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Effects of Methylphenidate on the Sensitivity to Reinforcement in Children Diagnosed with ADHD: An Application of Matching Law

Laura Kay Murray

EFFECTS OF METHYLPHENIDATE ON THE SENSITIVITY TO REINFORCEMENT IN CHILDREN DIAGNOSED WITH ADHD: AN APPLICATION OF MATCHING LAW

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Laura Kay Murray

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Laura Kay Murray

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Laura Kay Murray, M.A.

Western Michigan University, 1999

This experiment evaluated the effects of methylphenidate on sensitivity to reinforcement of children diagnosed with ADHD using matching law.

Four children (2 males and 2 females) between the ages of 6 and 10 who were previously diagnosed with ADHD completed easy math problems to earn tokens under four different variable-interval (VI) schedules of reinforcement presented in random order. The rate of completed math problems was plotted against the mean frequency of obtained reinforcers at each schedule value in tokens per minute. The data were fit to the following single-rate hyperbolic equation (Herrnstein, 1970): $R = kr/r+r_o$.

Results show that the behavior of female participants was not well described by the matching law under MPH or placebo conditions, thus making any comparison between conditions uninterpretable. Under MPH conditions, the matching functions for both male subjects resulted in a higher asymptotic value (k), higher variance accounted for, and higher values of r_o. In addition, it was demonstrated that MPH may alter the reinforcing value of different consequences.

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INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most commonly diagnosed behavior disorders among preadolescent children in the United States (Barkley, 1997) and questions regarding its etiology, symptom variation, and course have generated a vast literature. In efforts to understand ADHD, researchers have attempted to explain the behavioral symptoms by various theoretical models. For example, Quay (1988, 1997) has proposed that the behavioral problems observed in children diagnosed with ADHD are the result of an underactive Behavioral Inhibition System. This construct, initially developed by Gray (1987) to explain anxiety, is believed to control the reduction or inhibition of responding in the presence of stimuli that signal punishment or non-reward. This theory is supported by studies demonstrating that children diagnosed with ADHD perform poorly on tasks that require abrupt cessation of ongoing behavior in discrete trial situations. (e.g., Iaboni, Douglas & Baker, 1995; Shue & Douglas, 1992; Trommer, Hoeppner, Lorber & Armstrong, 1988; Schachar, Tannock, Mariott, & Logan, 1995).

Barkley (1990, 1997) has also offered a comprehensive theoretical account of ADHD behavior that implicates the construct of behavioral inhibition as the major impairment associated with observed behavioral problems. Barkley's (1997) model proposes that behavioral inhibition sets the occasion for the cessation of an ongoing behavior by providing the delay necessary for an executive decision to be made

considering both the immediate and delayed consequences. Barkley (1997) explains that the behavior of ADHD children is controlled more by the immediate context, whereas other children's behavior is more controlled by internally represented information that enables a child to maximize future outcomes. In other words, Barkley's model suggests that a behavioral inhibition system controls how children consider the potential outcome of their ongoing behavior and, in children diagnosed with ADHD, this system does not provide adequate opportunities for children to regulate their behavior.

The theory of behavioral inhibition is based primarily on cognitive and neuropsychological approaches to explaining overt behavior and has obvious limitations from a behavior-analytic perspective. For instance, the difficulty of forming a precise definition of response inhibition creates measurement problems. Even within the more traditional literature, the proposition of behavioral inhibition as a causative mechanism has met with criticism. For example, Haenlein & Caul (1987) discussed the concept of response inhibition as overinclusive. Moreover, the construct of behavioral inhibition fails to identify the specific responses or circumstances in which a child's behavior is or is not inhibited. A closely related criticism suggests that the behavioral inhibition conceptualization of ADHD describes the behavior pattern of those diagnosed, but does not explain it (Haenlein & Caul, 1987).

Another approach to conceptualizing ADHD, which offers more direct explanatory power and relies less on the hypothetical construct of behavioral inhibition, proposes that the behavior of children diagnosed with ADHD does not

change following some consequences in the same manner as the behavior of non-diagnosed children (Haenlein & Caul, 1987; Douglas, 1983) Such theories predict that the behavior of ADHD children requires higher rates of reinforcement than that of normal children to maintain comparable levels of behavior (Haenlein & Caul, 1987). Although this theory was initially described in terms of how "rewarding" certain consequences are for children, the general approach has merit from a behavioral analytic perspective. Specifically, it predicts that the behavior of children diagnosed with ADHD will not change or adjust as readily as the behavior of non-diagnosed peers under conditions where environmental contingencies are changing. This differential pattern of responding to consequences has been described as sensitivity to reinforcement.

A number of studies have investigated the theory of sensitivity to reinforcement in children diagnosed with ADHD across various tasks and settings (e.g., Cunningham & Knights, 1978; Douglas & Parry, 1983; Haenlein & Caul, 1987; Parry & Douglas, 1983; Quay, 1997). However, results regarding the differential sensitivity to reinforcement of children diagnosed with ADHD compared to normal children are mixed. For example, in studies examining the behavior of ADHD children under continuous reinforcement (CRF) and partial reinforcement (PRF) schedules, some studies reported no differences in the behavior of children diagnosed with ADHD and non-diagnosed peers (Cunningham & Knights, 1978; Pelham, Milich, & Walker, 1986), while other studies reported that ADHD children's behavior was less efficient (i.e. they earned fewer reinforcers) than the behavior of

their normal peers (Douglas & Parry, 1983; Parry & Douglas, 1983). The use of different experimental preparations, varying subject characteristics, and the use of different methods of measurement are likely reasons for the inconclusive results reported across these studies.

Due to the mixed results and discrepant methods used to measure sensitivity to reinforcement, a standardized, quantitative approach would contribute to our understanding of the basic behavioral processes associated with ADHD. The matching law is a mathematical equation that describes behavioral allocation under differing schedules of reinforcement and theoretically assesses an organism's sensitivity to consequences. Herrnstein (1961) demonstrated that pigeons distributed their responses between two concurrently available response alternatives in the same proportion that obtained reinforcement was distributed contingent upon those response alternatives. Subsequent research has generated more generalized quantitative descriptions of behavior that account for departures from Herrnstein's (1961) strict matching equation. For example, Herrnstein (1970) derived an equation to describe the manner in which behavior maintained by variable interval (VI) schedules varies as a negatively accelerating hyperbolic function of obtained reinforcement rates. This mathematical account of behavior specifies the relationship between reinforcement rate and behavior rate as follows (Herrnstein, 1970):

$$R = \frac{kr}{r + r_o} \qquad (1)$$

In this equation, R is the rate of the target response, r is the rate of reinforcement contingent upon the target response, k is a free parameter interpreted as the maximum possible rate of responding, and r_o is a free parameter believed to represent the rate of all other reinforcement delivered to the subject exclusive of the target response. The parameter r_o also represents the reinforcement rate required to maintain half-maximal responding and is conceptualized as a measure of reinforcer efficacy (e.g. Hernnstein,1970; Heyman, 1992).

