ASPARTAME AND SUCROSE EFFECTS
ON THE
REACTION TIME OF YOUNG CHILDREN

by

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(ABSTRACT)

Twenty "normal" (non-hyperactive) preschool children (9 girls, 11 boys) and 6 schoolage boys were maintained on a low sucrose diet for two weeks. During the second week, subjects were randomly assigned to one of two treatments (drink sweetened with either sucrose or aspartame). Cherry-flavored drinks mixed in a distilled water base were given daily. Subjects in the sucrose group received 3.4 g sucrose per kilogram of body weight, mixed to a concentration of 25 g per 100 ml. Subjects in the aspartame group received the same cherry-flavored drink mixed to a concentration of 8 g of aspartame per 100 ml of drink. A simple reaction-time task measured attention and alertness three times during the study: (1) prior to the low sucrose diet; (2) after one week of the low sucrose diet; (3) after one week of receiving the treatment. The dependent variable was the difference between reaction time at time 3 (after

treatment) and time 2 (at the end of one week of a low sucrose diet). An ANCOVA (2 levels of treatment, age as covariate) revealed no significant difference in the mean reaction times of the subjects in the sucrose and aspartame groups. However, the variance in reaction times for those in the sucrose treatment group was significantly greater ($p < .03$) than for those in the aspartame group.

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CHAPTER I

INTRODUCTION

The purpose of this study was to examine the effects of sucrose versus aspartame on the reaction times of young children.

Background

Popular literature has aspoused a relationship between dietary intake of sucrose and a variety of behavioral problems, such as discipline and/or learning dysfunction in children (Smith, 1979; Phlegar & Phlegar, 1978). However, very little empirical data are available to address this hypothesis. Studies that are available have typically used hyperactive (Conners, Goyette, Southwick, Lees, & Andrulonis, 1976; Goyette, Conners, Petti, & Curtis, 1978; Harley, Matthews, & Eichman, 1978; Harley et al., 1978; Kershner & Hawke, 1979; Langseth & Dowd, 1978; Prinz, Roberts, & Hantman, 1980; Rogers & Hughes, 1981; Swanson & Kinsborne, 1980) or emotionally disturbed patients (Conners & Blouin, 1982-83; Rapoport, 1982-83). Furthermore, available data on the effect of sucrose on behavior have been obtained using schoolage children as subjects. Exceptions include work by Prinz et al., (1980) and Rogers and Hughes (1981). The present study was conducted to assess the effects of sucrose on behavior of "normal" (non-hyperactive, non-disturbed) children. Furthermore, the present study included young children (3 - 8 years) as subjects.

Rationale

One explanation for a relationship between sucrose intake and behavioral problems has been put forth by Lendon Smith. He postulated that some children may be sensitive to sucrose if they have poor glucose tolerance. More specifically, he proposed that children who have a hypoglycemic response to high sugar loads will be irritable (Smith, 1979) and will not be able to maintain active attention when it is required. Indeed, Langseth and Dowd (1978) found that 86% of hyperactive boys in their study had an impaired glucose tolerance. However, one must bear in mind that in the normal population, only a small percentage of all subjects can be expected to have a hypoglycemic response to sugars. Indeed, the normal response to sucrose intake would involve an initial rise in blood glucose followed by a gradual release of insulin and gradual lowering of blood sugar to a normal level. However, glucose tolerance patterns may vary widely among individuals. Therefore, one might speculate that the task performance of individuals following sucrose intake would also vary. However, popular notions of the relationship between sugar intake and behavior propose that sugar will contribute to increased activity, negativism, or poor attention.

The present study focused specifically on the effect of sucrose on attention and response capabilities by measuring reaction response times among children who had received a drink sweetened with sucrose or aspartame. A reaction-time task was used because it has been shown to be an objective and sensitive measure for concentration, alertness, and attentiveness (Conners & Blouin, 1982-83; Elliott, 1970; Posner & Boies, 1971; Rapoport, 1982-83; Serio, 1975).

The reaction-time task used in this study involved responding to the sight of 10 blue slides randomly distributed in a carousel slide tray of 30 red and 40 blank slides. Reaction response times were measured at three times: (1) before the project began; (2) after one week on a low sucrose diet; (3) after one week on treatment (sucrose versus aspartame). The difference between the reaction time at Time 2 and Time 3 and Time 1 and Time 2 were computed and constituted the dependent measures.

Hypothesis

Following the notion put forth in popular literature, the following hypotheses were tested:

H_1: With age as a covariate, there will be a significant difference between reaction-time change scores of subjects receiving sucrose versus those receiving aspartame.

H_2: With height-weight ratio percentile as a covariate, there will be a significant difference between reaction-time change scores of subjects receiving sucrose versus those receiving aspartame.

H_3: With all subjects from both treatment groups combined, there will be a significant difference between the reaction-time scores at Time 1 (before the project began) and at Time 2 (after one week on a low sucrose diet).

CHAPTER II

REVIEW OF LITERATURE

Sucrose and Children's Behavior

Many authors, in popular literature, postulate that sugar is a major cause of a variety of childhood behavioral and learning disorders (Crook, 1980; Phlegar & Phlegar, 1978; Powers, 1974; Powers & Presley, 1976; Seifert, Stratton & Williams, 1980; Smith, 1976, 1979, 1981). Various authors have hypothesized that behavior is affected by sugar but have done so without a research base. Since popular literature adds little more than hypothesis to research, it will not be reviewed in this paper.

There have been a few empirical studies that investigated sugar and behavior, and the results are mixed. One of the most recent is a study by Conners and Blouin (1982-83) that discusses the nutritional effects on the behavior of children. They reported on their pilot study of 13 children who were hospitalized with severe behavior disorders, anxiety, and attention deficits. The sex of the children was not reported. Over a 2 to 4 week period each child received 50 g sucrose, fructose, or regular orange juice on alternate days in a modified Latin square design. Teachers, nurses, and observers monitored behaviors. The results showed two significant sucrose effects, with no difference between sucrose and fructose. When the sucrose treatment group was compared to the control group, results of laboratory observations showed an increase in total movement and a decrease in appropriate behavior. However, the teachers and nurses were unable to detect any differences among the children. Conners and Blouin (1982-83) reported that conclusions cannot be made from that pilot study at this time. Particularly, it cannot be concluded that deviant behavior is increased by sucrose because the appropriate behavior code is highly correlated (-0.97) with total motor activity. While only preliminary data have been obtained, those researchers also focused on attention and motor activity and analyzed the children's stimulus selection and perceptual decision processes on a Continuous Performance Task.

Rapoport (1982-83) reported on a sucrose challenge study involving 21 male grade school children who answered an advertisement and who were known to have adverse behavioral reactions to sugar. The children were separated into psychiatrically normal and clinically diagnosed groups and received all treatments using a double-blind challenge procedure. Glucose and sucrose in the amounts of 1.75 g per kilogram of body weight and saccharin (placebo) were added to a lemon-flavored ice slurry. The challenges were given two days apart and observations were made during the five hours after the ingestion of the ice slurry. Data on motor activity, behavior ratings, Continuous Performance Task (CPT), and memory were collected. Blood glucose, cortisol, insulin, and plasma epinephrine were also monitored. This information was collected over the five-hour period but the frequency or exact times of testing were not reported. The results did not show any significant effect on any of the behavioral measures when sucrose, glucose, or both were compared to the placebo. However, the children were significantly more quiet on the third testing day than on the first and became quieter as the day progressed, over each test day. Furthermore, the clinically diagnosed children became significantly less active three hours after ingesting sugar, and the normal children were significantly less active one hour after ingesting the glucose solution. Rapoport does not have an interpretation for this finding but reports that drowsiness is common during a glucose tolerance test on children this age. In contrast, three children became more active upon receiving sucrose than after receiving the placebo. These subjects are being retested. Also, the researchers did not observe any of the behavioral changes reported by the mothers. There were no abnormal glucose tolerance test values for any children. After receiving the sugar challenge, most children's blood sugar did rise but returned to baseline values within 90 minutes. Insulin levels were within the normal range in all cases. Although the cortisol was elevated in two children, it showed no relation to sugar challenge. The plasma catecholamine levels were not available.

Otto, Sulzbacher, and Worthington-Roberts (1982) measured the number of errors on a paired-association learning task and body and arm movements in Prader-Willi syndrome males after ingesting solutions of sucrose, complex carbohydrate in the form of cornstarch, or saccharin. Only one subject showed a positive response to sugar intake, i.e., there was an increase in learning-task errors with an increase in blood sugar. The movement scores for children on various solutions showed no significant difference. These findings must be interpreted with caution. The variability in response may have been caused by the mental retardation condition rather than the sucrose. O'Banion, Armstrong, Cummings, and Stange (1978) introduced sugar and other foods to an eight-year old autistic boy to observe changes in the boy's general activity and frequency of disruptive-aggressive behaviors. Ingestion of raw sugar cane did coincide with an increase in disruptive behaviors and caused an immediate high activity rate that wore off in 30 minutes. When sugar was introduced again six hours later, there was little reaction. This is a well-known phenomenon which Randolf (1962) documented. If a food which produces a reaction is introduced more often than every four to five days, a less severe reaction occurs. However, if four to five days have elapsed without the ingestion of this food, an acute or more severe reaction is likely to occur. Kershner and Hawke (1978) hypothesized that megavitamin ingestion would improve intellectual, perceptual, and behavioral measures in hyperactive learning disabled schoolage children. Instead they found that a high protein, low carbohydrate, sugar-free diet was associated with improvements observed. Both groups, one receiving the megavitamin and the other the placebo, showed significant improvement in hyperactivity, attention span, irritability, discipline, peer relations, and the parental behavior checklist. Caution must be exercised in interpreting the data because the study lacked a control group which could have helped to determine if the gains were due to maturation over the six months of the study or the Hawthorne effect induced by parents' high expectations.

A study by Prinz, Roberts, and Hantman (1980) is especially relevant because a control group was used. Also, there was a larger number of subjects. The subjects included 28 three- to eight-year-old boys and girls identified as hyperactive and 26 control subjects, four- to eight-years old. Mothers submitted a seven-day dietary record for their children and were told not to alter the child's diet from the usual pattern. The diets were analyzed in order to estimate the gross pattern of food consumption. Food was, therefore, classified into four general categories: (a) sugar products, including any food or beverage in which sugar was a substantial ingredient; (b) refined carbohydrates other than sugar products, such as bread, pasta, etc.; (c) nutritional foods, which include meats, vegetables, fruit, and dairy products; (d) unclassifiable, such as sauces or sugarless gum (Prinz et al., 1980). As a final analysis, the protein and carbohydrate contents were recorded for each food item. Seven scores were computed from each subject's dietary record. The dietary scores, sugar consumption, and percentage of food items not allowed on the Feingold diet were comparable for both the hyperactive and control groups. In the playroom, destructive-aggressive behavior, movement, and restless behavior of both groups were observed and tallied. Although the dietary scores were similar in both groups, the findings showed a significant positive correlation between consumption of sugar products and playroom behavior of young children. In the hyperactive children, a high ratio of sugar to nutritional foods was associated with higher scores of destructive-aggressive behavior. In the control subjects, the high sugar diet was associated with the number of quadrant changes in the room. It would seem, therefore, that sucrose is associated with certain behaviors, but it is worth noting that these behaviors appear to be different in hyperactive and normal children.

