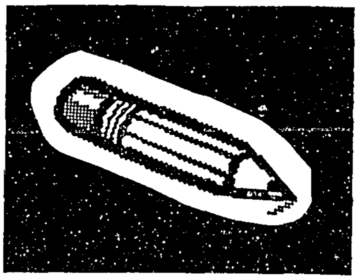
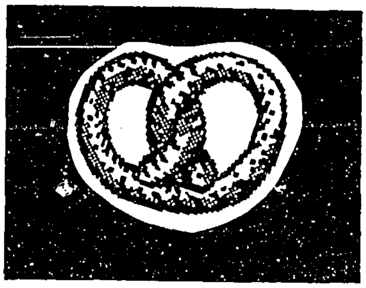


TAKE A LOOK AT THE FOLLOWING PICTURES. DO YOU KNOW WHAT THEY ARE? YOU WILL BE ASKED TO TELL ME WHAT THEY ARE LATER.







ALIEUXPWYPXR

Appendix G

Abbreviated Parent Rating Scale

ABBREVIATED PARENT RATING SCALE
Conners, 1980

Child's Name ____________________ Date __________

	Not at all	Just a little	Pretty much	Very much
1. Restless or overactive				
2. Inattentive, easily distracted				
3. Temper outbursts and unpredictable behavior				
4. Distractibility or attention span a problem				
5. Constantly fidgeting				
6. Daydreams				
7. Mood changes quickly and drastically				
8. Quarrelsome				
9. Restless, always up and on the go				
10. Fails to finsh things that he/she starts				
11. Cries often and easily				
12. Excitable, impulsive				
13. Stomach aches				
14. Headaches				
15. Difficulty in learning				
16. Easily frustrated in efforts				
17. Problems with sleep (can't fall asleep, up too early, up in night)				
18. Vomiting or nausea				
19. Bowel problems (frequently loose, irregular habits, constipation)				
20. Others (Please list)				

Appendix H

Abbreviated Teacher Rating Scale

ABBREVIATED TEACHER RATING SCALE
Conners, 1980

Child's Name ______________________ Date ____________

	Not at all	Just a little	Pretty much	Very much
1. Restless or overactive				
2. Inattentive, easily distracted				
3. Temper outbursts and unpredictable behavior				
4. Distractibility or attention span a problem				
5. Constantly fidgeting				
6. Daydreams				
7. Mood changes quickly and drastically				
8. Quarrelsome				
9. Restless, always up and on the go				
10. Fails to finsh things that he/she starts				
11. Cries often and easily				
12. Excitable, impulsive				
13. Stomach aches				
14. Headaches				
15. Difficulty in learning				

Appendix I

Daily Caffeine Consumption Checklist

DAILY CAFFEINE CONSUMPTION CHECKLIST

Please list the items and the amounts of each item that contained caffeine that your child consumed in the last 24 hours. Be specific on the amounts.

1. Amount of coffee consumed:

   Instant regular ______________
   Instant decaf ______________
   Instant freed dried ______________
   Percolated regular ______________
   Percolated decaf. ______________
   Dripolated regular ______________
   Dripolated decaf. ______________

2. How many ounces were in each cup of coffee? ______________
   (An average teacup contains six ounces and an average mug contains 8 ounces)

3. How much tea was consumed:

   Regular tea, bagged
   brewed 1 minute ______________
   brewed 3 minutes ______________
   brewed 5 minutes ______________
   Instant iced tea ______________
   Herb tea ______________

4. What brand of tea was consumed? ______________

5. How many ounces were in each cup/glass of tea? ______________
   (An average teacup contains six ounces and an average glass contains 10 ounces)

6. How many bottles/cans (or portions of bottles/cans) of soft drinks were consumed:

   Cola drinks ______________
   Diet cola drinks ______________
   Cola drinks (decaffeinated) ______________
   Diet cola drinks (decaffeinated) ______________
   Jolt Cola ______________
   Mountain Dew ______________
   Diet Mountain Dew ______________
   Mello Yellow ______________
   Sunkist Orange ______________
   Others: ______________
   ____
   ____
   ____

7. How many total ounces of soft drinks were consumed? ______________
   (An average can contains 12 ounces and an average bottle contains 16 ounces)