Research has demonstrated the value of Equation 1 and its derivatives as a valid descriptor of behavior with both nonhumans (e.g., see Baum, 1979; Davison & McCarthy, 1988 for reviews) and humans (see Kollins, Newland, & Critchfield, 1997; Pierce & Epling, 1983 for reviews). Further, the matching law has been shown to be useful in describing clinically-meaningful behavior in humans (e.g., Martens & Houk, 1989; Mace, McCurdy, & Quigley, 1990; Bradshaw et al., 1976). For example, Martens and Houk (1989) demonstrated that Equation 1 accounted for an average of 83% of the variance in disruptive behavior when measuring naturally occurring classroom behavior of individuals with developmental disabilities. Another relevant study by Bradshaw & Szabadi (1978) demonstrated how Equation 1 can be used to quantify changes in sensitivity to reinforcement and response rates in an individual experiencing manic and depressive episodes. In this experiment, a manic-depressive subject performed a laboratory task that involved pressing a key under varied rates of reinforcement delivered according to five variable-interval (VI) schedules. As predicted, estimates for k (maximal response rate) differed

significantly when the individual was manic (k was higher, indicating greater asymptotic response rate) versus depressed (k was lower). Changes in r_o also occurred in the manic (r_o decreased, indicating increased reinforcer efficacy) versus depressed (r_o increased) phases.

To our knowledge, only one study has used matching theory to assess sensitivity to reinforcement in children diagnosed with ADHD. In this study, Kollins, Lane, & Shapiro (1997) examined the differences in sensitivity to reinforcement between children diagnosed with ADHD and normal children by describing their behavior under concurrent VI VI schedules with a derived linear equation based on Equation 1 (Baum, 1979). Results demonstrated that the behavior of children diagnosed with ADHD was less likely to change in conjunction with changes in the rates of reinforcement compared to normal children. These findings support for the hypothesis that the behavior of children diagnosed with ADHD does not change in adaptive ways when environmental conditions change (i.e., lower sensitivity to reinforcement; Barkley, 1991, 1997; Hanlein & Caul, 1987; Quay, 1997). The results of Kollins, Lane & Shapiro (1997) also add to the accumulating data that matching law renders an accurate mathematical description of choice behavior with humans in applied settings.

Several important questions remain, however, regarding the utility of matching descriptions of ADHD behavior based on limitations of the Kollins, Lane & Shapiro (1997) study. Specifically, it is not clear whether matching theory actually describes a core deficit (i.e., sensitivity to reinforcement) in this population since the

linear equation used in this study failed to account for more than only a moderate proportion of the variance in responding of children diagnosed with ADHD (R^2 = 0.02 -0.78). Although a number of factors may contribute to this problem, the lack of a functionally-defined reinforcer is offered by the authors as a possible cause for the poor fit.

The purpose of the present study was three-fold. First, we sought to determine if matching theory describes the behavior of children diagnosed with ADHD under different VI schedules. Second, we were interested in determining whether matching theory could be used as a quantitative tool to document the effects of a commonly used medication, methylphenidate (MPH, Ritalin ®), on the behavior of ADHD children. Approximately 80-90% of school-age children diagnosed with ADHD receive stimulant medication, with many more children receiving MPH than any other stimulant. (Pelham, 1993). It has been repeatedly shown that MPH, a central nervous system stimulant, can be useful in reducing problem behaviors associated with ADHD (Barkley, 1990; Pelham, 1993). Little research, however, has examined the effects of methylphenidate on children diagnosed with ADHD as they perform a specific behavioral task designed to measure the construct of sensitivity to reinforcement. Thus, the study sought to determine whether methylphenidate alters sensitivity to reinforcement in children diagnosed with ADHD. Finally, the study aimed to replicate the findings of Northup, Fusilier, Swanson, Roane, & Borrero (1997) who demonstrated that MPH may act as an establishing operation that alters

the relative reinforcing effectiveness of various stimuli in children diagnosed with ADHD.

METHODS

Participants and Setting

Participants were two boys (ages 7 and 10) and two girls (ages 6 and 9). A previous diagnosis of ADHD, based on the *Diagnostic and Statistical Manual of Mental Disorders; Fourth Edition* (DSM-IV; American Psychiatric Association, 1994), and a current prescription for methylphenidate were required for participation in the study. In addition, all volunteers received a T-score greater than 65 on the Attentional Problems Subscale of the Child Behavior Checklist as rated by two adults with whom the child has significant contact (CBCL, Achenbach, 1991) and a T-score greater than 65 on the Impulsive-Hyperactive Subscale of the Conners Parent Rating Scale – 48 (CPRS, Achenbach & Edelbrock, 1991).

The first subject, Belle, was a 6-year-old female in kindergarten currently taking 5 mg of MPH three times a day. A 9-year-old female, Mandy, was in third grade currently taking 7.5 mg of MPH two times a day. The third subject, Derrek, was a 10-year-old male in fifth grade currently taking 10 mg of MPH two times a day. Finally, Willis was a 7 year old male in second grade currently taking 10 mg of MPH two times a day. No other medications were taken by the volunteers while participating in the study.

All volunteers were recruited from the local community via posted flyers and word of mouth. This study was conducted in a laboratory setting at Western

Michigan University, including one playroom filled with toys and rewards and a larger conference room where the volunteers participated in the experimental procedures. This room had a conference table in the middle where the children worked on math problems, one wall of desks containing one computer and printer, and a wall of bookshelves. This study was approved by the Human Subjects Institutional Review Board at Western Michigan University.

Apparatus/Materials

Reinforcer Survey

Reinforcer surveys containing 42 common childhood reinforcers, based on Northup et al. (1997), were vocally read to each participant during the screening sessions (See Appendix A). Subjects rated these reinforcers as "like not at all," "like a little," or "like a lot." The participants were also asked to list other small toys, edibles, or activities they enjoy. The highly rated items were made available for each individual subject and put on a list with token prices. A daily log was kept recording what each individual chose during the sessions.

Due to evidence that methylphenidate may act as an establishing operation that alters the relative reinforcing effectiveness of various stimuli, (Northup et al., 1997) the reinforcer survey was administered to each subject under the following two conditions: (1) when the child had taken his/her regular dose of methylpehnidate and (2) when the child had not taken any medication.

Math Sheets

The target response for the study was the completion of math problems, which were presented on sheets arranged in five rows with five problems in each row for a total of 25 per sheet. Easy math problems were selected as a potentially externally relevant response that could be performed at a relatively high rate. The difficulty level of the problems was individually determined. Belle and Willis were given problems consisting of two numbers, such as 7 and 2, and had to circle the bigger number. Mandy and Derrek were given single digit addition problems, such as 7 + 2 to complete. The math sheets for Mandy consisted of problems using primarily lower numbers, whereas Derrek's math sheet contained a wide range of all numbers. Easy math problems were defined as those that could be completed with greater than 90% accuracy during repeated trials in the screening sessions. Math sheets were printed on paper of different colors (blue, green, pink, and yellow) and each color corresponded to a different VI schedule value throughout the experiment.

Tokens

Colored poker chips were used as tokens, with each chip representing one "point." Reinforcers children had identified as preferred, based on the above survey, were assigned different point values based primarily on their monetary worth. Each child was allowed to save or spend their tokens following each trial. The point costs of some items were such that repeated trials were necessary to accumulate the needed amounts.

Cueing Tape

Audio cassette tapes presented a series of tones programmed to sound according to different variable-interval (VI) schedules. The schedules were approximated based on a poisson distribution (Fleshler and Hoffman, 1962) and consisted of twelve intervals with the following means: 6, 12, 20, 30 and 60 seconds. The order of the VI schedules was randomized for each session. The researcher listened to the tapes through "ear plug" headphones.

Medication Procedure

All medications were prepared by a pharmacist from the university health center according to a standard procedure. MPH tablets were encapsulated in opaque capsules to conceal taste, odor, and color. The capsules were then filled with dextrose. Placebo capsules were identical in appearance, but contained only dextrose. The pharmacist was given a pseudo-random sequence of how the MPH and placebo pills were to be prepared (with the rule of never exceeding two days in a row of either MPH or placebo). The pharmacist placed the appropriate capsules in a pill box labeled with days 1 through 8. Prior to each session, the researcher (L.M.) telephoned the parent(s) as a prompt to administer the pill corresponding to the appropriate day and time agreed upon by the researcher and parent(s). All pills were administered 45 minutes prior to a scheduled session. The experimenter (L.M.), the participant, and his/her parent(s) were all blind to the medication status, with only the pharmacist and

the senior investigator (S.K.) aware of the sequencing. The doses of MPH were based on each individual's normal dosage. Once the participant completed all sessions, the researcher opened a sealed envelope containing the medication/placebo sequence, breaking the double blind condition.