Abnormal patterns in the five-hour oral glucose tolerance test of blood samples have been noted by Langseth and Dowd (1978). Over a three-year period they evaluated 265 hyperactive schoolage children.

They found that 77% of the hyperactive children had abnormal curves on the glucose tolerance test: 50% had a low, flat curve similar to the one found in individuals with hypoglycemia, 15% had a curve with an excessive peak and rapid decline, and 11% showed a high peak with a slow recovery which is a common symptom in prediabetes. The test indicated that 86% of the children had an increased production of epinephrine, which is of interest since high levels of this hormone can cause the type of behavior seen in hyperkinetic children. Several comparisons can be drawn. Glucose tolerance curves are similar between hyperkinetic and hypoglycemic children. Likewise, nervousness and hyperactivity were observed in both types. Hyperkinetic children tend to have slow growth rates which is also predominant in juvenile diabetics. It seems, therefore, that the common denominator in all these conditions is the metabolism of glucose.

Some researchers are considering that perhaps those children who are behaviorally sensitive to sugar may, on the other hand, be sensitive to carbohydrate-protein ratio in the diet. Prinz et al. (1980) manipulated the ratio of sugar and carbohydrates to protein in children's diets, whereas Chiel and Wurtman (1981) manipulated the ratio of carbohydrate to protein in diets of rats. The proportion of carbohydrate and protein was correlated with increased spontaneous motor activity. Chiel and Wurtman gave two sets of 20 rats each a diet of 57% carbohydrate, 18% protein, and 15% fat or 75% carbohydrate, 0% protein, and 15% fat. They measured motor activity with an electric-eye device. The rats on the carbohydrate diet were continuously active with no quiescent periods, whereas the rats on the protein diet showed irregular and intense activity but with definite quiet periods. Low and moderate activity was recorded 26% and 57% of the time for the carbohydrate diet rats and 42% and 37% for the protein diet rats. The difference was found to be significant ($p < .01$). Chiel and Wurtman concluded that as the percentage of protein in the diet increased, the percentage of low activity increased and the percentage of moderate activity decreased. They added that proportions of carbohydrate and protein in meals can affect the amounts of tryptophan and tyrosine absorbed into the brain and can also affect the synthesis of serotonin and catecholamine transmitters. Furthermore, the protein-carbohydrate diet ratio may also alter the synthesis and release of monoamine neurotransmitters utilized by neurons affecting motor activity (Chiel & Wurtman, 1981).

In a letter to the editor of Pediatrics, Arnold and Nemzer (1982) discussed the new evidence from the Chiel and Wurtman (1981) and Prinz et al. (1980) research and its implication towards dietary control of hyperkinesis. The evidence from these studies seems to indicate that the carbohydrate-protein ratio affects activity level. Biochemically, it is documented that a deficit of either catecholamines or serontin (both neurotransmitters) or both are implicated in hyperkinesis. Amino acids available in dietary protein: tyrosine, phenylalanine, and tryptophan are precursors for production of these neurotransmitters. Protein consumption raises the serum level of these amino acids, and carbohydrate consumption lowers the levels of these amino acids. Furthermore, since these serum precursors freely cross the blood-brain barrier through a low affinity transport mechanism, the serum level influences availability of precursors for brain production of the neurotransmitters (Arnold & Nemzer, 1982, p. 250). In conclusion, Rumsey and Rapoport (1983) stress that even if heightened activity and high carbohydrate diets are demonstrated in children, it would be difficult to interpret because carbohydrates affect both the blood sugar levels and neurotransmitters such as serotonin.

Aspartame

Aspartame is a nutritive sweetener that is marketed by Searle Consumer Products, Division of Searle Pharmaceuticals, Inc., Chicago, Illinois. It has a potency approximately 200 times an equivalent amount of sucrose. Aspartame is a dipeptide composed of two amino acids: aspartic acid and phenylalanine. Aspartame is considered a nutritive substance because some of its components, aspartic acid and phenylalanine, occur naturally in foods. In addition, it is metabolized in the body the same way as these naturally-occurring components (Wheeler, 1982).

The Food and Drug Administration first granted authorization to use aspartame in certain foods and for certain technological purposes on July 26, 1974 (Federal Register, 1974, July 26). Objections were raised concerning the use of aspartame by children, particularly because phenylalanine and aspartic acid toxicity might cause brain damage resulting in mental retardation, endocrine dysfunction, or both (Wheeler, 1982). Several research studies address these issues. Frey (1976) tested 126 apparently healthy children and adolescents and found no unusual phenylalanine or tyrosine levels in the blood. Furthermore, no side effects were reported. In a weight-reduction program for adolescents, Knopp, Brandt, and Arky (1976) found no detectable effect of the aspartame, and any side effects were equally distributed between the aspartame and placebo groups. There has also been concern that aspartame would be risky for children with phenylketonuria (PKU) and individuals heterozygous for phenylketonuria. Koch, Schaeffler, and Shaw (1976) reported on the effects of loading doses on two PKU and two normal adolescents. Although there was a slight elevation of serum phenylalanine and tyrosine in all children, these authors report that it is of little clinical significance. They do add, though, that for young children the amount of phenylalanine in aspartame is significant and, therefore, should be calculated as part of that child's total diet allowance. Stegink, Filer, Baker, and McDonnell (1979) reported that eight females known to be heterozygous for phenylketonuria adequately metabolized and cleared the phenylalanine contained in the aspartame. As a result of these more recent studies, the Commissioner of Food and Drugs found that the available data establishes aspartame as safe for human consumption (Federal Register, 1981, July 24) and, therefore, it was approved for marketing.

Diet and Hyperactivity

For many years doctors, scientists, educators, and parents have been trying to find the cause of and treatment for hyperactivity in children. In the 1970's, Dr. Benjamin Feingold (1975) proposed that food coloring and food additives were the cause of hyperactivity and learning disorders of half of the children identified as such. Feingold stated: "Those children who react to synthetic additives have genetic variations - not abnormalities - which predispose them to such adverse responses. An innate releasing mechanism is involved in the disturbance" (Institute of Food Technologists, 1976, p. 153). Feingold devised a diet omitting food additives and coloring, which was also low in salicylates. Based on his clinical experience at the Kaiser Permanente Medical Center, Feingold reported in 1973 that of those children diagnosed as hyperkinetic, 30-50% showed a "dramatic therapeutic response" in 3 to 31 days after being on the diet (Williams & Cram, 1978). Feingold has made some very dramatic claims and is supported by many families with personal success stories; but the medical and scientific communities have not accepted Dr. Feingold's claims because of the shortcomings of his hypothesis and research. Feingold's hypothesis was not based on scientific principles of biochemistry and nutrition. Instead, it was derived from intuitions and clinical experience (Williams & Cram, 1978). Furthermore, the clinical measures used were global rather than specific. Other reasons why it is impossible to evaluate Feingold's claims include: (a) use of non-uniform diagnostic standards; (b) no operational definition of hyperactivity; (c) no description of objective instruments to measure behavior, cognition, etc.; (d) no specifications of chemicals and at what concentration they should be allowed on or excluded from the diet; (e) a lack of biological information from animals in in-vitro studies; and (f) inadequate information regarding the natural history of this syndrome (National Institutes of Health, 1982; Spring & Sandoval, 1976). Feingold himself stated that his diet does not help all children, but he does not specify which children are allegedly benefited (Levine & Liden, 1976).

The numbers of children the diet has helped is suspect due to a strong Hawthorne effect. Most important, the families that used the Feingold diet were not blind to the diet and the possible positive effects on the child's behavior. In addition, Spring and Sandoval (1976) point out that the positive results could have occurred because today's society is predisposed towards treatments that eliminate chemical additives and drugs and parents and schools may be more accepting of the food additive explanation for the child's behavior because it removes the blame from them. Furthermore, Spring and Sandoval (1976) point out the extra effort of the parent's food shopping and meal preparing, which the diet requires, could have created a more positive attitude. Such attitude change is predicted by dissonance theory. The parent, in order to justify a major expenditure of effort, would rationalize a more positive attitude towards the value or outcome of the effort. The attention and vigilance of the parent and the inclusion of the whole family on the diet, as Feingold suggested, could have positively influenced the child's behavior. Williams and Cram (1978) proposed that parents are supportive of the diet because it enables them to be the primary therapeutic agents.

There is little evidence to support Feingold's hypothesis that an additive-free diet improves behavior in hyperkinetic children. Two well-known studies (Conners, Goyette, Southwick, Lees & Andrulonis, 1976;

Harley et al., 1978) used a counter-balanced double-blind research design to test Feingold's hypothesis. Researchers in both studies were careful to operationally define hyperactivity in their schoolage and preschoolage subjects. The study design consisted of a baseline period during which the children remained on their normal diets and were removed from any medication. In both studies, the subjects were then randomly assigned to a treatment: half were placed on the Feingold diet for four weeks, followed by the control diet for four weeks; the other half were placed on the diets in reverse order. Conners et al. (1976) prepared a list of permitted foods for each diet, being careful to disguise the Feingold diet and making the shopping and food preparation the same for both diets. Harley et al. (1978), on the other hand, supplied all foods to the families. In both studies, parents were required to keep a diet journal in order to monitor compliance. Parents and teachers used standardized behavior ratings to measure the children's behavior in the Conners et al. (1976) study. A variety of measurements were used in the Harley et al. (1978) study: (a) behavior was rated in the classroom; (b) activity level was measured during a laboratory test; (c) a cognitive test measured attention and impulsivity; and (d) parents and teachers evaluated behavior.

The possible bias of order effect makes their findings inconclusive. Both found a significant number of children with improved behavior when the control diet treatment was given first and the Feingold diet second. In the Conners et al. (1976) study, the teachers reported improved behavior; in the Harley et al. (1978) study, the parents noted the improvement. Of those with noted improvement, a significant number were preschool age. There was no consistent improvement on any of Harley's objective measures.

Both researchers treated their results with caution. They questioned whether the families were aware of the identity of the diets, especially with all the publicity the Feingold diet had had.

Another aspect of Feingold's hypothesis is that any infraction of the diet will almost immediately cause a deterioration in the child's behavior. Many placebo-additive challenge studies have been conducted to test this point (Goyette, Conners, Petti & Curtis, 1978; Harley, Matthews, & Eichman, 1978; Mattes & Gittleman-Klein, 1978; Weiss et al., 1980). The subjects included preschool and schoolage children who had problematic behavior and showed improvement, according to parents, when placed on the Feingold diet. While maintained on the Feingold diet, the subjects were randomly assigned to a treatment of either a placebo or challenge cookie, candy bar, or soft drink, depending on the study. In the various studies, the challenge substance included artificial food coloring dosages ranging from 26 to 78 mg. Goyette et al. (1978) and Harley, Matthews, and Eichman (1978) were the only ones who used a double-blind design in which the subjects received both the placebo and challenge material. Parent and teacher behavior evaluations were one form of measurement used by all. Goyette et al. (1978) also used a tracking task, actometer, and paired-association learning task. Harley, Matthews, and Eichman (1978) included social and psychological information and a tally of defined classroom behaviors taken by two trained observers during academic seat work. A psychiatric exam and a laboratory test for distractability were also used in a study by Mattes and Gittleman-Klein (1978). The results are all the same: there was no significant difference in any of the measures between subjects receiving the additive and placebo treatments.