8. How much chocolate was consumed:

Hot chocolate ______________
Chocolate milk ______________
Milk chocolate ______________
Baking chocolate ______________

9. Are there any other foods/drinks consumed that contained chocolate? _____ If so, what were they?

____
____
____

10. How much chocolate was consumed in total? ______________

11. Were any non-prescription drugs ingested that contain caffeine:

No Doz ______________
Vivarin ______________
Anacin ______________
Midol ______________
Dristan ______________
Sinarest ______________
Coryban-D ______________
Caffedrine ______________
Other: ______________
____
____

12. How many pills/capsules were ingested? ______________

13. Are there any other items consumed that you know contain caffeine. Please list the item and the approximate amount below.

______________ ______________
______________ ______________
______________ ______________
______________ ______________

To the best of my knowledge the above is an accurate accounting of the items and amounts of caffeine that your child has consumed in the last 24 hours.

______________________________ ______________
Signature Date

Appendix J

Principal/Teacher Consent

Principal - Teacher Consent for Participation in an Investigation

Western Michigan University

Department of Psychology

We would like the students in your first and second grades to participate in a research study, that will provide information for a doctoral dissertation, on the effects of caffeine on blood pressure, heart rate, attention, task performance, and memory retention. We hope to learn if caffeine ingestion alters the way a child learns and remembers in a classroom-like situation.

As participants, your students, with their parents help will first be asked to complete two questionnaires concerning their medical history and typical caffeine ingestion. We will then ask the parents to help monitor their child's caffeine abstinence throughout the study and have them maintain an unchanged diet and exercise regime. The study will last approximately five weeks with sessions at school, every other day between 9 and 11 am during independent study. In each of these sessions the student will be out of classroom for approximately 30 minutes. Thirty minutes prior to each session we will have the student drink a 6 ounce glass of Tang which may or may not contain caffeine. Then, the student will work on computer tasks in a private room while we measure heart rate and blood pressure. The equipment used to perform these measurements is non-invasive and painless. the student does not need any previous computer skills to participate in this study. At the end of the study the student will be paid $20.00 for his/her participation. These sessions will only take place while a school nurse is on school premises. In the case that the school does not have a trained nurse on staff, the sessions will only be conducted when an authorized school employee, trained in emergency medical first aid is on premises.

The research involves minimal risk for the student. The highest dosage of caffeine given will be limited to 4 mg/kg. At 4 mg/kg for a 60 pound child, the caffeine ingested would be 110 mg. This amount of caffeine is equivalent to one cup of coffee, or a 16 oz. bottle of caffeinated soda. The maximum dosage any child will receive is 180 mg. of caffeine. The computer tasks the student will be working on are not difficult and similar to situations that they would experience in a normal classroom setting. In the unlikely event that the student would become stressed, the tasks will be immediately terminated and relaxation exercises commenced. In addition to payment, you, your students and your student's parents may experience the added benefit of increased knowledge as to how the student reacts to caffeine consumption, along dimensions relevant to learning. If interest warrants, we will make available a program to help decrease caffeine consumption at the conclusion of the investigation.

Information obtained in this study will be confidential, with access restricted to experimenters. All identifying information will be removed and data will be stored in a locked file cabinet within the Behavioral Medicine Laboratory, Western Michigan University for a period of seven years. By signing this Principal - Teacher Consent for Participation document, you give permission for the research study to be conducted in your school, and for the data to be used in scientific presentations and publications.

Participation is voluntary; your decision will not in any way prejudice relations with Western Michigan University. Although we strongly recommend that you and your student's commitment be for the full length of the study for maximum benefit to all involved, you will be free to discontinue participation at any time without prejudice.

This study has been approved by a university panel (Human Subjects Institutional Review Board) assigned to protect subject's rights. Questions or complaints regarding this research or your rights may be directed to Suzanne L. Keller at 387-4464 or Dr. R. Wayne Fuqua at 387-4474.

Your signature below indicates that you have read and understood the above information and decided to allow your students to participate in the study. You will be given a copy of this form to keep.