General Procedures

First Screening Session

At the first session, the purpose and procedure of the study was reviewed with the parent and child to gain both consent and assent, respectively. Initial screening forms (i.e., CBCL, CPRS) and a release to contact their physician were completed by the parent. It was determined and recorded whether the participant's regular dosage of MPH was active at the time of this session or if it had been three or more hours since administration and thus considered inactive. The child responded to the reinforcer survey, followed by a 10-minute break during which s/he chose a reward such as an activity, edible, or small toy. Next, the child completed three 10-minute trials of math sheets. Each trial was separated by a 10-minute break during which a reward was chosen. Math sheets were scored to ensure the child could complete problems at 90% or better accuracy.

After the session, the child's prescribing physician was contacted and agreed to the child's participation in the study by providing written consent and a prescription to prepare the MPH and placebo capsules as described above.

Second Screening Session

This session took place when the child had not received his/her typical dose of MPH (or if they were not medicated during the first session, at a time when they had received their typical dose of MPH). The child participated in procedures identical to the first screening session with the exception of the medication status.

Baseline

Following the screening sessions, the child participated in two separate sessions without receiving any capsules to obtain baseline behavioral data. The child was seated with math worksheets directly in front of him/her and a plastic jar placed further in front of the child to hold the tokens. Each child was given the following identical instructions prior to beginning the task (adapted from Northup et al., 1997):

> Once I say "START," you can earn tokens for doing these math problems. You can work as fast as you want or as slow as you want. You can do as much as you want, as little as you want, or none at all. Sometimes when you are working, I will drop a token in this jar. I will say "STOP" when we can take a break. Your break will be for ten minutes and during that time, you may cash in the tokens you receive for prizes that you said you liked. After ten minutes, we will work again for a while.

When the experimenter said "start," she started the cue tape and the child began the math problems. A token was dropped into the jar every time the child completed a math problem following the completion of an interval. The rates of reinforcement varied based on the different VI schedules. For example, the VI-6 schedule produced a tone, on average, every 6 seconds, producing approximately 10 tokens per minute.

Following ten minutes on one schedule, the experimenter said "stop" and the child was allowed a 10-minute break during which they could cash in their tokens for a variety of reinforcers based on their self-reported preferences or they could save their tokens.

During each session, the completion of math problems was reinforced according to four different VI schedules presented in random order. A discriminative stimulus (of different colors of paper for the math sheets) accompanied each different VI schedule. Belle and Derrek each participated under the following schedules: VI-6, VI-12, VI-20, and VI-30. In an effort to generate greater response variability, Mandy and Willis participated under the following schedules: VI-6, VI-12, VI-30 and VI-60.

Phase II

Following these baseline measures, the volunteers participated in eight more sessions consisting of the medication manipulation between MPH and placebo. Forty-five minutes prior to each scheduled session, the researcher telephoned and the parent(s) were prompted to administer a pill from the appropriate day label on their pill box. The child then completed the procedures in an identical manner as in Baseline.

Dependent Measures

Dependent variables recorded for analysis included the number of problems completed, percent accuracy, number of tokens received, and rewards chosen after

each 10-minute session. Qualitative data were also collected at the end of each session, which involved asking children whether they believed that s/he received his/her medication or not that day and asking how they felt during the session. Finally, informal behavioral observations of such behavior as talking aloud, spinning in chair, or crawling on the floor were recorded by the experimenter.

Data Analysis

Based on previous research (e.g., Bradshaw, Szabadi, & Bevan, 1976), data were averaged at each schedule value. The mean rate of completion of math problems (in problems/minute) was computed across all days for each VI schedule. These data were then expressed as a function of the obtained rate of reinforcement at each schedule value (in tokens/minute). Rectangular hyperbole were fit to the data by computer program using nonlinear least-squared regression analysis (Wilkinson, 1961), giving estimates of the theoretical maximum response rate (k) and the reinforcement frequency corresponding to half-maximal response rate (r_o). Proportion of variance in the data accounted for (r^2) by the hyperbolic function was also calculated.

RESULTS

Two of the principal goals of the present study were (1) to determine if matching theory described the behavior of children diagnosed with ADHD under different VI schedules and (2) to use matching theory as a tool to document whether methylphenidate alters sensitivity to reinforcement in children diagnosed with ADHD. To address these goals, Figures 1 through 4 show the rate of completed math problems by obtained reinforcement rate for each child under methylphenidate and placebo conditions, including the fitted hyperbolic functions and the estimated equation parameters. Figure 1demonstrates that the single-alternative form of the matching law accounted for 33% and 1% of the variance in the rate of math problems completed under placebo and methylphenidate, respectively, for Belle. Under placebo, the hyperbolic function reached its asymptote (k) at 7.36 responses/minute with an estimated value of r_o at 0.67 reinforcements per minute. Stated differently, 7.36 responses/minute is the maximum response rate and 0.67 is the amount of reinforcers per minute needed to maintain half-maximal response rate (3.18 responses/minute). On methylphenidate, the hyperbolic function reached its asymptote (k) at a higher value of 11.67 responses/minute with a requirement of -0.06 (r_o) reinforcements per minute to maintain half maximal response rate. Due to the negative value of r_o, the parameters matching law produced under the averaged MPH conditions for Belle are not interpretable. Matching law appears to appropriately