In spite of the lack of significant results, some observations are worth noting. The mother of one child, 2 years, 10 months, in the Weiss et al. (1980) study consistently reported behavior deterioration after the food color challenge; and the mother guessed five out of six times when the child received the additive. But since there were no other observations, the change in behavior cannot be clinically significant. Goyette et al. (1978) found that some children, not a significant number, performed less well on the distraction and tracking task one hour after ingesting the food coloring. In addition, three hours after ingestion of the additive a significant deterioration of behavior was reported by the parents only. Goyette et al. (1978) also noted that activity level increased during the first hour after ingestion of both the placebo and challenge material and then returned to baseline. Harley, Matthews, and Eichman (1978) noted that a small subset of children, especially preschool age, seemed to demonstrate hyperkinetic symptoms after ingesting the food coloring. In the Mattes and Gittleman-Klein study (1978) a mother noted increased irritability and fidgetiness in her ten-year-old son and correctly guessed eight out of the ten times he received the additives. The boy himself and the teacher did not report similar findings.

Swanson and Kinsbourne (1980) found slightly more positive results in their food additive challenge study. They administered stimulant drugs to forty children. Twenty, who were non-responders to the drug and also had low scores on Conners' parent-teacher behavior questionnaire, were labeled as non-hyperactive subjects. Twenty, who were responders to the drug and had high scores on the questionnaire, were labeled hyperactive subjects. The subjects were admitted to the hospital and placed on the Feingold diet. The challenge material was in the form of a capsule, and the dosage of food coloring was 100 or 150 mg. A paired-association test was the dependent variable. The results show that after the ingestion of the additives the hyperactive group made more errors compared to the placebo group. The performance of the non-hyperactive group was not significantly different. These findings should be interpreted with caution, however, because the pattern of the placebo performance is very different in the two groups.

Reaction Time

Reaction time has been recognized since the mid-nineteenth century as a potentially powerful means to document mental events with physical measures (Brebner & Welford, 1980). Reaction time represents a direct measurement of mental processing and is frequently used in the study of human information processing (Geller, 1978). Simply, reaction time is the passage of time from the onset of a stimulus to the initiation of the response. The mental processes that deal with this task include: (a) receiving the stimulus signal by a sense organ and conveying these data by afferent nerves to the brain; (b) identifying the signal; (c) choosing the corresponding response; and (d) initiating the action that constitutes the response.

There are distinctive characteristics of a reaction-time study. First, the latency between the stimulus presentation and the subject's response to that stimulus is the primary dependent variable. Second, the subject is told that the response latency is being measured and that it is important to respond as quickly as possible. Third, there must be no uncertainty as to the appropriate response to the particular stimulus and the emphasis is on the speed of responding, not the frequency of error. Finally, an opportunity to practice is given and this helps maintain a low error rate.

The time required for the reception of the signal is short, taking only a few milliseconds. The response process is also short for simple hand actions that require little strength because pushing a button is the only demand (Welford, 1980). The time that it takes for identifying the signal varies with the type, number, and intensity of signals. The time required for choosing a corresponding response depends on the number of choices and how well the choice corresponds to the response.

It is evident that alertness and attention are important factors in being able to respond correctly in a reaction-time task. Posner and Boies (1971) described attention as alertness and the ability to select information from one source or of one kind rather than another. Conners and Blouin (1982-83), Elliott (1970), Krupski and Boyle (1978), and Serio (1975) reported that reaction time is an appropriate type of measurement for attention and alertness.

Numerous studies have demonstrated that reaction time changes during normal growth and development (Eckert & Eichorn, 1977; Elliott, 1970; Goodenough, 1935; Luria, 1932; Surwillo, 1977). Luria's (1932) early experiments on the reactive process in young children emphasized the diffuse character of their responses and their inability to make a prompt response or to inhibit unnecessary additional responses. The development of the reactive process occurs through a qualitative change in structure. In other words, the structure changes from diffuse to controlling and functional. Improvement in voluntary control is demonstrated when there are fewer useless movements preceding and accompanying the act of pushing the key; there is also less body tension. Developmental changes in diffuse responses are more markedly improved with age than speed of reaction. Goodenough's (1935) research showed a fairly regular decrease in reaction time with age and generally boys react faster and with less variability than girls. Although sex differences appear in children as young as three, the differences are actually very small and there is much overlapping between the sexes. Goodenough (1935) reported that the median reaction time decreased with age and that the spread of individual scores decreased even more rapidly with age. She also added that children's reactions became more stable from one trial to the next as they got older. In 110 subjects that Surwillo (1977) tested, a three-fold decrease in simple reaction time was reported for children between 4 and 17 years. Eckert and Eichorn (1977) reported that although there is consistent and significant improvement in mean reaction times from 4½ to 11½ years in both boys and girls, the greatest improvement was between the ages 4½ to 5½ and 5½ to 6½. Luria (1932) and Goodenough (1935) believed that young children's slower reactions were not due to external distractions but rather to a diffused excitation that made the child unable to make the single integrated movement to press the button even though the child's attention was centered on the task. They also agreed that in normal children this diffused reaction is replaced by more integrated reactions by 7 or 8 years. At 3½ years the average reaction time attained was 34.9% of adult speed but indicated only 11.2% of adult controlled integrated reaction. Individual differences were, of course, marked at all age levels (Goodenough, 1935).

Goodenough (1935) compared reaction-time tests with scores on Minnesota Preschool Tests, Merrill-Palmer Tests, the Arthur Performance Scale, and the Stanford-Binet. The comparisons showed a very low and non-significant relationship between reaction time and scores on intelligence tests that did not involve speed. But positive correlations at all ages and for both sexes were shown between speed of reaction and performance tests requiring speed. She found no consistent differences between different socio-economic groups. Correlations between reaction time and body size tended to be positive but very low. With the comparison of reaction time and physical activity, 5 out of 6 correlations were positive and showed that greater activity level is correlated with faster reaction times.

Very little reaction-time research on young children has been reported. Exceptions include Smothergill and Kraut (1980), Blake (1980), Serio (1975), and Kaufman, Belmont, Birch, and Zach (1973). Smothergill and Kraut (1980) used 5-year-old boys and girls to show that the relative dominance of a stimulus dimension is related to the form of attention it receives. The two forms of attention include encoding and alertness. Encoding is described as the activation of specific pathways where external information becomes internal information in the brain. Alertness is a nonspecific reaction to a stimulus which induces a state of arousal or readiness to respond to external information. Smothergill and Kraut (1980) believe that the effect of familiarization, either alertness decrement or encoding facilitation, affect reaction time. Reaction times were slower when the warning signal preceding the task was the same as the familiarized stimulus versus when the warning signal was different from the familiarized stimulus. This described the alertness decrement. Encoding facilitation refers to the situation in which a neutral warning signal is presented. Under that condition, subjects responded faster to the familiar stimulus than to the novel stimulus.

Smothergill and Kraut (1980) proposed that the position of color or form in the child's dominance hierarchy is a variable that affects whether alertness or encoding will be the stronger attentional response to a stimulus. Eleven male and 11 female 5-year-olds were familiarized to one of the following: blue circle, red circle, blue square or red square. Smothergill and Kraut (1980) tested reaction time under the following four conditions: (a) test stimulus identical to familiar stimulus on both color and form; (b) test stimulus different from familiar stimulus on both color and form; (c) test stimulus different color but same form as familiar stimulus; (d) test stimulus same color but different form as familiar stimulus. For each child, color and form dominance was assessed. The results showed that "to the degree that dimensions differed in dominance, faster responses occurred in the partial change condition in which the value of the non-dominant dimension rather that the dominant dimension was different from familiarization" (Smothergill & Kraut, 1980, p. 202). Thus, a child who was assessed as having form dominance and familiarized on a blue circle would have a faster reaction time than when the stimulus was a red circle. The authors interpreted their findings in relation to the components of attention as follows: "Familiarization facilitated encoding the value of the dominant dimension with the result that faster responses occurred when that value was unchanged from familiarization" (Smothergill & Kraut, 1980, p. 202). On the other hand, "familiarization decreased the alerting strength of the value of the non-dominant dimension so that slower responses occurred when that value was unchanged" (Smothergill & Kraut, 1980, p. 202).

Blake (1980) conducted research to determine those components of information processing that showed developmental change. The subjects included young children (4.7 to 5.4 years), older children (8.6 to 9.2 years), and adults (20 to 32 years). The stimuli were cards with simple geometric shapes drawn on them. The cards had 2, 4, 6, or 8 shapes. The shapes on the cards were either all the same or with only one shape different. On the "different" cards the position of the odd shape was rotated. The subject's task was to verbally respond whether the shapes on the card were all the same or different. Blake (1980) reported that the younger children responded faster on the "different" card trials with the smaller arrays. Their reaction times increased on the "different" card trials as the array size increased. Instead of indicating a limited capacity interpretation, Blake explained that her findings indicated that the younger children had a more difficult time locating the form that was different as the number of shapes increased. This is supported by the finding that almost all of the increased reaction times occurred when the different form was located on the bottom left. Comparison of these results with Blake's previous studies, she says, seems to indicate that age differences are in the storage characteristics rather than encoding. Encoding is the basis of age differences in the processing capacity.

In another study, the reaction time of kindergartners who attended a morning session was compared to those who attended an afternoon session (Serio, 1975). The school policy in that district was that by the end of the year all children had attended both the morning and afternoon sessions. Therefore, reaction-time scores were collected both in the morning and afternoon for each child. Serio found that reaction time varies significantly with the time of day when testing occurred. The morning kindergartners responded significantly faster than did those in the afternoon session.

Kaufman, Belmont, Birch, and Zach (1973 studied the developmental changes in reactions to tactile and visual stimuli. They presented a series of tests to 152 chidren, 3 to 9 years old. The interpolation series included: (a) visual RT with a 3-minute period of somatosensory interpolation (VTV) and (b) tactile RT with a 3-minute period of visual interpolation (TVT). The prestimulation series consisted of: (a) visual RT with tactile prestimulation (VT); (b) tactile RT with visual prestimulation (TV); (c) tactile RT with tactile prestimulation (TT); and (d) visual RT with visual prestimulation (VV). They reported that in all children RT did increase when interpolated stimulation was in the modality other than that used for the RT signal. But different effects on RT were recorded at different ages. Children under 5 years had a profoundly slower visual RT when the visual stimuli was interpolated by somatosensory stimulation (VTV) than when the tactile RT was interpolated by visual stimuli (TVT). The 6-year-olds' results showed that in both conditions their visual and tactile

RT scores were about equal. Then in the children 7 to 9 years, the visual interpolation influenced the tactile RT (TVT) more strongly than the somatosensory interpolation affected visual RT (VTV). The results were significant ($F = 50.762$, $p < .01$) and show that with increasing age there was a shift from greater tactile to greater visual interpolation. The results from the prestimulation series show that heteromodal prestimulation increased RT and homomodal prestimulation had no effect on RT in younger children. Prestimulation shortened RT in the older children. The authors also concluded that prior tactile stimulation is a greater distraction than prior visual stimulation in young children. In contrast, prior visual stimulation has greater alerting value than tactile stimulation in older children.

As a result of research conducted with children, the following general statements can be made regarding reaction time. Speed increases with age. Boys react faster and with less variability than girls. Diffused responses become more accurate with age. The responses between trials stabilize with age. Reaction times vary significantly with the time of day tested. Younger children (3 to 5 years) are distracted by prestimulation and more so by prior tactile than visual stimulation. Prestimulation has alerting value with visual being greater than tactile stimulation for older children (7 to 9 years).