____________________________ ________________
Principal Signature Date

____________________________ ________________
Teacher Signature Date

Appendix K

Human Subjects Institutional Review Board
Application and Approval

WESTERN MICHIGAN UNIVERSITY
HUMAN SUBJECTS INSTITUTIONAL REVIEW BOARD (HSIRB)
HUMAN SUBJECTS APPROVAL FORM

RESEARCH MAY NOT BEGIN UNTIL THE PROTOCOL HAS BEEN REVIEWED AND APPROVED BY THE HUMAN SUBJECTS INSTITUTIONAL REVIEW BOARD,WHICH MEETS ON A REGULAR MONTHLY BASIS. PROTOCOLS MUST BE RECEIVED BY RESEARCH AND SPONSORED PROGRAMS AT LEAST SEVEN DAYS PRIOR TO A REGULARLY SCHEDULED MEETING IN ORDER TO BE ACTED ON AT THAT MEETING. THE FORM MUST BE TYPEWRITTEN, EXCEPT FOR SIGNATURES.

PRINCIPAL INVESTIGATOR*: Suzanne L. Keller, M.A.

DEPARTMENT: Psychology

Office Address: 273 Wood Hall

Office Phone: 387-4464

Home Address: 226 Stuart Ave. Kalamazoo, MI 49007-3218 (Zip Code)

Home Phone: (616) 383-2171

PROJECT TITLE: Effects of caffeine consumption on cardiovascular indices, attention, task performance, and memory retention in children.

PROPOSED PROJECT DATES: From 1/1/93 To 5/30/93

SOURCE OR POTENTIAL SOURCE OF FUNDING: Private

APPLICATION IS: New XX Renewal ____

Protocols for projects extending beyond one year from date of HSIRB approval must be submitted annually for renewal.

If this proposal is approved by the Institutional Review Board, the Principal Investigator agrees to notify the HSIRB in advance of any changes in procedures which might be necessitated. If, during the course of the research, unanticipated subject risks are discovered, this will be reported to the IRB immediately.

Suzanne Keller 11/23/92
P. I. Signature Date

*If the Principal Investigator is a student, complete the following:

Undergraduate Level Research: ____ Graduate Level Research: Dissertation

Faculty Advisor: R. Wayne Fuqua, Ph.D. Telephone: 387-4474

Department: Psychology

R. Wayne Fuqua 11-23-92
Advisor Signature Date

VULNERABLE SUBJECT INVOLVEMENT (Fill out if applicable)

Research involves subjects who are (check as many as apply)

1. __X__ Children (any subject under the age of 18) Approximate age 6 - 8 yrs old.
2. _____ Mentally retarded persons
3. _____ Mental health patients
   _____ Check if institutionalized
4. _____ Prisoners
5. _____ Pregnant women
6. _____ Other subjects whose life circumstances may interfere with their ability to make free choices in consenting to take part in research;

____
(Describe)

LEVEL OF REVIEW

To determine the appropriate level of review, refer to WMU Policy Guidelines for categories of exempted research (Appendix B).

________	Exempt	(Forward the original application to the Chair of the Department for a cover letter, then forward to HSIRB Chair via RSP)
___X___	Subject to Review	(Forward original application plus 8 copies to HSIRB Chair via RSP)

BLOOD PRODUCTS INVOLVED

If your research involves the collection of blood or blood products, then pick up and complete an addendum (HSIRB Collection of Blood and Blood Products Form).

PLEASE TYPE THE REQUESTED PROTOCOL INFORMATION ON THE FOLLOWING PAGES. You may attach additional sheets as necessary and reference the appropriate page.

ABSTRACT: Briefly describe the purpose, research design, and the site of the proposed research activity.

Caffeine is one of the most commonly used drugs in the western world today. Average intake of caffeine in the United States has been estimated at greater than 200 mg. daily per person. This intake is equivalent to two to three cups of coffee for every man, woman and child. Although conflicting, the current literature suggests that this level of caffeine ingestion may have detrimental physiological effects on one's cardiovascular system, as well as affecting the ability to attend to, cognitively process, and complete tasks.