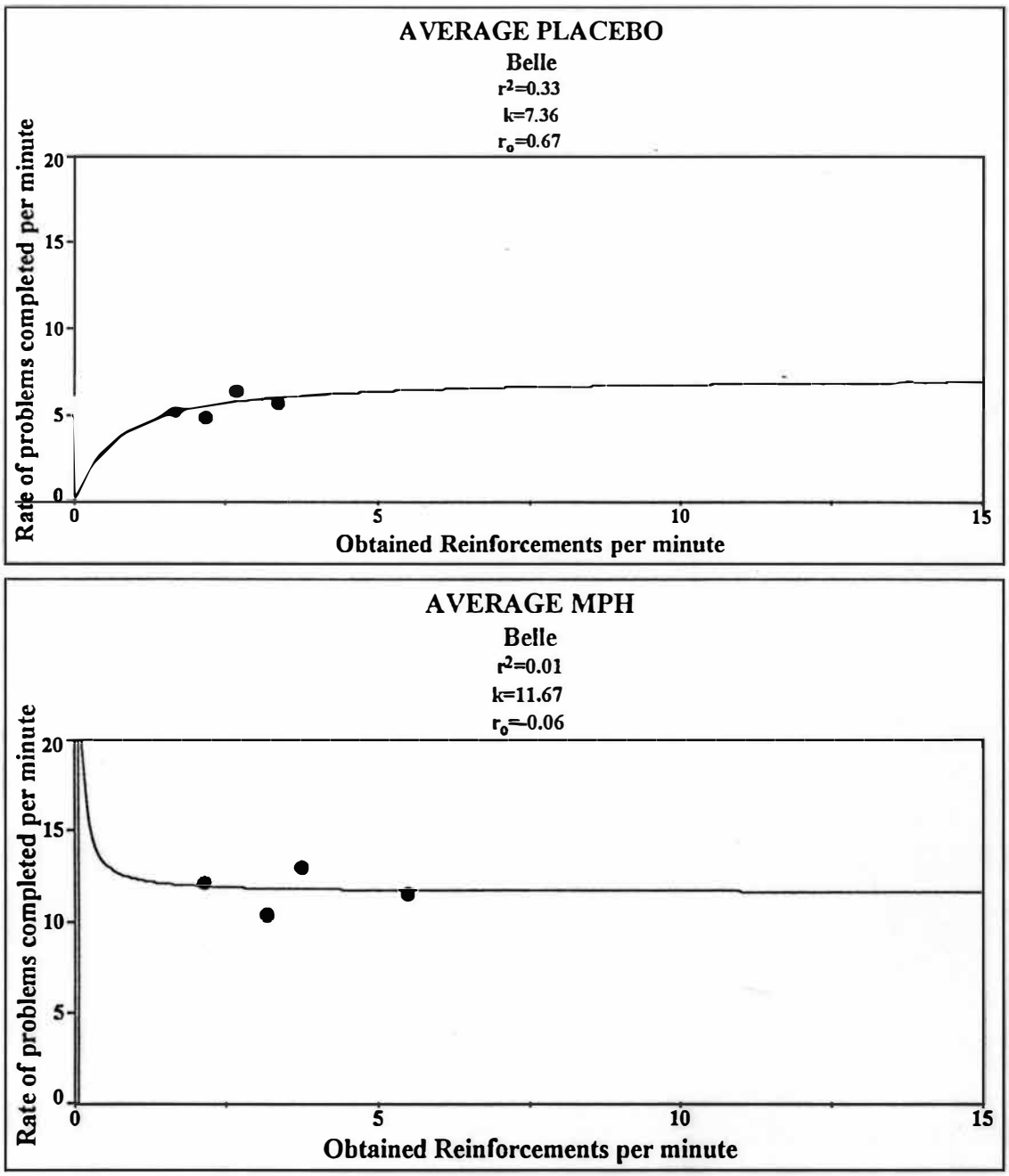

Figure 1. Average Placebo and MPH for Belle.

describe Belle's behavior under placebo condition, but no comparison can be made between placebo and MPH conditions.

Figure 2 shows Mandy's performance on the task with matching law accounting for 95% and 4.3% of the variance under averaged placebo and methylphenidate conditions, respectively. The placebo condition rendered a hyperbolic function reaching its asymptote at 32.34 responses/minute and produced the estimated value of r_o to be 1.56 reinforcements/minute. Under methylphenidate, Mandy's behavior was described by a hyperbolic function reaching asymptotic value at 25.08 responses/ minute, estimating the r_o value at -.023 reinforcements/minute. Due to this negative value of r_o, the matching law parameters are rendered uninterpretable. The matching theory seems to, again, adequately describe behavior under the placebo condition but no comparison can be made between MPH and placebo conditions for this subject.

Figure 3 demonstrated that matching law accounted for 8.25% and 96% of the variance under placebo and methylphenidate conditions, respectively, for Derrek. Thus, matching theory adequately described the relationship between the rate of problems completed and contingent reinforcement under the MPH condition. Under placebo conditions, the hyperbolic function reached asymptote at 29.44 responses/ minute with an estimated r_o value of 0.13 reinforcements/minute. During methylphenidate conditions, Derrek's behavior rendered a hyperbolic function reaching a higher asymptote of 39.37 responses/minute and a higher estimated value of r_o (.297 reinforcements/minute). These parameters demonstrate a higher average

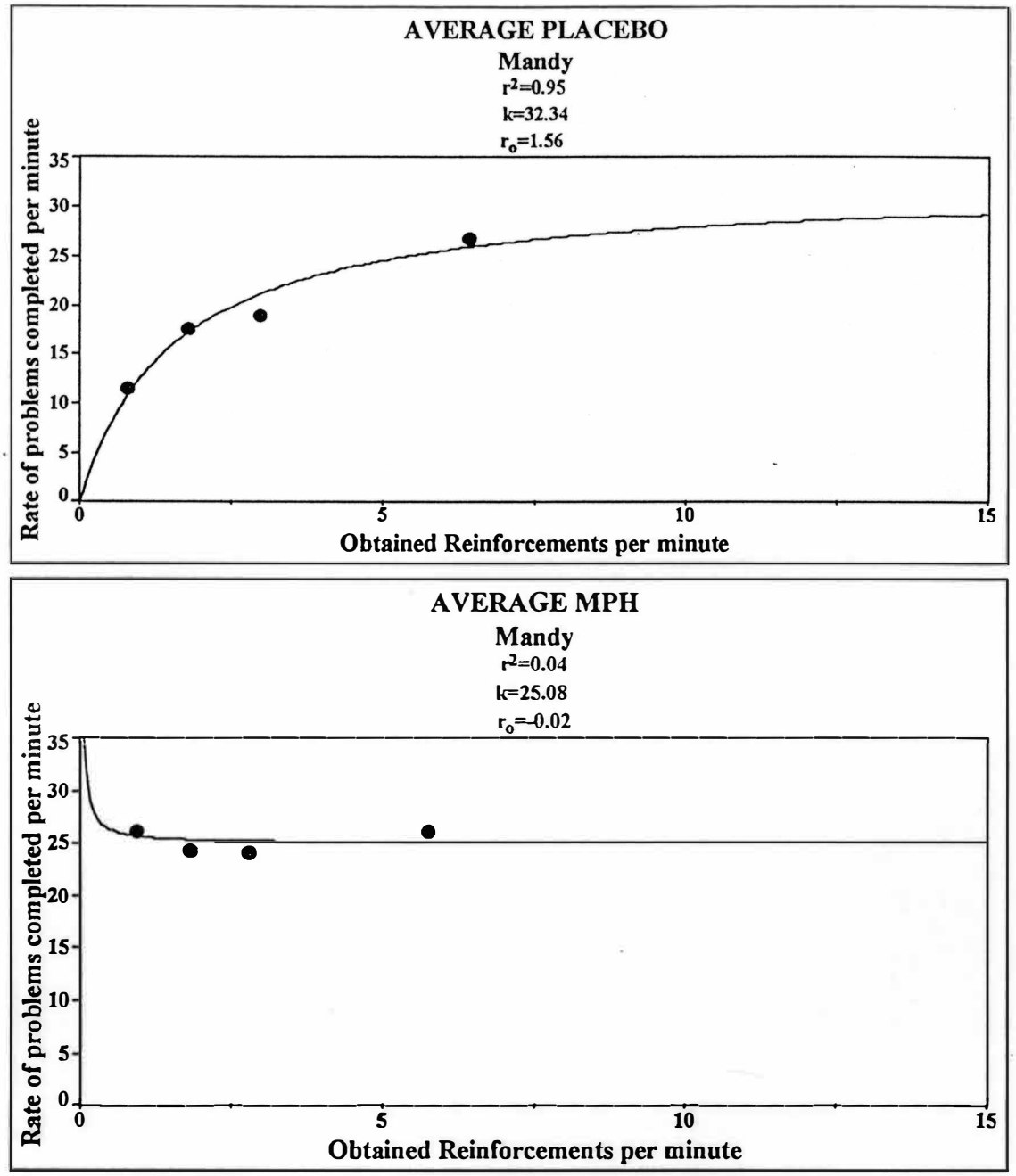

Figure 2. Average Placebo and MPH for Mandy.