Summary

In this study, the researcher was interested in the effects of sucrose and aspartame on children's behavior as measured by reaction time. Therefore, the literature on those areas reporting the effect of sucrose and aspartame on behavior was reviewed. Literature on the Feingold diet was reviewed because sucrose is one factor in the Feingold hypothesis. Also, the literature on reaction time was reviewed to establish the appropriateness of the methodology and to establish what factors should be controlled in research using reaction-time measures. Briefly, the review of the literature revealed the following: (a) The evidence on sucrose and behavior is contradictory and inconclusive. Removing sucrose from the diet is associated with improvement in attention span, irritability, and hyperactive behaviors. But when sucrose treatment is introduced, the contradictory results include both an increase and a decrease in activity. Also, some studies have found sucrose to decrease appropriate behavior and increase quietness. (b) Research on aspartame showed no physical changes or side effects in children or adolescents. (c) The results from the research testing the Feingold hypothesis must also be reviewed cautiously. Researchers studying the effects of the Feingold diet reported improved behavior when the control diet was followed by the Feingold diet. On the other hand, no behavioral differences were reported in the food-additive challenge studies. When positive results have been found with the Feingold diet, the research designs have been subject to criticism due to possible order effects and/or Hawthorne effect. (d) Reaction-time speed, accuracy, and consistency improves with age. Boys, in general, respond faster than girls. Prestimulation is a distraction to very young children and an alerting factor to schoolage children.

CHAPTER III

METHODS, MATERIALS, AND PROCEDURES

This study was conducted to determine the effects of sucrose versus aspartame consumption on reaction time of young children. Subjects were placed on a low sucrose control diet for 7 days and then given a treatment of a drink sweetened with either sucrose or aspartame daily for a week. Reaction-time difference scores were analyzed to determine the effects measured at Day 0 test (before diet), Day 7 test (after one week of control diet), and Day 14 test (after one week of treatment).

Method

Recruitment. The directors of various day care centers and preschools in Blacksburg were contacted for permission to approach parents requesting their child's participation. One day care center director and one Montessori preschool director granted permission to contact parents. Parents were informed of the project through letter and personal contact at the schools. When these methods failed to produce an adequate number of participants, parents were contacted by telephone; and the project, the need and importance of their participation were more fully explained. When this did not produce the minimal number of subjects, personal friends of the author's major professors were contacted and agreed to participate.

Subjects. Nine preschool girls, 11 preschool boys (3 to 5.6 years) and six schoolage boys (6.7 to 8.5 years) from the Blacksburg, Virginia community comprised the sample. "Normal" children were recruited for this study. In this study, "normal" was defined as without: (a) hyperactivity; (b) diabetes in the family; (c) genetic disorders, including mental and physical retardation; (d) emotional disturbance; or (e) medication taken on a regular basis. So that race was not a variable, only Caucasian children were used in this study. Although all 26 subjects completed the study, data from one preschool female and two preschool males were not included in the final analysis. The female was dropped because she had to start medication after the study had already begun. Two boys were dropped because family schedules prohibited them from receiving treatment on one or more days.

Dietary Manipulation. Parents of the participants were instructed to eliminate known sources of sucrose from the child's diet for a 14-day period. Artificial sweeteners and artificially sweetened foods were also excluded. Instructions were provided for reading food labels in order to avoid hidden sugars. Sample menus and a dietary guide for planning a well-balanced meal were provided to both the parents and the day care centers and schools the children attended (see Appendixes A, B, C, D, E). These dietary plans and menus had been reviewed by L. J. Taper of the Department of Human Nutrition and Foods at Virginia Polytechnic Institute and State University. The dietary plans provided nutrients at levels that would promote normal growth and development for the age group being studied.

For the first seven days of experimental manipulation all subjects were fed a low sucrose diet. For the next seven days the subjects remained on a low sucrose basal diet. In addition, they were randomly assigned to a sucrose or no-sucrose treatment group.

The treatment consisted of Kool-Aid brand strawberry-flavored drink sweetened with sugar or with aspartame. The children in the sucrose treatment group received a total of 3.4 g sucrose per kilogram of body weight per day. This sucrose concentration was 25 g sucrose per 100 ml of fruit drink. The no-sucrose solution was sweetened with aspartame using a concentration that would constitute a sweetness comparable to that of the sucrose solution: 8 g per 100 ml of fruit drink. Comparability was established through a series of taste tests.

The drinks were served to the children daily. Specially marked cups were prepared for each child so that: (a) the correct amount of sucrose solution would be ingested and (b) the treatment groups would not be revealed. The investigator was the only person who knew the treatment assignments.

Parents kept a journal of all food ingested by the child for the entire two-week period. This was the only feasible control to be assured that the children did not stray from the diet.

Design and Analysis. Table 1 describes the design of this research study. In this design, both experimental groups were their own controls. The control period was the one week where all children were on the low sucrose diet before the treatment was given. On Days 8 - 14, this investigator distributed the treatment (drink sweetened with either sucrose or aspartame) in individualized cups marked to assure the correct dosage of drink for each subject. The investigator remained with the subject until all the drink was consumed and removed the cups to assure that the child's teachers or parents were blind to the treatment group. The reaction-time responses were collected three times: RT_1 was collected on Day 0 before the low sucrose diet began; RT_2 was

Table 1

Research Design

		Sucrose Group (n = 11)	Aspartame Group (n = 12)
Day 0	RT_1 Measurement		
Day 1 - 7		Low sucrose diet	Low sucrose diet
Day 7	RT_2 Measurement		
Days 8 - 14		Low sucrose diet Sucrose drink	Low sucrose diet Aspartame drink
Day 14	RT_3 Measurement		

collected on Day 7 after one week of the low sucrose diet; and RT_3 was collected on Day 14 after the subjects had received one week of treatment, either sucrose or aspartame. Data included the Day 7 minus Day 14 reaction-time difference scores for each of the measurements as well as the Day 7 minus Day 0 difference scores.

Materials

Reaction-Time Apparatus. A Hunter Klockcounter reaction-time apparatus measured the child's ability to stay alert and encode during a series of slides. Each child was instructed to press the button as soon as he/she saw a blue square. Ten slides of blue squares were randomly interspersed among 30 slides of red squares and 40 blank slides. Blank slides were placed after each red and blue square slide in order to lengthen the time between the colored slides and thus be sure the young child had enough time to encode and respond. Slides of blue squares were placed in different random orders for each of the three observations to avoid contaminating the response scores due to a practice effect (see Appendixes F, G. H). The individual slides were presented continuously at one-second intervals. Since a blank slide followed each colored slide, the child had approximately two seconds to determine if the presented slide was red or blue and to respond accordingly before a colored slide would appear again. A Kodak Carousel slide projector was synchronized with the Hunter Klockcounter so that if a novel blue slide was visible the counter started measuring the hundredths of seconds until the child stopped it by pressing the button. The mean of each of the 10 responses was computed and used as the response score. Prior to the experiment, two college students were trained to correctly operate the reaction-time apparatus and score response measurements.

Procedures

Prior to the test date, a practice session was arranged with each of the subjects. A practice session was advisable in order to familiarize the child with the testing room, the equipment, and the examiners. The examiner accompanied the subjects into the testing room and sat on the floor next to the subject to assist the child in hitting the button and to model the attentive behaviors towards the screen. To determine the child's dominant hand, he/she was asked to pick up a pencil that was presented at the midline. After this was determined, a paper hand cutout was taped 2 inches from the button on the appropriate side of the button. The child was instructed to rest his/her "button pushing" hand on the paper hand and to sit on the other hand. A practice session was also required to assure that the child could visually identify the red and blue square slides shown on the screen as well as be able to follow the instructions. The practice set included two slides to determine whether each subject could correctly identify each color. Three sets of five slides with two blue squares each were used to practice the button-pressing procedure (See Appendix I).

Small, private, quiet rooms without distraction were used for testing. Windows were shaded and any pictures on the viewing wall, where the screen was located, were removed. All testing was done between 9:30 and 11:30 a.m. The reaction-time response button was secured to a child-size table and placed 76 inches from the screen. The child responded with his dominant hand and between responses rested his hand flat on the desk. A Kodak Carousal slide projector and Hunter

Klockcounter were placed on top of another table located 11½ feet from the screen. Two examiners stood behind the child and operated the slide projector and wrote down the response scores while another examiner sat on the floor beside the child and looked forward at the screen because children seemed to feel more comfortable if an adult was sitting near and was visible. Furthermore, since there could not be any verbal coaxing or coaching during the testing, the adult staring at the screen served as a reminder and model of the appropriate behavior.

Reaction-time measurements were taken on three test days: Day 0, 7, and 14. On these test days, the examiner escorted the subjects, one at a time, to the testing room. First, the examiner reviewed the reaction-time instructions. The child had one practice "warmup" session which consisted of identifying the red and blue squares and reacting to five slides presented at the testing speed and without stopping. After the "warmup" set, the examiner offered verbal reinforcements for correctly watching the slides and hitting the button when the blue slide appeared. The child was also reminded to respond as fast as he/she could. No response scores were recorded for the practice or "warmup" sessions and no verbal interaction occurred during the test slide presentations. On Day 14 the children's reaction times were measured between 30 to 40 minutes following the ingestion of sucrose or aspartame. Waiting 30 to 40 minutes was based upon Langseth's and Dowd's (1978) methodology used in their glucose tolerance research which allows time for the sucrose to be absorbed into the blood stream. After the child completed viewing the 80 test slides, the examiner recorded the total reaction time, thanked the child for helping, and verbally reinforced participation (see Appendix J).

CHAPTER IV

RESULTS

The purpose of this study was to determine the effect of the consumption of sucrose versus aspartame on the reaction-time responses of young children, 3 to 8 years old. The mean ages of the subjects were as follows: preschool boys 1724 days (4.7 years); preschool girls 1689 days (4.6 years); and schoolage boys 2856 days (7.8 years). The mean age for the sucrose group was 2071 days (SD = 654 days) and for the aspartame group it was 1945 days (SD = 526 days). A t-test showed no significant age differences between the treatment groups ($t = .51$, $p < 1$).

Reaction times of 17 preschool and 6 schoolage subjects were measured at three separate times. The baseline measurements were taken the morning of the day before the restricted sucrose diet began. A second measurement was taken after each child had been on the restricted sucrose diet for 7 days. Post-test measurements were taken after children had received daily administration of the treatment (fruit-flavored drink sweetened either with sucrose or aspartame) for 7 days.

The data to be analyzed included the difference scores of the reaction times measured at the beginning of the study (RT_1), after a seven-day low sucrose diet (RT_2), and following treatment (RT_3). Reaction time was measured in response to sets of slides with 10 blue slides randomly interspersed among 30 red slides and 40 blank slides. Subjects were asked to respond to these slides by hitting a button as fast as they could. A difference score was computed by subtracting the post-test reaction-time (RT_3) score from the pre-treatment measurement (RT_2) to determine the effect of the treatment. The amount of change in the reaction time that resulted from a seven-day low sucrose diet was obtained by computing the difference between RT_2 and RT_1. Likewise, the change from the beginning to end was computed by the difference between RT_3 and RT_1. Means and standard deviations for all scores are shown for both groups in Table 2. If a subject failed to respond to a slide before another one appeared, it added two full seconds to the RT score since there was at least a two-second interval between each target slide. A series of t-tests indicated no significant sex differences between subjects' scores at RT_1 ($t = 21$, $p < 1$), RT_2 ($t = 21$, $p < 1$), or RT_3 ($t = 21$, $p < 1$). Therefore, data for both sexes were combined for subsequent analyses.