In spite of evidence for significant consumption, very little research has been done on the effects of caffeine on children. The limited findings suggest that caffeine consumption may affect the cognitive and behavioral skills necessary for success in school. Elkins, et al. (1981) found that there was a significant increase in vigilance and a decrease in free recall at 10 mg/kg. No effects were obtained from lower dosages in this study.. At 5 mg/kg, Rapoport, et al., (1984) found only minor elevations in blood pressure and heart rate with tolerance developing rapidly. Baer (1987) found that with 2.5 mg/kg of caffeine, that there were only small and inconsistent effects on the behavior of young children. Baer suggested that to accurately determine effect much higher dosages should be given. Given the research findings to date, the only effects expected from 4 mg/kg caffeine as proposed in this study would be slight increases in blood pressure and heart rate, some increase in vigilance and a possible decrease in overall performance. The literature cites no deleterious effects with caffeine dosages of less than 12-15 mg/kg. The effects at this level include, nervousness and feeling jittery, as reported by the subjects.

Given the widespread consumption of caffeine in carbonated beverages, verification and elaboration of previous research with children seems warranted. Valuable information can be obtained to qualify the effects of caffeine on this population.

The proposed study will clarify whether caffeine has an effect on the cognitive processes, such as attention, task completion and memory retention, as well as if these effects are indeed detrimental to the learning processes of children. These results will add valuable information to the literature to allow for more educated decisions on whether caffeine should be incorporated into or deleted from children's diets.

Subjects will be assessed under caffeine and no-caffeine states while being presented with a series of computer tasks to complete. These tasks will consist of arithmetic problems, digit duplication, conditioned discrimination, and a direction following task to measure performance, a delayed match to sample, free recall, and direction following task to measure memory, and random attention tasks to measure attention.

A per-session alternating-treatment design across subjects in which the child will be given one of the three levels of caffeine each session, will be utilized. Caffeine will be introduced randomly in a double-blind schedule with each subject being exposed to three different levels of caffeine (0 mg/kg, 2 mg/kg, and 4 mg/kg). The maximum dosage will not exceed 180 mg. of caffeine, which is equivalent to 2 cups of coffee or 3 cans of caffeinated soda. Although this may be more than the subject typically ingests at one time, the caffeine level is far lower than suggested detrimental levels of 12-15 mg/kg utilized in prior research. The research site will be a meeting room in the school that the subjects are currently enrolled in.

BENEFITS OF RESEARCH: Briefly describe the expected benefits of the research.

Participants in the study will receive $20.00 upon completion of the experiment. More importantly the subjects and their parents will have a better understanding of the effects of caffeine on physiology and cognitive skills relevant to academic success.

Overall benefits of this study include a more comprehensive knowledge of the role caffeine ingestion plays on the cardiovascular indices of heart rate and blood pressure, as well as it's effects on attention, performance and memory in children.

CHARACTERISTICS OF SUBJECTS: Briefly describe the subject population (e.g., age, sex, prisoners, people in mental institutions, etc.). Also indicate the source of subjects.

The subjects will be 6 - 8 year old males and females currently in the first and second grades, enrolled in local schools.

SUBJECT SELECTION: How will subjects be selected? Approximately how many subjects will be involved in the research? (Attach advertisement for subjects)

A letter will be sent home to the parents/guardians of the children in the classes selected. Inclusion will be based on approval of participation by parents/guardians and ability to meet inclusionary criteria. Inclusionary criteria consists of: 1) evaluation of consuming no more than 300 mg. of caffeine daily, 2) agreement to abstain from all sources of caffeine during the course of the study, and 3) agreement to make no major changes in diet or exercise over the course of the study. Six to eight year-old children have a mean blood pressure reading of 90 mmHg. (systolic blood pressure) and 60 mmHg. (diastolic blood pressure). Subjects who display elevated blood pressure readings (greater than 140 mmHg., systolic blood pressure and 80 mmHg., diastolic blood pressure) will be excluded from the study. Twenty subjects will be needed for this study.

RISKS TO SUBJECTS: Briefly describe the nature and likelihood of possible risks (e.g., physical, psychological, social) as a result of participation in this research.

Minimal risk is involved. Caffeine ingestion will be limited to 2 mg/kg and 4 mg/kg with a maximum of 180 mg of caffeine administered. The computer tasks are of such a nature as to place minimal stress on the individual. The equipment used to monitor the physiological levels is non-invasive, painless and electrically safe. A subject could conceivably overreact either physiologically or psychologically to a particular task, although the likelihood of this risk is extremely low.

PROTECTION FOR SUBJECTS: Briefly describe measures taken to protect subjects from possible risks, if any.