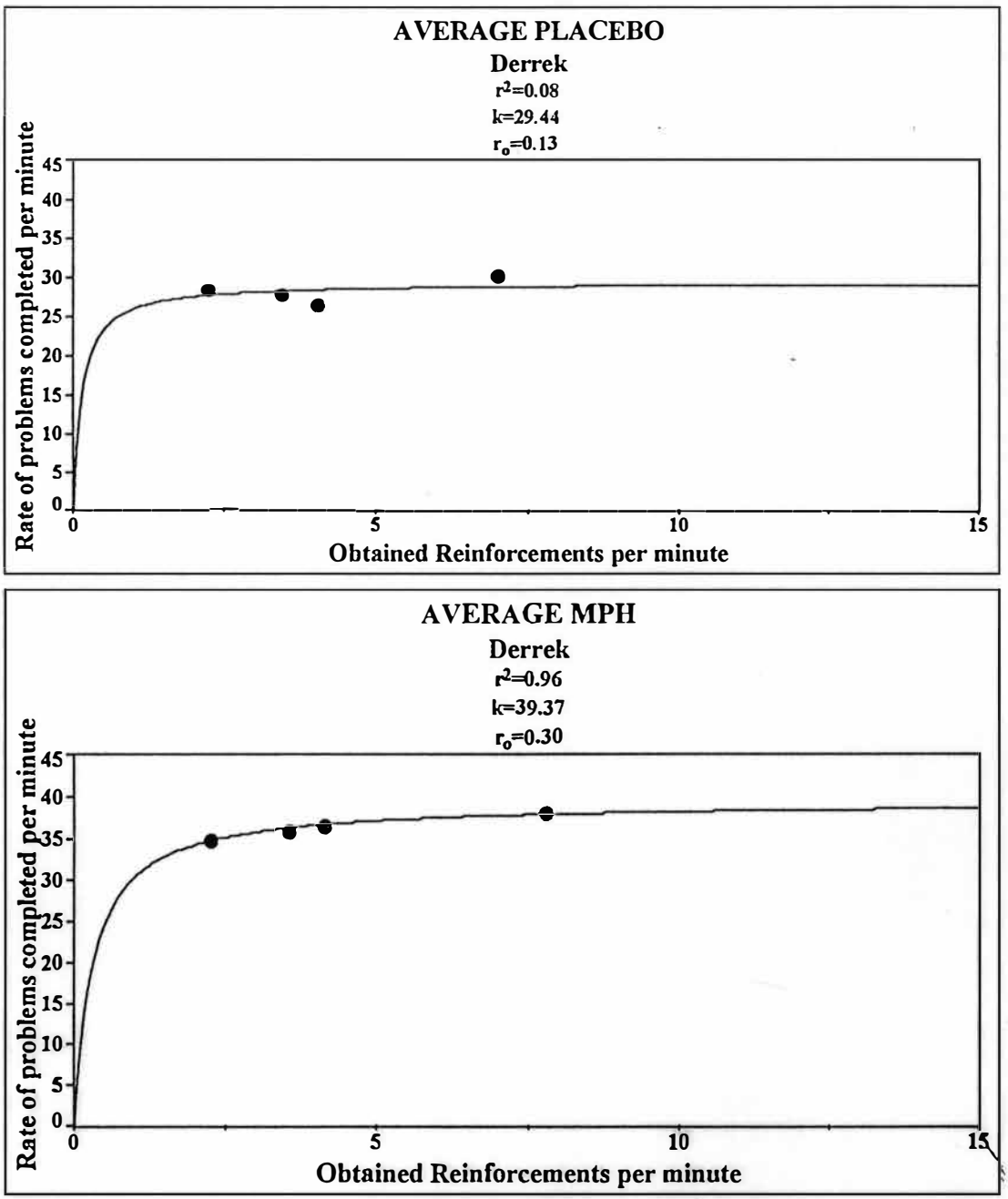

Figure 3. Average Placebo and MPH for Derrek.

maximum response rate under the MPH condition. The estimated value of r_o was also higher under MPH conditions, suggesting that more reinforcers were needed to maintain half-maximal responding. This may also be interpreted as a lower sensitivity to reinforcement while taking MPH versus placebo.

Figure 4 represents Willis's data, showing that 17% and 43% of the variance was accounted for by the matching law under the placebo and methylphenidate conditions, respectively. Thus, matching theory better described behavioral change under MPH versus placebo conditions for this participant. The placebo conditions rendered matching law parameters of 9.20 responses/minute (k) for the asymptote and 0.13 reinforcements/minute for r_o. During methylphenidate conditions Equation 1 yielded a slightly higher asymptotic value of 10.14 responses/minute and an estimated r_o value of 0.396 reinforcements/minute. Willis reached a higher maximum response rate during MPH conditions. The estimated values of r_o demonstrate that Willis required more reinforcers per minute to maintain half-maximal responding under MPH conditions versus placebo conditions.

The third goal of the present study was to replicate the findings of Northup et al. (1997) which demonstrated that MPH may act as an establishing operation that alters the relative reinforcing effectiveness of various stimuli. Table 1 shows the proportions of tokens spent under MPH versus placebo conditions on the three categories of reinforcers available, including tangible, edibles, and activities. Reinforcement effects were demonstrated across all four participants in a consistent manner. Specifically, the proportion of tokens spent on tangibles was higher during