Table 2

Means and Standard Deviations of Total Response Times and Difference Scores Broken Down By Sex and Treatment

	T_1		T_2		T_3		$RT_3 - RT_1$		$RT_2 - RT_1$		$RT_3 - RT_2$	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Sucrose Group:												
Males(n = 7)	8.08	1.56	5.67	2.63	8.33	3.35	.24	2.67	-2.41	1.56	2.65	3.89
Females(n = 4)	9.16	2.19	8.50	4.26	9.07	2.67	-.09	2.79	-.66	2.39	.58	4.54
Aspartame Group:												
Males(n = 8)	9.91	4.24	6.84	3.67	9.30	4.97	-.61	2.05	-3.07	1.61	2.46	1.92
Females(n = 4)	12.37	3.77	8.91	5.52	10.40	3.48	-1.98	1.71	-3.46	3.12	1.48	2.14
Total Group	9.65	3.34	7.13	3.79	9.16	3.75	-.49	2.31	-2.52	2.12	2.02	3.06

Independent t-tests showed no significant differences between treatment groups in reaction-time scores at RT_1, i.e., prior to the low sucrose diet ($t = -1.7$, $\underline{p} < 1$). Also, the groups were not significantly different at RT_2, i.e., after low sucrose diet and before treatment ($t = -.52$, $\underline{p} < 1$). Therefore, it was concluded that random assignment had not favored one group over the other prior to treatment. However, it should be noted that the variability in scores of aspartame subjects at RT_1 was significantly greater (SD = 4.1) than for the sucrose group (SD = 1.79), $\underline{F} = 5.26$ (11, 10), $\underline{p} < .02$. Also, the variability in the difference scores following treatment ($RT_3 - RT_2$) was significantly greater for the sucrose group ($\bar{x} = 1.9$, SD = 4.05) than for the aspartame group ($\bar{x} = 2.14$, SD = 1.95), $\underline{F} = 4.29$ (10, 11), $\underline{p} < .03$. The variability in the aspartame group at RT_1 could have been due to the fact that there were more subjects in that group who failed to respond to one or more slides, thus inflating the variance (2 seconds of time was added to the score when a slide was missed). It is more difficult to explain the variability of sucrose subjects' difference scores. This again could have been inflated due to a high number of missed cues per group as shown in Table 3. Further discussion of this will follow the results of the test of the hypotheses.

To test the hypothesis of no significant differences between treatment groups in terms of difference scores (RT_3 - RT_2), a General Linear Model procedure from the Statistical Analysis System (SAS) was used. A 2 X 2 (Treatment X Sex) factorial analysis of covariance was used with height-weight ratio and age as covariants. A formula for unequal cell sizes was used. None of the F values were significant. They were as follows: (a) treatment, $F(1,22) = .00$, $p < 1$; (b) sex, $F(1,22) = .00$, $p < 1$; (c) treatment by sex interaction, $F(1,22) = .01$, $p < 1$; (d) age, $F(1,22) = .36$, $p < 1$; and (e) height-weight ratio, $F(1,22) = 1.46$, $p < 1$.

Additional analyses were done by using age alone as covariant. A 2 X 2 (Treatment X Sex) factorial analysis again yielded no significant results. The F values were as follows: (a) treatment, $F(1,22) = .77$, $p < 1$; (b) sex, $F(1,22) = .77$, $p < 1$; (c) treatment by sex interaction, $F(1,22) = .13$, $p < 1$; and (d) age, $F(1,22) = .05$, $p < 1$.

When the height-weight ratio alone was used as a covariant, a 2 X 2 (Treatment X Sex) factorial analysis

Table 3

Number of Missed Cues Broken Down By Measurement Time and Treatment Groups

Sucrose				Aspartame			
Observation	RT_1	RT_2	RT_3	Observation	RT_1	RT_2	RT_3
1	2	2	1	12	4	3	3
2	0	1	4	13	1	2	1
3	0	2	0	14	0	1	0
4	0	0	0	15	1	0	0
5	0	0	0	16	0	0	0
6	0	0	0	17	1	2	4
7	0	0	0	18	0	1	3
8	0	0	0	19	1	1	1
9	0	0	0	20	0	0	0
10	0	0	2	21	0	0	0
11	0	1	0	22	0	0	0
				23	0	0	0

of covariance yielded no significant results. The *F* values were as follows: (a) treatment, $F(1,22) = .01$, $p < 1$; (b) sex, $F(1,22) = .13$, $p < 1$; (c) sex by treatment interaction, $F(1,22) = .04$, $p < 1$; and (d) height-weight ratio, $F(1,22) = 1.21$, $p < 1$.

Followup Analysis

As a result of the concern that the number of missed slides unduly inflated the variance of some subjects, data from all subjects who missed one or more cues were dropped from the file and additional tests were computed. This procedure resulted in the loss of four subjects from the sucrose group and seven from the aspartame group. This left eleven subjects, 10 of which were boys. Data from the one girl were dropped and the final followup analysis was conducted with 5 children in each treatment group. A t-test indicated that the ages were equally distributed in the two groups ($t = .46$, $p < 1$).

Means and standard deviations for all scores are shown for both groups in Table 4. A series of t-tests yielded no significant differences in the means of the two groups at RT_1 ($t = -.32$, $p < 1$) or at RT_2 ($t = -.07$, $p < 1$). Thus, the groups were not biased in favor of either treatment prior to its onset.

Table 4

Means and Standard Deviations of Total Response Times and Difference Scores for Followup Subjects Broken Down By Treatment[a]

	T_1		T_2		T_3		$RT_3 - RT_1$		$RT_2 - RT_1$		$RT_3 - RT_2$	
Group	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Sucrose	7.53	1.51	4.82	1.86	7.26	2.07	-.27	.86	-2.71	.53	2.43	.67
Aspartame	7.90	2.17	4.93	2.46	6.72	1.79	-1.18	.92	-2.98	1.33	1.80	.83
Total Group	7.72	1.77	4.88	2.06	6.99	1.85	-.73	.96	-2.84	.97	2.12	.78

[a]n = 10, all males

To reanalyze the data for the main hypothesis, i.e., that the change scores from RT_2 to RT_3 (after low sucrose and after treatment) were affected by the treatment, an analysis of covariance with treatment as the main effect and age as the covariate was executed using the General Linear Model program from the Statistical Analysis System (SAS). The means (adjusted for age) were: 2.43 (SD = .36) for the sucrose group and 1.80 (SD = .36) for the aspartame group, $F(2,7) = .78$, $p < 1$. Therefore, the change scores ($RT_3 - RT_2$) were not significantly different between the sucrose and aspartame groups.

Effect of Low Sucrose Diet

A secondary purpose of the present study was to test the effect of a low sucrose diet on the reaction-time scores of children. When data from all original subjects (n = 23) were combined and the scores at RT_1 were compared to those at RT_2, a t-test showed a significant change: $t = -5.69$, $p < .0001$. The mean RT_1 was 9.65 (SD = 3.34); at RT_2 it was 7.13 (SD = 3.79). Thus, speed of reaction time increased after one week on a low sucrose diet. This result must be interpreted with caution since it is possible that the measure used at RT_2 differed slightly from that used at RT_1.

CHAPTER V

DISCUSSION

The purpose of the present study was to determine whether sucrose and aspartame have a significant effect on speed of reaction time of young children. Reaction times of subjects were measured before a seven-day sucrose-restricted diet (RT_1), at the end of the seven-day low sucrose diet (RT_2), and after seven days of dietary treatment with either sucrose or aspartame (RT_3).

Difference scores were used (RT_3 - RT_2 and RT_2 - RT_1) to determine whether there were significant changes in mean reaction-time responses as a result of a low sucrose diet as compared to an unrestricted diet (RT_2 - RT_1) or as a result of the sucrose or aspartame treatment (RT_3 - RT_2). Analysis of covariance yielded no significant main effects (treatment or sex) or interactions. Further, the covariates of age and height-weight ratio were non-significant. Thus, mean difference scores (RT_3 - RT_2) were apparently not different for the treatment groups. The mean difference score for the sucrose subjects was 1.90 and for the aspartame subjects was 2.14. However, examination of the variances for the treatment groups revealed that the mean changes in reaction-time scores during the treatment phase ($RT_3 - RT_2$) were significantly more variable for the sucrose group than for the aspartame group. The standard deviation for sucrose subjects' change scores was 4.05, whereas for the aspartame it was 1.95, ($F(10,11) = 4.29$, $p < .03$. The difference scores for the sucrose group ranged from -3.43 seconds (faster) to +9.85 seconds (slower). In the aspartame group, the difference scores ranged from -.89 seconds (faster) to +6.77 seconds (slower). This outcome indicates that the individual responses to a sucrose diet, as measured by reaction-time change scores, are more variable than are the changes in response to aspartame. A possible explanation for this finding might be that the groups differed in variability at the onset of the study. Therefore, variabilities at the various measurement times (RT_1, RT_2, RT_3) as well as for change scores were compared for the treatment groups via ANOVAs. The only measurement that showed any significant difference in variability was RT_1 when subjects in the aspartame group had greater variability ($p < .02$). It is possible, then, that subjects in the sucrose group were more unstable in their responses. Future researchers should employ a cross-over design in order to rule out the possibility that one group is less stable in responses than another.

In summary, results of this study revealed no significant differences in mean changes in reaction-time scores of subjects receiving a diet containing sucrose versus those who received a diet containing aspartame.

Effects of Low Sucrose Diet

The finding that reaction time improved after 7 days on a low sucrose diet must be interpreted with caution. Although it is possible that the low sucrose diet may have had an effect on the improved reaction time, it is also possible that the measures used at RT_2 differed slightly from those used at RT_1.

To start the clock, a spring-loaded switch would swing into a notch filed into the slide tray opposite the slot where a blue slide was placed. The notches were hand-filed and, therefore, had imprecise angles which may have caused an error in starting the clock. The amount of error cannot be determined at this time.

Methodological Considerations

The study of nutritional influences on human behavior is still in its early stages. The best methodologies and procedures are still being tested. Conners and Blouin (1982-83) wrote that these kinds of studies can expect significant problems with respect to ecologic validity, generalizability across situation and measures, sensitivity, and reliability of measures. An important methodological consideration is the dose-response and time-action parameters of the nutritional influence. Rumsey and Rapoport (1983) pointed out that high dosages are a frequent strategy because of the assumption that there would be an increased probability of identifying behavioral effects. Determining how much is a high dosage among individuals is difficult and unique to each substance. The amount of sucrose used in the present study (3.4 g/kg body weight) is considered to be a high dosage. It is almost twice as much as Rapoport used (1.75 g/kg body weight). In an effort to assure that dosage is more equivalent among all subjects, the substance may be dispensed in relation to body weight. In reviewing the sucrose challenge literature for children, (Conners & Blouin, 1982-83; Langseth & Dowd, 1978; O'Banion et al., 1978; Otto et al., 1982; Prinz et al., 1980; and Rapoport, 1982-83) only one study (Rapoport, 1982-83) other than the present one, controlled for the amount of treatment substance (sucrose) in relationship to body weight. In the research that tested the effects of food additives and food coloring, a standard amount of the chemical substance was administered for all subjects (Goyette et al., 1978; Harley, Matthews & Eichman, 1978; Mattes & Gittleman-Klein, 1978; Swanson et al., 1978; and Weiss et al., 1980). The frequency and specific times of collecting data are also important in nutrition research. In the present study, behaviors were assessed 30 to 40 minutes after ingesting the challenge substance. This methodology is similar to that of Conners and Blouin (1982-83), Goyette et al. (1978), Otto et al. (1982), Rapoport (1982-83), Swanson and Kinsbourne (1980), and Weiss et al. (1980). Although it was not possible to measure the children's blood sugar levels at regular intervals as was done by Langseth and Dowd (1978), Otto et al. (1982), and Rapoport (1982-83), it would have provided information on the relationship between levels of glucose and ability to attend to stimuli.