If physiological levels approach extreme levels, or if a subject appears to be experiencing unwarranted side effects (i.e. anxiety, mood changes, excitability, inattentiveness, restlessness, and crying) all testing and monitoring will cease. A session will be terminated if blood pressure readings exceed 160/95 mmHg. Relaxation techniques will be implemented. An extensive debriefing will also follow. Continued participation in the investigation will be jointly determined by the subject, subject's parent/guardian and the experimenter. Equipment operators will be trained to recognize and implement interventions in such a situation.

CONFIDENTIALITY OF DATA: Briefly describe the precautions that will be taken to ensure the privacy of subjects and confidentiality of information. Be explicit if data is sensitive.

All data will be kept in a locked file within the Behavioral Medicine Laboratory, in Wood Hall. Data will only include the subject's code number and will not be able to be matched up with subject's name. All experimenters will sign a form stating that cofidentiality must be maintained. An informed consent form will be given to the subject and parent/guardian outlining the issues of confidentiality. Please see attached for parent/guardian and subject informed consent forms.

INSTRUMENTATION: If questionnaires, interview schedules, data collection instruments, other than standardized instrumentation on file with the HSIRB, or advertisements for subjects are used, please identify them and attach a copy of what will be used in the project.

Subject Recruitment letter (Appendix A)
Caffeine Consumption Checklist (Appendix B)
Participant Information Form (Appendix E)
Hypercard Computer Task examples (Appendix F)
Abbreviated Conner's Rating Scale (Teacher and Parent) (Appendix G and H)
Daily Caffeine Consumption Checklist (Appendix I)
Principal - Teacher Consent for Participation in an Investigation (Appendix J)

INFORMED CONSENT: Attach a copy of the informed consent (if applicable). Each subject should also be given a copy.

Please see attached. (Appendix C and D)

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3899

WESTERN MICHIGAN UNIVERSITY

Date: February 12, 1993

To: Suzanne Keller

From: M. Michele Burnette, Chair M. Michele Burnette JKS

Re: HSIRB Project Number 92-12-16

This letter will serve as confirmation that your research protocol, "Effects of caffeine consumption on cardiovascular indices, attention, task performance, and memory retention in children" has been approved after full review by the HSIRB. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the approval application.

You must seek reapproval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: February 12, 1994

xc: Fuqua, PSY

BIBLIOGRAPHY

American Journal of Psychology, (1989). AJP Forum, Recency effect in recall of a word list when an immediate memory task is performed after each word presentation. American Journal of Psychology, 102, 265-270.

American Psychiatric Association (1994). Diagnostic and statistical manual of mental disorders, Fourth Edition. Washington DC: American Psychiatric Association.

American Psychiatric Association (1987). Diagnostic and statistical manual of mental disorders, Third Edition, Revised. Washington DC: American Psychiatric Association.

Baer, Ruth A. (1987). Effects of caffeine on classroom behavior, sustained attention and a memory task in preschool children. Journal of Applied Behavior Analysis, 20, 225-234.

Baker, W. J. & Theologus, G. C. (1972). Effects of caffeine on visual monitoring. Journal of Applied Psychology, 56, 422-427.

Bourne, L. E., & Ekstrand, B. R. (1985). Psychology: its principals and meanings (5th ed.). New York: CBS College Publishing.

Castellano, C. (1976). Effects of caffeine on discrimination learning, consolidation, and learned behavior in mice. Psychopharmacology, 48, 255-260.

Claris Corporation, (1992). Hypercard 2.1 (Computer Program). Claris Corporation, Software Division of Apple Corporation

Conners, C. (1975). A placebo crossover study of caffeine treatment of hyperkinetic children. International Journal of Mental Health, 4, 132-143.

Conners, C. (1979). The acute effects of caffeine on evoked response, vigilance, and activity level in hyperkinetic children. Journal of Abnormal Child Psychology, 7, 145-152.

Conners, C. (1980). Normative data on revised Conners parent and teacher rating scales. Journal of Abnormal Child Psychology, 8, 271-280.

Curatola, P. W., & Robertson, D. (1983). The health consequences of caffeine. Annals of Internal Medicine, 98, 641-653.

Davidson, R. A., & Smith, B. D. (1991). Caffeine and novelty: Effects on electrodermal activity and performance. Physiology and Behavior, 49, 1169-1175.