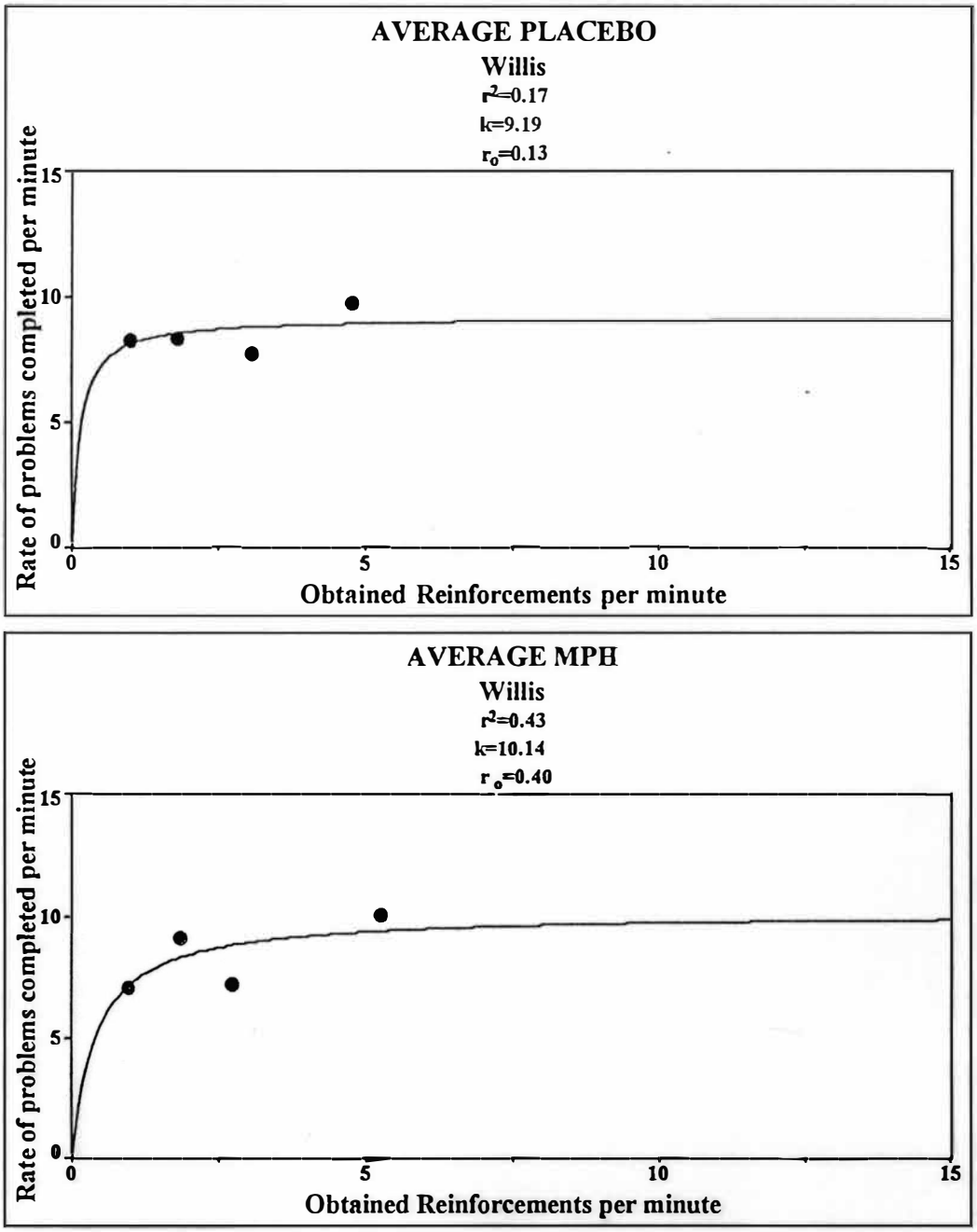

Figure 4. Average Placebo and MPH for Willis.

MPH conditions as compared to placebo conditions. While the participants were receiving a placebo, a larger proportion of tokens were spent on edibles by all subjects. Finally, the proportion of tokens spent on activities was higher during the placebo conditions for Belle and Mandy, and higher during the MPH conditions for Willis. (Derrek never chose an activity as a reinforcer.)

Table 1

Proportions of Tokens Spent Under MPH Versus Placebo Conditions Across the Three Categories of Reinforcers Available

	Belle		Mandy		Derrek		Willis	
	MPH	Placebo	MPH	Placebo	MPH	Placebo	MPH	Placebo
Tangibles	0.75	0.51	0.83	0.75	0.93	0.74	0.73	0.58
Edibles	0.12	0.22	0.17	0.22	0.07	0.26	0.23	0.42
Activity	0.14	0.27	0	0.03	0	0	0.35	0

Additional qualitative data demonstrate more off-task behavior during placebo conditions such as spinning around in a chair, playing with a writing utensil, and talking and/or singing. In addition, the math sheets completed during MPH sessions were much neater than those completed under placebo conditions for most subjects. For example, on placebo days, Belle drew lines all over her math worksheets instead of just circling the answers separately.

DISCUSSION

This study sought to examine the behavioral sensitivity to changing rates of reinforcement in children diagnosed with ADHD while taking MPH versus a placebo. Results of this study suggest that Herrnstein's (1970) law of effect describes a hyperbolic relationship between behavior rate and contingent reinforcement under both conditions for the two male participants. In comparison, the matching law accounted for only negligible amounts of behavioral variance and rendered uninterpretable parameters under the MPH conditions for both female participants.

Before interpreting our results, several limitations warrant discussion. First, reinforcers were individually determined based on the subject's verbal report and not functionally determined. Research has demonstrated that a paired stimulus format of reinforcer preference assessment is the most accurate in determining salient reinforcers (e.g., Northup, Jones, Broussard, & George, 1995; DeLeon & Iwata, 1996). Thus, there may be a discrepancy between those reinforcers reported as preferred by the participants and those that would function as such after a more elaborate behavioral analysis. Second, in comparison to other studies within the basic and applied areas, the VI schedules used were rich and produced relatively low response variation. Future studies that produce greater response variation due to leaner VI schedules of reinforcement may result in behavioral patterns that are better described by Equation 1. Third, this study used 10 minute sessions to record behavior

during each VI schedule which may not be long enough to observe response variation when contingencies change from trial to trial. For example, Bradshaw & Szabadi (1978) used session lengths of 75 minutes and obtained behavior that was very well described by Equation 1 (e.g., R^2 = 0846 - 0994). Future studies should utilize both a wider range of schedule values and longer session lengths to obtain optimal response variation under varying contingencies. Finally, compliance with medication manipulations was directed by a phone call and assessed by parental report. Future studies should, if feasible, use direct administration by researchers to confirm compliance with experimental procedures and maximize the likelihood of standardization across conditions.

Despite these limitations, several findings from the present experiment are of interest. First, the female participants behaved substantially different than the male participants. The gender differences observed in this study are concordant with the findings of Kollins, Lane & Shapiro (1997) which reported that female participants (both ADHD and control) generally did not allocate their behavior to track changing reinforcement contingencies. The Kollins study suggested that their consequences (Nintendo time) may not have functioned as a reinforcer for the female participants. Although the current study used individually preferred reinforcers to attempt to correct for this, similar results were obtained. It is possible that, for the females, the items selected on the survey, and subsequently made available, were not functional reinforcers for the target behavior. Idiosyncratic features of these subjects participation may have also contributed to their discrepant results. For example,

Belle was repeatedly sick which caused several sessions to be rescheduled and to be conducted while she was at less-than-optimal health. This poor health may have affected her behavior independently of the programmed reinforcement contingencies. Due to her health, Belle was also prescribed antibiotics which expanded the length of time between sessions significantly. This increased length of time may have reduced the salience of the reinforcers made available based on self-report. The other female subject, Mandy, had the MPH dosage used in the experiment evaluated soon after completion of the study and increased from 7.5mg to 10 mg. As dosage is a critical variable related to MPH effects (e.g., DuPaul & Barkley, 1993), this suggests that Mandy's dosage used during this study may not have been within the optimal effectiveness range for her (e.g., Sprague & Sleator, 1977; Rapport et al., 1987). In addition, due to an inability to swallow pills, Mandy had her MPH dosage and placebo prepared in powder form which was dropped on her tongue. These uncontrollable situational factors may have affected the apparent gender differences found.

The finding of differences between genders may simply add to the literature on various other differences found in boys and girls diagnosed with ADHD, such as a higher prevalence rate among boys (Ross & Ross, 1982) and a lower risk of girls for ODD and CD relative to boys (Biederman, 1997). A recent meta-analysis of past research on gender differences in samples of ADHD children concluded that girls were more impaired in their intelligence, less hyperactive, and less likely to show

various externalizing symptoms, such as aggression, defiance, and conduct problems (Gaub & Carlson, 1997).

On this note, future research should examine whether the gender differences found in the present study exist on a larger scale or if they are, in fact, due to idiosyncratic features. The findings of differences in gender could lead to a number of additional questions, such as whether the construct of sensitivity to reinforcement is being measured correctly. If sensitivity to reinforcement is being measured correctly and the differences observed are not due to idiosyncratic features, then it may be possible that a different underlying behavioral mechanism is at work in females versus males who present with ADHD symptomatology. This may further help to explain some of the other differences seen between genders with this disorder.