When studying nutritional effects, it is important that the subject and the subject's family be blind to the treatment being received. In the present study it was not financially possible for this author to stock each participating family's home with permitted foods as Harley, Matthews, and Eichman (1978) did. The families in the present study were given lists of permitted and forbidden foods, shopping and product tips, and suggested menus and recipes. The parents remained unaware of the treatment (sugar or aspartame) their child received by not having access to the drink. Also, since both treatments were sweet, the children could not detect the difference. In other diet research, the families were responsible for food shopping and/or food preparation (Conners et al., 1978; Harley, Matthews & Eichman, 1978; Harley et al., 1978; and Prinz et al., 1980). These researchers took precautions to assure that the families were blind to the treatment. This was accomplished in the Conners study (1978) by disguising both the control and Feingold diet and listing permitted and forbidden foods. The control diet was carefully devised to ensure its similarity to the Feingold diet in the following ways: degree of time in preparation, shopping and monitoring, food items drawn from same food groups, palatability, ease in following, and plausibility as an effective treatment (Conners et al., 1978, p. 156).

Rumsey and Rapoport (1983) suggested that double-blind controlled conditions are very effective in diet research so as to control for non-specific factors that may contribute to the placebo effect. A design in which each subject serves as his/her own control was used in the present study. Perhaps results may have been different if a double-blind design had been used. To do so, the length of the study would have had to be increased. However, if this study had been longer, perhaps even fewer families would have been willing to participate and the degree of compliance among the children would have deteriorated.

Protein/Carbohydrate Ratio

Some researchers have suggested that the balance between protein and carbohydrates and sucrose may be related to behaviors. In the present study, parents were instructed to eliminate sucrose and to provide a nutritionally balanced diet. The ratios between protein and carbohydrates were not enforced or computed. Although Kershner and Hawke (1978) were researching the effects of megavitamins on the behavior of hyperactive, learning-disabled children, part of their research design was to enforce a high protein, low carbohydrate and no sugar diet. Although the diet was not described in detail, it appears that there was some control over the protein and carbohydrate ratio in the diet. Similarly, Prinz et al. (1980) computed ratios between food types. They found that a high ratio of sugar foods to nutritional foods (protein, vegetables, fruit, and dairy products) correlated with behavior. They reported that sucrose apparently caused a different response in the two samples. The hyperactive children displayed more destructive-aggressive behavior; whereas the normal control children displayed more movement within the room. Chiel and Wurtman (1981) manipulated the protein-carbohydrate ratio in the diet of rats. They concluded that as the dietary protein increased, the percentage of low activity increased. It appears that the hypothesis that the protein-carbohydrate balance affects activity warrants further research and stricter control in behavior and diet.

Characteristics of Subjects

One major diffference between the present study and the ones already mentioned is the characteristics of the subjects. All other studies used children with learning disorders or diagnosed as hyperactive or with a psychiatric disorder and sometimes used "normal" children as controls. The present study used "normal" children exclusively. It is worth noting that any special characteristics of the subjects can affect the results.

Reaction Time

The developmental conclusions about reaction time research by Elliott (1970), Goodenough (1935), Luria (1932), and Surwillo (1972) were replicated in this present study. Reaction time does speed up as children grow older. The mean reaction-time scores for the schoolage boys were faster than the preschool boys and girls across all three test situations. The data from this study also support Goodenough's (1935) conclusion that the spread of individual response scores decreases with age. Examining the ranges shows that the schoolage boys had a much smaller spread of response times than both the preschool boys and girls.

One aspect of the data from the study contrasts with Goodenough's (1935) results. She reported that boys generally react faster and with less variability than girls the same age. The data from this study do not demonstrate the same conclusion. The average response time for the preschool boys and girls showed no significant sex differences.

CHAPTER VI

CONCLUSIONS

The hypothesis in the present study, i.e., that subjects receiving sucrose would have a slower reaction time than those receiving aspartame, was based on the assumption that high sucrose intake would cause an initial rise in blood sugar level followed by a drop in blood sugar. This occurs in some individuals following an insulin response to initial blood sugar increases. It is important to note that individuals will have varying levels of blood sugar fluctuations. Some individuals may experience an initial rise in blood sugars followed by a gradual lowering. Others may experience an initial rapid increase in blood sugars followed by an overshoot of insulin which may make the drop in blood sugar dramatic. The exact timing of the peak and nadir could not be determined in the present study.

In the present study, reaction times were measured between 30 and 40 minutes following the ingestion of sucrose or aspartame. The timing of individual responses to the sucrose load could have dramatically affected reaction times. It would be expected that no changes in blood sugar should occur as a result of the ingestion of aspartame, which has a protein-based formula. Therefore, an inspection of the variances in reaction times of subjects in the two treatment groups might provide helpful information on the nature of responses to the treatment. Indeed, a t-test for differences in variances indicated that the standard deviations of reaction times for subjects receiving sucrose (SD = 4.05) versus those receiving aspartame (SD = 1.95) were significantly different, $F(1,11) = 4.29$, $p < .03$). Apparently the reaction time of some children increased and others decreased. It would appear that the sucrose treatment may be linked to both fast and slow reaction-time responses, depending on each child's individualized blood sugar absorption rate.

Recommendations for Future Research

The significance of the response variance in the subjects who received sucrose seems to indicate that sugar and aspartame have differential effects on reaction-time behavior. It cannot be determined at this time whether the lack of other significant results was due to the limited number of subjects, the inability to have complete dietary control, experimental error, failure of the equipment to respond when the subject pushed the button, or that the treatment had no effect.

It is worth noting that finding families to participate in this study was extremely difficult. The fact that the data were collected in the summer seemed to have bearing on some families' inability or unwillingness to participate in the project. Vacation plans and out-of-town guests made scheduling impossible and adhering to a strict diet too difficult. Other mothers reported that the summer months lacked the routines of the school year and made any kind of restrictive diet too difficult to enforce. Another problem was the mothers' reluctance to put in the necessary time and energy in implementing and enforcing the diet when there were older children in the family. Other families refused to participate because they did not want their child to possibly receive the sucrose treatment. Many parents also worried about the degree of compliance for their child. Many of the families that were finally recruited were already concerned about sucrose consumption and had eliminated many known sucrose sources from their diets. Also, most of these families were associated with the college in a professional and/or student role. These two characteristics of the families used in this study may have some influence on the results. It goes without saying that the children from families with very different habits and education may very well present very different results.

One way to avoid some of these problems in scheduling and dietary control could be alleviated by evaluating subjects in a residence or summer camp situation. Food intake and amount could be strictly controlled and food ratios of carbohydrate, protein, and fat manipulated. The research of both Chiel and Wurtman (1981) and Prinz et al. (1980) seems to indicate that the ratio of protein to carbohydrates can affect motor activity. If this is true, perhaps the dosage of 3.4 g/kg body weight was not a high enough dosage for some children whose diets had a high protein content. The results may be affected if not only a higher dosage of sucrose was given but if the drink was given two times daily.

If this research is replicated, a more sophisticated and accurate projector and clock counter must be used. A highly sensitive response button and computerized digital clock counter would be more accurate in measuring the reaction response. Also, a machine that presents the slides at accurate intervals would eliminate most of the error that was present in this study.

Although the research testing for the effects of food additives showed no significant or consistent effects from artificial coloring, it is advised to use an additive-free food substance as the challenge material (Conners, 1978; Goyette et al., 1978; Harley, Matthews & Eichman, 1978; Mattes & Gittleman-Klein, 1978; Swanson et al., 1978; and Weiss et al., 1980).

The type of activity prior to the reaction-time task should also be controlled. Serio (1975) found that the amount and type of activity prior to testing affected the speed of young children's responses.

There are many factors that can affect the speed of a response. The distance the hand travels to hit the button is one factor. The relationship of the child's arm to the height of the table may be a factor in the child's efficiency of movement. Future researchers should control for the relationship of the child's arm to the height of the table, perhaps by measuring the angle of the elbow. To be able to adjust for each child, equipment for this research should include an adjustable table and chair. Body tension may also be a factor that can affect the speed of a response. A machine that could detect arm and hand tension could also offer information on each child's physical ability to respond.

Dietary compliance was not a problem. Contrary to the parents' expectations, the children who participated were highly motivated. This was evident in their will power to refrain from foods containing sucrose. Parents reported with surprise and pride that their children refused sweet treats without prompting and were able to delay gratification (i.e., freeze wedding cake and Grandma's cookies). Parents reported that the children did not resort to whining, crying, or fussing to receive sugar foods. It appears that the methodology of this research was not as difficult as the parents expected.

The children tolerated the drink well. No one refused the drink or made any comments to give the impression that they could tell which treatment they were receiving. Two boys did report an occurrence of diarrhea and nausea. The data of one preschool boy who had diarrhea were dropped because treatment was interrupted. A schoolage boy who experienced nausea continued on the treatment schedule and completed the study. The cause of these isolated occurrences was not known and there is no way to determine whether these occurrences were linked to the treatment.

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Appendix A

Food Purchasing

It is important for you to read the ingredient list on the food labels to determine if the product has any hidden sugars. Food items listing sugar, brown sugar, molasses, corn sweetener, dextrose, sucrose (any word ending in "ose" is a sugar product) should be avoided. The ingredients are listed by weight. Therefore, there is more of a beginning ingredient than of one listed at the end. For example, Honey Nut Cheerios' ingredients include: oat flour, <u>sugar</u>, defatted wheat germ, wheat starch, <u>honey</u>, <u>brown sugar syrup</u>, salt, almonds, and more. Obviously this product is not allowed on the low sucrose diet.

To assist you in your food purchases, the items listed below have no sugars or artificial sweeteners.

<u>Applesause</u>

homemade (no added sugar)

Kroger Natural Style

<u>Cereal</u>

oatmeal (from scratch)

wheat and rice puffs

Nabisco shredded wheat

Cheerios

Kroger Toasted Oats

Crackers

Premium saltines

Zesta saltines

Triscuits

Peanut Butter

Annie Kay's

Natural peanut butter

homemade in blender

Snacks

Sunshine brand Cheese-its

Country Oven Shoe String Potatoes (in can)

Corn Tortilla (in refrigerator case)

Country Oven Sesame Sticks

Appendix B

Prohibited Foods

sugar	cookies	soft drinks
candy	syrup	pies
honey	condensed milk	cakes
jam/jelly	chewing gum	sweetened cereal
canned fruit in heavy and light syrup	jello	pudding
	sweet rolls	molasses
fruit drinks: Kool-Aid, Hi-C, etc.	ice cream	yogurt with fruit
	coconut	sweet pickles
frozen yogurt	dried fruit	carob

any artificially sweetened foods: NO

saccharin, Sweet n' Low, Sugar Twin, Sucaryl, Equal

diet soda	diet jello (D-zerta)	
sugar free gum	sugar free candy	diet pudding

Appendix C

Daily Food Intake For Children 4 to 5 Years Old

(from: Endres, J. B. & Rockwell, R. E. *Food, Nutrition, and the YoungChild*. St. Louis: The C. V. Mosby Company, 1980, p. 109.)