Elkins, R. N., Rapoport, J. L., Zahn, T. P., Bushbaum, M. S., Weingartner, H., Kopin, I. J., Langer, D., & Johnson, C. (1981). Acute effects of caffeine in normal prepubertal boys. American Journal of Psychiatry, 138, 178-183.

Engle, R. W., Carullo, J. J., & Collins, K. W. (1991). Individual Differences in working memory for comprehension and following directions. Journal of Educational Research, 84, 253-262.

Erikson, G. C. (1985). The effects of caffeine on memory for word lists. Physiology and Behavior, 35, 47-51.

Fagan, D., Swift, C. G., & Tiplady, B. (1988). Effects of caffeine on vigilance and other performance tests in normal subjects. Journal of Psychopharmacology, 2, 19-25.

Foreman, N., Barraclough, S., Moore, C., Mehta, A., & Madon, M. (1989). High doses of caffeine impair performance of a numerical version of the Stroop Task in men. Pharmacology Biochemistry and Behavior, 32, 399-403.

Gilbert, R. M. (1976). Caffeine as a drug of abuse. In R. J. Gibbins (Ed.), Research advances in alcohol and drug problems (pp. 49-176). New York: John Wiley.

Gilliland, A. R., & Nelson, D. (1939). The effects of coffee on certain mental and physiological functions. The Journal of General Psychology, 21, 339-348.

Graham, D. M. (1978). Caffeine: Its identity, dietary sources, intake and biological effects. Nutritional Review, 36, 97-102.

Greden, J. F. (1980). Caffeine and tobacco dependence. In H. I. Kaplan, A. M. Freedman, & B. J Sadock (Eds.), Comprehensive textbook of psychiatry, 3rd edition: Vol. 2 (pp. 1645-1652). Baltimore: Williams & Williams.

Guralnik, D. B. (Ed.). (1984). Webster's New World Dictionary of the American Language. New York: Warner Books.

Harvey, D. H. & Marsh, R. W. (1978). The effects of de-caffeinated coffee versus whole coffee on hyperactive children. Developmental Medicine and Child Neurology, 20, 81-86.

Heinbuck, C. L., & Hershberger, W. A. (1989). Development of visual attention: A stereoscopic view. Perception & Psychophysics, 45, 404-410.

Henry, L. A. (1991). The effects of word length and phonemic similarity in young children's short-term memory. The Quarterly Journal of Experimental Psychology, 43, 35-52.

Hitch, G. J., Halliday, M. S., Dodd, A., & Littler, J. E. (1989). Development of rehearsal in short-term memory: Differences between pictorial and spoken stimuli. British Journal of Developmental Psychology, 7, 347-362.

Hull, C. L. (1935). The influence of caffeine and other factors on certain phenomena of rote learning. The Journal of General Psychology, 249-273.

Izzo, J. L., Ghosal, A., Kwong, T., Freeman, R. B., Jaenike, J. R. (1985). Age and prior caffeine use alter the cardiovascular and andrenomecullary responses to oral caffeine. American Journal of Cardiology, 53, 918-922.

Kaplan, P. S. (1991). A child's odyssey: Child and adolescent development (2nd ed.). St. Paul, MN: West Publishing Company.

Keller, S. L. (1988). Effects of caffeine consumption on cardiovascular reactivity to social stress. Unpublished master's thesis, Western Michigan University, Kalamazoo MI.

Landrum, R. E., Meliska, C. J., & Loke, W.H. (1988). Effects of caffeine and task experience on task performance. Psychologia, 31, 91-97.

Lane, J. D., & Williams, R. B. (1985). Caffeine affects cardiovascular responses to stress. Psychophysiology, 22, 648-655.

Lane, J. D., & Williams, R. B. (1987). Cardiovascular effects of caffeine and stress in regular coffee drinkers. Psychophysiology, 24, 157-164.

Leviton, A. (1992). Behavioral correlates of caffeine consumption by children. Clinical Pediatrics, 31, 742-750.

Loke, W. H. (1988). Effects of caffeine on mood and memory. Physiology and Behavior, 44, 367-372.

Loke, W.H., Himrichs, J. V., & Ghoneim, M. M. (1985). Caffeine and diazepam: Separate and combined effects on mood, memory, and psychomotor performance. Psychopharmacology, 87, 344-350.