A second important finding is that the matching functions for both male subjects resulted in a higher asymptotic value (k) under MPH conditions indicating that their overall rates of behavior were elevated under these conditions as compared to placebo conditions. At least two interpretations are possible. First, the parameters may have reflected the simple rate-increasing effects of MPH (e.g., Heyman, 1992; Barkley, 1990; Rapport, DuPaul, & Smith, 1985). Second, the elevation may have reflected greater overall on-task behavior (e.g., Barkley, 1990; Barkley & Cunningham, 1979), which would further support research on the effectiveness of MPH to increase on-task behavior (for review see Barkley, 1990). The variance accounted for by the matching law was higher under the MPH conditions for both male subjects, suggesting that their behavior more closely tracked the changing rates

of reinforcement while taking MPH versus placebo. Contrary to our initial hypothesis, however, the values of r_o increased under MPH conditions as compared to placebo conditions. The original hypothesis proposed that under MPH conditions, children would become more sensitive to the changing rates of reinforcement, thus decreasing r_o values. Recall that according to matching theory, r_o represents the reinforcement needed to maintain half-maximal response rate. It also is conceptualized as a measure of extraneous reinforcement such that if the surrounding environment is reinforcing, r_o would need to be higher to maintain this response rate. The results indicate that, due to elevated r_o values under MPH conditions, these male subjects may have decreased in their sensitivity to reinforcement. The results may also be interpreted as a higher sensitivity to all extraneous reinforcement in the environment, thus increasing the estimated value of r_o while still tracking environmental contingencies closely. This may also be an observation of the interaction effects of dose, reinforcement rate, and surrounding contingencies (Heyman, 1992; Northup et al., 1999). Future research should examine if this pattern is consistent under MPH versus placebo conditions.

Regarding the third goal of the study, research has repeatedly demonstrated that certain medications may affect specific behaviors by altering the effects of controlling environmental variables and/or increasing sensitivity to particular kinds of stimuli (Branch, 1984). Many studies suggest interactive effects between MPH and immediate environmental conditions (e.g., Northup et al., 1997; Whalen, Henker, Collins, Finck, & Dotemoto, 1979; Wilkison, Kircher, McMahon & Sloan, 1995).

For example, Northup et al. (1999) showed that the behavioral effects of MPH were influenced by immediate environmental conditions for each participant. In addition, it was reported that the differences in behavior between MPH and placebo conditions suggest that MPH altered antecedent rather than consequent effects (Northup et al., 1999). In the present study, the experimenter was present throughout the sessions and may have acted as a discriminative stimulus (Michael, 1993). Thus, MPH may have altered this as an antecedent effect, rather than affecting the consequent effects (Northup et al., 1999).

In addition, our results are concordant with those reported by Northup et al. (1997) in suggesting that MPH alters the reinforcing value of different consequences, particularly edibles and activities. For example, while taking MPH, all subjects spent less tokens on edibles. These results have several implications concerning the use of salient reinforcers in behavioral interventions. First, it adds support to the idea that a stimulus known to function as a reinforcer may not do so in the same manner or degree while taking methylphenidate versus a placebo. Second, it demonstrates the importance of a professional's awareness concerning a child's medication status while performing various interventions that require the use of reinforcers. Research in this area represents advances toward an understanding of the behavioral mechanisms of action of MPH in applied settings.

This study represents an attempt to further explain the behavior seen in children diagnosed with ADHD by extending basic science principles to applied settings of human behavior (Martens et al., 1989; Martens et al., 1990; Kollins et al.,

1997). Specifically, the present research used VI schedules and matching theory to examine the underlying behavioral mechanisms at work in children diagnosed with ADHD while under different environmental contingencies, and after taking MPH versus a placebo. Results suggest that different behavioral mechanisms may be at work under MPH versus placebo conditions. This study also demonstrated that this difference was observed in boys and not girls. Future research should seek to clarify the observed gender differences as they are related to the behavioral mechanisms associated with ADHD symptomatology. It would also be beneficial to continue examining how MPH serves to alter the effectiveness of various contingencies and the underlying mechanism of sensitivity to reinforcement.

Beyond the above conclusions drawn from the present data, results also support further use of principles derived from basic research to more applied settings (e.g., Mace, 1994; Mace & Wacker, 1994). Basic science discoveries are continually shown to stimulate the development of behavioral technologies, as reciprocally, applied research findings promote examination of basic behavioral processes that may be underlying particular problems and/or symptoms. There is an increasing body of literature specifically using mathematical accounts of behavior, such as matching law, in applied settings with success (e.g., Kollins et al., 1997; Mace et al., 1988; Martens et al., 1990). There remains many questions as to how applicable basic research principles are to applied settings given the complex and dynamic nature of human behavior. However, the progress basic research has made in understanding

fundamental behavioral processes has been, and should continue to be the source of many applied research ideas and methodologies.

Appendix A

Background Addendum

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most commonly diagnosed behavior disorders among preadolescent children in the United States (Barkley, 1997) and questions regarding its etiology, symptom variation, and course have generated a vast literature. For over two decades, ADHD has been conceptualized as a disorder associated with deficits in three primary areas: sustained attention, impulsiveness, and hyperactivity (American Psychiatric Association [APA], 1980, 1987, 1994; *Diagnostic and Statistic Manual of Mental Disorders; III, III-R, IV*; Barkley, 1997; Douglas 1974). These core deficits result in a number of difficulties, such as poor school performance (e.g., Carlson & Bunner, 1993), poor peer and family relations (e.g., Barkley, 1997), anxiety and depression (e.g., Thompson, Riggs, Mikulich, & Crowley, 1996), aggression (e.g., Hinshaw, Zupan, Simmel, Nigg, & Melnick, 1997; Satterfield, Swanson, Schell, & Lee, 1994), and early substance experimentation and abuse (e.g., Schubiner, et al., 1995; Thompson et al., 1996). Many of these difficulties continue into adulthood and, therefore, generate further problems (e.g., Murphy, & Barkley, 1996; Wilens, Prince, Biederman, Spencer, & Frances, 1995).

In efforts to understand ADHD, researchers have attempted to explain the behavioral symptoms by various theoretical models. One attempt to establish a theoretical link among the symptoms seen in those diagnosed with ADHD was based on Gray's (1987) theory of anxiety. Gray (1987) described approach and avoidance behavior as a function of two hypothesized brain systems. The first system, the Behavioral Reward System (REW), is hypothesized to control the increases in

responding in the presence of stimuli that signal reward (hope) or non-punishment (relief). The second system, the Behavioral Inhibition System (BIS), is hypothesized to control the reduction or inhibition of responding in the presence of stimuli that signal punishment or non-reward. Gray (1987) has supported this theory by demonstrating that behaviors hypothesized to be controlled specifically by the BIS system can be modified in expected ways following pharmacological intervention. For example, some anti-anxiety drugs (such as alcohol) impair passive avoidance (or the withholding of responses under threat of punishment or nonreward) and increase resistance to extinction (or the cessation of ongoing behavior), both of which are believed to be mediated by the BIS. Gray (1987) goes on to propose a neurochemical (noradrenergic) and neuroanatomical (Septo-Hippocampal System) basis for the BIS based on drug and lesioning studies conducted with nonhumans.

Quay (1988,1997) has extended Gray's (1987) theory from anxiety to explain ADHD behavior as the result of an underactive BIS. In other words, children diagnosed with ADHD are consistently found to have difficulty in withholding inappropriate responses or inhibiting responding in general. This theory is supported by studies showing that ADHD children perform poorly on tasks that require inhibition of responding (Iaboni, Douglas, & Baker, 1995; Gordon, 1979; McClure & Gordon, 1984; Schachar, Tannock, Marriott, & Logan, 1995; Schachar, Tannock, & Logan, 1993; Tannock, Schachar, Carr, Chajczyk, & Logan, 1989; Tannock, Schachar, & Logan, 1995; Oosterlaan & Sergeant, 1998; Douglas, 1983, 1988; Firestone & Douglas, 1975; Parry & Douglas, 1983). For example, recent research

has used a go/no go discrimination task which requires subjects to learn by trial and error to respond to some stimuli and withhold responses to other stimuli (e.g., Iaboni et al., 1995). Results from these studies demonstrated that children diagnosed with ADHD show an excess of commission errors, or problems in withholding responses to incorrect stimuli (e.g., Iaboni et al., 1995; Shue & Douglas, 1992; Trommer, Hoeppner, Lorber & Armstrong, 1988). Research also indicates that ADHD children perform poorly on DRL (differential reinforcement for low-rate responding) tasks that require low rates of responding in order to earn reinforcement (Gordon, 1979; McClure & Gordon, 1984). Quay's theory is further supported by psychopharmacological research that suggests that agents altering noradrenaline function were the most efficacious in improving behavior in ADHD (e.g., methylphenidate; Quay, 1997). Such findings are consistent with Gray's initial hypothesis that BIS functioning is mediated by noradrenergic mechanisms.