	Servings Per Day	Average Size Per Serving	Avoid
Milk Group	2 to 3	½ to 1 cup milk	ice cream
milk		1 to 2 oz. cheese =	
cheese		1-2 slices	yogurt
		1-2 one inch cubes	
		¼ to ½ cup cottage cheese	
Meat and Alternatives	4 total		
egg		1	canned products
lean meat)			
fish)	2	4 Tbsp./2 oz.	
poultry)			
peanut butter		2 Tbsp.	
dried peas, beans	2*	½ cup	
nuts		1½ oz. approx. ¼ cup	
Fruits and Vegetables	4 total		
Vit. C-citrus	at least	½ cup/1 small fruit	dried fruit-
berries, tomato	1/day		raisins, dates
cabbage, cantelope			
apple, banana, pear			
fruit juice, unsweetened		½ cup	fruit drink
canned fruit, packed in			fruit packed in
own juice		½ cup	heavy syrup

	Serving Per Day	Average Size Per Serving	Avoid
Vegetables			
green	1	¼ cup/4 Tbsp.	canned
yellow and other (potatoes, carrots, etc.)	2	¼ cup/4 Tbsp.	products
Breads and Cereals	4 total		
whole grain		3/4 to 1 slice	baked goods: donuts, pie, cake, cookies, etc.
Ready-to-eat cereals shredded wheat, rice/wheat puffs, cheerios		1 oz.	all sugar coated
cooked cereals oatmeal, grits, macaroni, rice, spaghetti		½ cup	instant oatmeal canned products
Fats and Carbohydrates butter, margarine, mayonnaise, oil	3 total	1 tsp.	

*use additional servings of meat and eggs when legumes are omitted.

Appendix D

Sample Menus

	Breakfast	Snack	Lunch	Snack	Dinner
Mon.	milkshake: ½ c. banana and 8 oz. milk W.W. toast with butter	½ apple with peanut butter	2 oz. chicken 2 slices W.W. bread with mayonnaise, carrot sticks milk	orange juice and saltines	spaghetti with meat sauce tossed salad with dressing* milk fresh fruit
Tue.	1 egg W. W toast with butter grapefruit juice milk	Cheese-its and juice	2 oz. ham on bun potato salad peas peaches milk	fresh fruit salad	fish sticks noodles spinach ½ banana milk
Wed.	½ c. oatmeal 2 Tbsp. raisins ½ orange milk	Unsweetened grape juice and Triscuits	tomato soup cheese toast* celery sticks pear milk	popcorn and juice	pork chop casserole with rice, tomato, green pepper* green beans milk
Thu.	grapefruit sections 1 oz. cereal ¼ c. strawberries milk	saltines and apple juice	tuna salad corn cabbage wedge milk mixed fruit	celery and cream cheese	chicken acorn squash biscuits with butter milk sliced pineapple

	Breakfast	Snack	Lunch	Snack	Dinner
Fri.	2 slices bacon ½ English muffin orange juice milk	cheese and Triscuits	deviled eggs green beans bread and butter unsweetened applesauce milk	celery and peanut butter	1 sausage macaroni and cheese sliced tomatoes fresh fruit milk
Sat.	½ orange french toast* (slice) milk	apple juice and Cheese-its	grilled cheese carrot and celery sticks fruit strawberry milkshake*	popcorn	hamburger on bun sliced tomatoes green beans fruit salad milk
Sun.	1 egg ½ English muffin butter grapefruit sections milk	fresh fruit	peanut butter and banana sandwich carrot sticks apple juice	milkshake	turkey broccoli mashed potatoes baked apples* milk
Mon.	oatmeal with cinnamon 2 Tbsp. raisins milk orange juice	tomato juice and Country oven potato sticks	sausage biscuit mixed vegetables baked peaches* milk	½ hard boiled egg and juice	liver casserole Mediterranean style* cauliflower pineapple milk
Tue.	cereal (no sweetener) strawberries milk	raw vegetables and dip	taco salad* crackers milk	unsweetened applesauce	beef stew cole slaw biscuits with butter milk

	Breakfast	Snack	Lunch	Snack	Dinner
Wed.	1 egg ½ English muffin fruit juice milk	orange slices	chicken noodle soup cottage cheese carrot sticks apple and orange slices milk	mixed cereal mix*	lasagna tossed salad french bread ½ banana milk
Thu.	plain yogurt mixed with fresh fruit toast with butter	popcorn and juice	baked chicken buttered potatoes coleslaw milk pineapple	baked apple*	eggplant parmesan* french bread peas milk fruit
Fri.	french toast* (1 slice) milk fruit juice	grapes and Cheese-its	spanish rice* broccoli bread and butter milk pears	milkshake: plain yogurt and fruit	meat loaf creamed potatoes green beans milk pineapple chunks
Sat.	cereal (no sweetener) grapefruit sections milk	fresh fruit	egg salad sandwish with mayonnaise carrot and cucumber sticks fruit milk	juice and Triscuits with cheese	broiled fish lima beans yellow squash milk fruit salad
Sun.	1 egg ½ bagel 1 slice bacon orange juice		chili beans tossed salad corn bread milk pears		tuna casserole beets bread and butter milk fruit salad

*Recipes provided - see Appendix E

Appendix E

Recipes

Baked Apples

Select well-flavored apples. Core. Put in baking dish. In each apple put a dash of cinnamon and nutmeg. Cover the bottom of the baking dish with boiling water. Bake at 400° until soft (30 minutes or more). Several times during the baking, spoon the pan juices over the apples.

Baked Peaches

Peel, cut in half, and remove the stones. Place in a shallow baking dish, cut side up. Fill each cavity with chopped nuts, ½ t. butter, a few drops of lemon juice and a dash of nutmeg. Bake 20 minutes at 350°.

If using canned peaches buy only those peaches packed in their own juice, or water, or unsweetened fruit juice. Prepare the same as above. Bake 15 minutes at 350°.

Cheese Toast

Melt Cheese-Whiz over low heat. Pour over whole wheat toast. Garnish as you like with: a shake of paprika, a bit of crisp bacon, a sprig of parsley or watercress, or a few slices of stuffed olive.

Eggplant Parmigiana

1 medium eggplant, peeled and cut in 1 inch cubes
½ cup chopped onion
½ cup chopped green pepper
½ small clove garlic(minced)
1 t. leaf oregano, crushed
¼ cup butter or marg.
2 - 6 oz. cans tomato paste
1 cup water
¼ t. salt
1 cup seasoned croutons
¼ cup Parmesan cheese

Cook eggplant in boiling salted water for 3 minutes; drain and place in shallow baking dish, 10 x 6 x 2 inches. In saucepan, cook onion, green pepper, garlic, and oregano in butter or margarine until tender. Add tomato paste, water, and salt; heat. Pour sauce over eggplant. Bake in preheated oven 350° about 45 minutes. Remove eggplant from oven. Turn temperature up to 425°. Top eggplant with croutons; sprinkle with cheese. Return to oeven and bake for an additional 15 minutes. Makes 6 servings.

French Toast (makes one serving)

- 1 egg beaten
- ¼ t. vanilla extract
- 1 slice raisin toast

Combine egg and vanilla. Add bread; allow to absorb as much egg as possible. Turn to absorb remaining egg. Place in heated non-stick skillet that has been sprayed with non-stick cooking spray. Cook until browned on both sides, turning once.

Liver Casserole Mediterranean Style (makes 6 servings)

- 1½ lbs. sliced beef liver
- 3 Tbsp. flour
- 3 Tbsp. olive or vegetable oil
- 1 package (about 7 oz.) chicken-flavored rice and vermicelli mix
- 1 package (10 oz.) frozen Spanish-style zucchini, carrots, and pearl onions in sauce.

Cut liver into serving-size pieces; coat with flour. Heat oil in a large skillet; brown liver on both sides in oil; remove from skillet and keep warm. Stir in rice and vermicelli mix; brown lightly; add water called for on the label. Heat to boiling; lower heat; cover; simmer 10 minutes. Stir in Spanish-style vegetables, crushing the sauce cubes with the back of a spoon and stirring into liquid. Lay browned liver over rice; cover the skillet. Simmer 5 minutes or until liquid is absorbed and vegetables are tender.

Milkshake (makes one serving)

- 1 cup milk
- 1/2 to 3/4 t. extract or 1/2 banana or 1/2 cup strawberries
- 3 ice cubes

Put all ingredients in a blender and mix 30 seconds or until frothy.

Mixed Cereal Snack (makes 4½ cups)

1/3 cup margarine
1 t. Italian seasoning)
½ t. onion powder) or to your taste
½ t. garlic powder)
1½ cups Spoon Size shredded wheat
1½ cups Cheerios
1½ cups unsalted dry roasted peanuts

Prehat oven to 300°. In medium saucepan over medium heat, melt margarine. Stir in seasonings and cook 2 minutes. In a large bowl toss together Spoon Size shredded wheat and Cheerios and peanuts. Gradually pour seasoned margarine over the cereal mixture; toss to coat evenly. Spoon mixture into a 15 x 10 inch baking pan; bake 15 minutes or until crisp.

Pork Chop Casserole (makes 4 servings)

4 large pork chops with fat trimmed off
1 cup long grain rice (uncooked)
2 tomatoes, sliced
1 green pepper, sliced
1 onion, sliced
2 cups beef broth

Brown chops. Put rice in a 2 qt. casserole. Layer chops, tomato, green pepper and onion on top of rice. Pour broth over the layers. Cover and bake 45 minutes (or until rice is cooked) at 350°.

Salad Dressings

(a) oil and vinegar

(b) French Dressing (mix in bottle or jar with cover)
½ cup olive or salad oil, 2 Tbsp. mild vinegar, 1 t. salt, ½ t. pepper, ½ clove garlic (do not leave in jar for more than one day). Cover. When ready to serve, remove the garlic and shake hard to blend. Makes ½ cup.

(c) Cream French Dressing
To the above recipe add 1 Tbsp. heavy cream or sour cream just before serving and shake well.

(d) Russian Dressing
Mix ½ cup mayonnaise, ½ cup chili sauce (or to taste).

Spanish Rice (makes 4 to 6 servings)

Put in a large frying pan
2 Tbsp. bacon fat or butter
2 onions, sliced thin
Cook until the onion is soft. Add
1 cup uncooked rice or 1-1/3 cups precooked rice
Stir until the rice is lightly browned. Add
3 cups boiling water or stock (1-1/3 cups for precooked rice)
2 8-oz. cans tomato sauce or 2 chopped green peppers and
1 cup canned or fresh tomatoes
salt and pepper to taste
Chili powder or prepared mustard to taste

Stir well with a fork, cover and cook slowly until the rice is tender (10 minutes for precooked rice, 30-40 minutes for uncooked rice). Sprinkle with cheese after serving.