Lowenkron, B. (1988). Generalization of delayed identity matching in retarded children. Journal of the Experimental Analysis of Behavior, 50, 163-172.

Lowenkron, B. (1989). Instructional control of generalized relational matching to sample in children. Journal of the Experimental Analysis of Behavior, 52, 293-309.

Marschalek, D. G. (1988). Processing and memory of color, contour, and pattern found in computer digitized color pictures for elementary children. Journal of Educational Computing Research, 4, 403-412.

Ohnishi, A., Branch, R. A., Jackson, K., Hamilton, R., Biaggioni, I., Deray, G., & Jackson, E. K. (1986). Chronic caffeine administration exacerbates renovascular, but not genetic hypertension in rats. Journal of Clinical Investigation, 78, 1045-1050.

Pillette, W. L. (1983). Caffeine: Psychiatric grounds for concern. Journal of Psychosocial Nursing and Mental Health Services, 21, 19-24.

Potter, W. F. (1993). Multi-component Learning and Assessment Program. (Computer Program). Kalamazoo, MI: Western Michigan University.

Rall, T. W. (1980). Central nervous system stimulants: The xanthines. In A. G. Gilman, L. S. Goodman, & A. Gilman (Eds.) The pharmalogic basis of therapeutics, 6th ed. (pp. 592-607). New York: Macmillan

Rapoport, J. L., Berg, C. J., Ismond, D. R., Zahn, T. P., & Neims, A. (1984). Behavioral effects of caffeine in children. Archives of General Psychiatry, 41, 1073-1079.

Rapoport, J. L., Jensvold, M., Elkins, R., Buchbaum, M.S., Weingartner, H., Ludlow, C., Zahn, T. P., Berg, C. J., & Neims, A. H., (1981). Behavioral and cognitive effects of caffeine in boys and adult males. The Journal of Nervous and Mental Disease, 169, 726-732.

Robertson, D., Frolich, J. C., Carr, R. K., Watson, J. T., Hollifield, J. W., Shannel, D. G., & Oates, J. A. (1978). Effects of caffeine on plasma renin activity, catecholamines and blood pressure. The New England Journal of Medicine, 298, 181-186.

Rosenberg, L. (1985). Breast cancer and the consumption of coffee. American Journal of Epidemiology, 122, 391-399.

Shapiro, D., Lane, D. & Henry, J. P. (1986). Caffeine, cardiovascular reactivity, and cardiovascular disease. In K. A. Matthews, S. M. Weiss, T. Detre, T. M. Dembroski, F. Balkner, S. B. Manuck, & R. B. Williams (Eds.), Handbook of stress reactivity, and cardiovascular disease (pp.311-327). New York: John Wiley.

Sutherland, D. J., McPherson, D. D., Renton, K. W., Spencer, C. A., & Montague, T. J. (1985). The effect of caffeine on cardiac rate, rhythm, and ventricular repolarization. Chest, 87, 319-324.

Terry, W. S. & Phifer, B. (1986). Caffeine and memory performance on the AVLT. Journal of Clinical Psychology, 42, 860-863.

van Dusseldorp, M., Smits, S., Thien, T., & Katin, M. B. (1989). Effect of decaffeinated versus regular coffee on blood pressure. A 12-week double-blind trial. Hypertension, 14, 563-569.

Watkinson, B. (1985). Maternal caffeine use before during and after pregnancy and effects upon offspring. Neurobehavioral Toxicology and Teratogeny, 7, 9-17.

Weiss, B., & Laties, V. G. (1962). Enhancement of human performance by caffeine and the amphetamines. Pharmacological Review, 14, 1-36.

Whittsett, T. L., Manion, C. V., & Christensen, H. D. (1984). Effects of coffee and caffeine. American Journal of Cardiology, 53, 918-922.

Zimmerberg, B., Carr, K. L., Scott, A., Lee, H. L., & Weider, J. M. (1991). The effects of postnatal caffeine exposure on growth, activity and learning in rats. Pharmacology Biochemistry and Behavior, 39, 883-888.

Zwyghuizen-Doorenbos, A., Roehrs, T. A., Lipshutz, L., Timms, V., & Roth, T. (1990). Effects of caffeine on alertness. Psychopharmacology, 100, 36-39.