Taco Salad (makes 4 servings)

Shred ½ head lettuce and quarter 3 tomatoes. Spread the lettuce and tomato on individual plates. Add Dorito or Frito chips. Put your favorite chili in the center. Sour cream on the side can be quite tasty.

Sources

Betty Crocker's Cookbook. New York: Golden Press, 1972.

The Fannie Merritt Farmer Boston Cooking School Cookbook. Tenth Edition completely revised by Wilma Lord Perkins, Boston: Little, Brown and Company, 1959.

June Roth's Fast and Fancy Cookbook. New York: Fawcett Publications, 1969.

Appendix F

Placement of Blue Slide (Response Stimuli) in Test 1

1.	Red	21.	Red	41.	Red	61.	Red
2.	Blank	22.	Blank	42.	Blank	62.	Blank
3.	Red	23.	Red	43.	Blue	63.	Red
4.	Blank	24.	Blank	44.	Blank	64.	Blank
5.	Blue	25.	Red	45.	Red	65.	Red
6.	Blank	26.	Blank	46.	Blank	66.	Blank
7.	Red	27.	Red	47.	Red	67.	Red
8.	Blank	28.	Blank	48.	Blank	68.	Blank
9.	Red	29.	Red	49.	Red	69.	Blue
10.	Blank	30.	Blank	50.	Blank	70.	Blank
11.	Red	31.	Red	51.	Blue	71.	Red
12.	Blank	32.	Blank	52.	Blank	72.	Blank
13.	Red	33.	Blue	53.	Red	73.	Red
14.	Blank	34.	Blank	54.	Blank	74.	Blank
15.	Blue	35.	Red	55.	Blue	75.	Blue
16.	Blank	36.	Blank	56.	Blank	76.	Blank
17.	Blue	37.	Red	57.	Red	77.	Red
18.	Blank	38.	Blank	58.	Blank	78.	Blank
19.	Red	39.	Blue	59.	Red	79.	Red
20.	Blank	40.	Blank	60.	Blank	80.	Blank

Appendix G

Placement of Blue Slide (Response Stimuli) in Test 2

1.	Red	21.	Red	41.	Red	61.	Red
2.	Blank	22.	Blank	42.	Blank	62.	Blank
3.	Red	23.	Red	43.	Blue	63.	Blue
4.	Blank	24.	Blank	44.	Blank	64.	Blank
5.	Red	25.	Red	45.	Red	65.	Red
6.	Blank	26.	Blank	46.	Blank	66.	Blank
7.	Red	27.	Red	47.	Blue	67.	Blue
8.	Blank	28.	Blank	48.	Blank	68.	Blank
9.	Red	29.	Red	49.	Red	69.	Blue
10.	Blank	30.	Blank	50.	Blank	70.	Blank
11.	Red	31.	Blue	51.	Red	71.	Red
12.	Blank	32.	Blank	52.	Blank	72.	Blank
13.	Red	33.	Red	53.	Red	73.	Red
14.	Blank	34.	Blank	54.	Blank	74.	Blank
15.	Red	35.	Red	55.	Blue	75.	Red
16.	Blank	36.	Blank	56.	Blank	76.	Blank
17.	Red	37.	Red	57.	Blue	77.	Blue
18.	Blank	38.	Blank	58.	Blank	78.	Blank
19.	Blue	39.	Red	59.	Red	79.	Red
20.	Blank	40.	Blank	60.	Blank	80.	Blank

Appendix H

Placement of Blue Slide (Response Stimuli) in Test 3

1.	Red	21.	Red	41.	Red	61.	Blue
2.	Blank	22.	Blank	42.	Blank	62.	Blank
3.	Red	23.	Red	43.	Red	63.	Blue
4.	Blank	24.	Blank	44.	Blank	64.	Blank
5.	Red	25.	Red	45.	Red	65.	Red
6.	Blank	26.	Blank	46.	Blank	66.	Blank
7.	Red	27.	Blue	47.	Red	67.	Red
8.	Blank	28.	Blank	48.	Blank	68.	Blank
9.	Blue	29.	Red	49.	Red	69.	Red
10.	Blank	30.	Blank	50.	Blank	70.	Blank
11.	Red	31	Blue	51.	Red	71.	Red
12.	Blank	32.	Blank	52.	Blank	72.	Blank
13.	Red	33.	Red	53.	Red	73.	Red
14.	Blank	34.	Blank	54.	Blank	74.	Blank
15.	Blue	35.	Red	55.	Blue	75.	Blue
16.	Blank	36.	Blank	56.	Blank	76.	Blank
17.	Red	37.	Red	57.	Red	77.	Red
18.	Blank	38.	Blank	58.	Blank	78.	Blank
19.	Blue	39.	Red	59.	Blue	79.	Red
20.	Blank	40.	Blank	60.	Blank	80.	Blank

Appendix I

Directions for Practice Session

Examiner (E): Introduces child to those in the room and seats child. Offers child a pencil from midline (to establish dominant hand).

"Now put this hand on the paper hand beside the button and sit on your other hand."

"(Assistant) is going to tell you what to do, so put on your listening ears and listen very carefully."

"Hit the button now. Good. Again. Good. Now hit the button again."

"You are going to help us with this experiment. I want you to look at the screen. I am going to show you a square. What color is this square?"

Subject (S): "Red"

E: "What color is this square?"

S: "Blue"

E: "Now this is what you will do. Whenever you see the blue square you will hit the button as fast as you can with the hand on the table. After hitting the button, quickly place your hand back on the table."

"You are going to look at some slides and (assistant) will help you. Are you ready to begin?"

Advance slides slowly. Remind child the instructions when needed.

E: "Good. (Assistant) will help you again. When you see the blue square, what will you do as fast as you can?"

S: "Hit the button."

E: "Right. Are you ready to begin?"

Advance the slides slowly. Remind child to be fast and return hand beside button and watch screen closely.

E: "This is hard work and requires a lot of concentration. You are remembering to hit the button when you see the blue square."

"This time you will do it all by yourself. Remember to be as fast as you can. Are you ready to begin?"

Advance slides slowly.

E: "Wonderful! You have done the task correctly. You can show us again how fast you are. You can do it all by yourself. But this time the slides will go fast. So watch the screen very closely. Hit the button fast when you see the blue square. Are you ready to begin?"

Advance slides without stopping.

E: "When the slides go fast, you really have to watch closely and think very hard. But you are doing it correctly."

"We have time for you to watch the slides one more time. The slides will go fast again and you are going to hit the button as quickly as you can when you see what?"

S: "The blue square."

E: "Right. Are you ready to begin?"

Advance slides without stopping.

E: "You have worked very hard. Thank you for helping with our experiment. We will come back again and you can show us again how fast you can hit the button."

Appendix J

Directions for Test Session

Examiner (E): 1) Brings in child and sits him/her down; 2) reintroduces child to examiners; and 3) places paper hand on the appropriate side of the button to coincide with child's Dominant Hand.

"Today you are going to help us again. Remember this hand is placed flat here and sit on your other hand."

"These are your instructions, so put your listening ears on and listen very carefully."

"We are going to make sure the button works. Hit the button now. Good! Again. Good! One more time. Great!"

"Now you are going to look at the slides again. I want you to look at the screen. What color is this square?"

Subject (S): "Red"

E: "What color is this square?"

S: "Blue"

E: "The directions are the same as before. Whenever you see the blue square you will hit the button as fast as you can with the hand laying on the table. After hitting the button, quickly place your hand back on the table."

"You will look at these slides and hit the button all by yourself. The slides will go fast."

"Do you understand what to do?"

"Are you ready to begin?"

Advance the practice slides without stopping.

E: "Good. You correctly hit the button when you saw the blue squares. This time you will look at many,

many slides. You will have to watch <u>very</u> closely and pay attention to the colored squares. You will do this all by yourself."

"You are going to show us <u>how</u> <u>fast</u> you can hit the button when you see the blue square. Remember to quickly return your hand to the table."

"Are you ready to begin?"

Present test tray without stopping.

E: "You have worked very hard. It takes a lot of concentration to look at that many slides, doesn't it? Thank you again for helping us with our experiment. You will come back next week and show us again how fast you are."

Appendix K

COLLEGE OF HUMAN RESOURCES

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Blacksburg, Virginia 24061 - 8299

DEPARTMENT OF FAMILY AND CHILD DEVELOPMENT (703) 961-4794 or 4795

Dear Parents:

Have you ever suspected a connection between sugar in the child's diet and hyperactivity, inattention, or low frustration tolerance? Many parents have wondered about this but there is no research to answer the question. We would like to study this problem and your support and assistance is requested.

Previous studies examining the effect of sucrose on behavior have used hyperactive children as subjects. This research, though, will be focusing on the normal child. At least 30 (15 boys, 15 girls) normal children are required. Potential subjects would not include children with any of the following: a) Diabetes in family; b) Genetic disorders, including retardation; c) Emotional disturbance; d) Medication taken on a regular basis; or e) race other than Caucasian.

Strict dietary control and manipulation will be necessary. Parents of participants will be instructed to eliminate known sources of sucrose from the child's diet for a 14 day period. A dietary guide and sample menus will be provided that will ensure nutritional adequacy and eliminate sugar.

Experimental manipulation would be as follows: a) seven days of low sucrose for all subjects; b) seven days in which subjects are assigned to a high or low sucrose diet. The low sucrose diet will contain Equal (a non-saccharin sweetener).

Fruit-flavored drinks will be given at two snacks at the child's day care center. These drinks will contain the sucrose or Equal. Meanwhile all children will receive low sucrose diets at home or for other meals in the day care center.

Parents and teachers will be unaware of which children receive sucrose and which days it is given. This is to prevent a Hawthorne effect in parental ratings of behavior.

To observe the results of this dietary experiment,

Page 2
Parents

we plan to measure reaction time and frustration tolerance (a puzzle too difficult for the child) as well as parent and teacher ratings. The child will have a chance to have success in the puzzle task and will be rewarded for effort. Rewards will be pencils or balloons.

Results of the study will be made available to parents. To participate in this study will require some time and effort on the parents' part but the importance of this issue clearly calls for this type of study.

Wouldn't you be proud to know that you helped future parents know whether there is any real basis for the suggestion that sugar causes behavioral difficulties? They would appreciate it, we're sure.

If you have questions, please do not hesitate to call one of us.

Sincerely,

(signed)

Cosby S. Rogers
Assistant Professor
Child Development

(signed)

Shirley C. Farrier
Associate Professor
Child Development

(signed)

Graduate Student

Appendix L

Consent of Participation in Child Development/Nutrition Study

Virginia Polytechnic Institute and State University

Department of Family and Child Development

Department of Human Nutrition and Foods

I have received an oral explanation of the study. I understand the following:

1) I must provide a low sugar diet for my child for a two-week period during the study.

2) I will keep a food intake journal for a two-week period during the study. The journal will include the types and amount of food ingested by my child.

3) I will rate my child's behavior at the beginning, middle, and end of the study.

4) My child will participate in a reaction-time task as well as a frustration tolerance task. The frustration will be eliminated at the end of the task.

Procedures do not involve risk to participants. All information will be confidential. If at any time a participant, parent of a participant, or the investigators believe that the health of the subject may be improved, the individual may drop out of the program.

I understand the above and agree to participate and allow my child to participate in the Child Development/Nutrition study to be conducted by Virginia Polytechnic Institute and State University, Blacksburg, Virginia in May, 1983.

Name______________________

Date______________________

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