Some researchers have specifically examined inhibitory control in children diagnosed with ADHD by using the stop-signal paradigm (e.g., Schachar & Logan, 1990; Schachar et al., 1995). This task is a well-established and theoretically derived method requiring rapid and accurate execution of an action (primary task; a forced-choice reaction task) along with occasional and unpredictable presentation of a stop signal (a tone) that instructs participants to withhold the motor response to the primary task. These researchers have repeatedly found that children diagnosed with ADHD had flatter inhibition functions and longer SSRTs (latency of the stopping process as the stop signal reaction time) than normal control children, indicating

deficient inhibitory control (Schachar & Logan, 1990; Schachar et al., 1995). Schachar et al. (1995) have extended this paradigm to include an additional requirement of an immediate, separate and overt response to the stop signal (secondary task, response re-engagement). Results have demonstrated that children diagnosed with ADHD have deficits not only in inhibitory control, but also in response re-engagement (Schachar et al., 1995; Oosterlaan & Sergeant, 1998).

This stop signal task has also been used to demonstrate further support for pharmacological interventions that alter behavioral symptoms of ADHD. Numerous studies have shown that the differences in inhibitory control seen between children diagnosed with ADHD and controls can be ameliorated by methylphenidate (van der Meere, Shalev, Borger & Gross-Tsur, 1995; Tannock et al., 1995; Tannock et al., 1989). For example, Tannock et al. (1989) found that MPH improved the efficiency of the central inhibitory mechanism (shown by steeper inhibition functions) and improved the primary task response process (shown by faster responding and fewer omissions and commissions errors).

Another body of research used an information-processing paradigm to isolate the cognitive deficit in those diagnosed with ADHD to the motor control stage rather than to an attentional or information-processing stage. For example, Sergeant & van der Meere (1988) found that children diagnosed with ADHD performing an information-processing task were less likely to alter their subsequent responding when they made an error than were non-diagnosed children. van der Meere & Sergeant (1988a) specifically investigated the distractibility of hyperactive children in

a focused attention task, defining distractibility as the failure to inhibit processing of irrelevant information. Results demonstrated that hyperactives and controls did not differ significantly in task efficiency in the distraction condition, indicating that hyperactives do not have a focused attention deficit (van der Meere & Sergeant, 1988a). It has been shown that the information-processing approach consisting of encoding, search, and decision stages have failed to differentiate between hyperactives and controls in controlled processing studies and may be better explained by output-related processes. (Sergeant & Scholten, 1983, 1985; van der Meere & Sergeant, 1987).

Barkley (1990, 1997) has also offered a comprehensive theoretical account suggesting that poor behavioral inhibition is the major impairment associated with ADHD. According to Barkley, behavioral inhibition does not directly cause the cessation of a response, but sets the occasion for stopping an ongoing response by providing the delay necessary for an executive decision to be made considering both the immediate and delayed consequences. Barkley proposes that this deficit in response inhibition leads to secondary impairments in four neuropsychological abilities, including working memory, self-regulation of affect/motivation/arousal, internalization of speech, and reconstituation. These executive functions are critical for self-regulation and goal-directed persistence but require an initial response inhibition to be effective and work to decrease motor activity. Barkley (1997) explains that the behavior of ADHD children is controlled more by the immediate context, whereas other children's behavior is more controlled by internally

represented information that enables a child to maximize future outcomes. Moreover, it is hypothesized that children with ADHD simply do not inhibit a behavioral response long enough to understand the consequences adequately. Barkley (1997) further claims that behavioral inhibition and its related executive functions are particularly required to maximize reinforcement under conditions where there is a delayed consequence, when a conflict is confronted between the immediate and delayed consequences of a response, or when one must generate a novel response to solve a problem. These conditions that require withholding of a response in the presence of stimuli signaling punishment or non-reward are the exact conditions under which ADHD children have the most trouble.

The theories presented are based primarily on cognitive and neuropsychological approaches to explaining behavior and have met with some criticism. For example, the difficulty of forming a precise definition of response inhibition creates measurement problems. Another criticism is that the concept of response inhibition is overinclusive (Haenlein & Caul, 1987). Moreover, the literature supporting this theory fails to identify specifically which responses and circumstances are inhibited in ADHD children. A closely related limitation suggests that the behavioral inhibition conceptualization of ADHD describes the behavior pattern of those diagnosed, but does not explain it (Haenlein & Caul, 1987).

Another approach to conceptualizing ADHD that relies less on the hypothetical construct of behavioral inhibition proposes that children diagnosed with ADHD do not respond to the consequences of their behavior in the same manner as

their non-diagnosed peers (Haenlein & Caul, 1987). Such theories predict that the behavior of ADHD children requires higher rates of reward than that of normal children to maintain comparable levels of behavior. This differential pattern of responding to consequences has been termed sensitivity to reinforcement and has been explicated in several ways by researchers. For example, Haenlein and Caul (1987) suggest that children diagnosed with ADHD typically need more of a reinforcer(s) to experience the same pleasure or reward that is experienced by normal children. Haenlein & Caul (1987) describe this characteristic as an elevated reward threshold. Thus, the behavior of ADHD children would not change as readily as non-diagnosed peers in the presence of changing rates of consequences. Some other theories dealing with sensitivity to reinforcement include the suggestion that there is an optimal level of arousal and that too much or too little arousal will lead to poor performance (Hebb, 1968; Zentall, & Zentall, 1983). Thus, normal children are able to cope with the increased arousal of rewards and limit their impulsive responses, whereas hyperactive children are unable to hold these responses. Douglas (Douglas & Peters, 1979; Parry & Douglas, 1983; Firestone & Douglas, 1975) proposes that children diagnosed with ADHD are oversensitive to rewards and are subject to elevated frustration associated with the nonappearance of anticipated rewards. She specifically suggests that reinforcement schedules that are not consistent, continuous and immediate serve to over-arouse and distract hyperactive children due to their tendency to seek immediate and concrete rewards.

In an attempt to gain a deeper understanding of a basic behavioral process underlying ADHD symptomatology, a number of researchers have attempted to measure this construct of sensitivity to reinforcement in children diagnosed with ADHD across various tasks and settings (e.g., Cunningham & Knights, 1978; Douglas & Parry, 1983; Haenlein & Caul, 1987; Parry & Douglas, 1983; Quay, 1997). However, results regarding the differential sensitivity to reinforcement of ADHD children are mixed. For example, in studies examining the behavior of ADHD children under continuous reinforcement (CRF) and partial reinforcement (PRF), some studies reported no differences in the performance of ADHD children and non-diagnosed peers (Cunningham & Knights, 1978; Pelham, Milich, & Walker, 1986), while other studies reported that ADHD children's performance was less accurate that normal peers (Douglas & Parry, 1983; Parry & Douglas, 1983). Specifically, Cunningham & Knights (1978) found both hyperactive and control children reached criterion faster under punishment versus reward conditions. For example, all children learned the task faster and showed greater resistance to extinction when marbles were taken away from them. Parry & Douglas (1983) reported no significant differences between hyperactives and controls under continuous reward, but significantly inferior performance from hyperactive children under two different partial reward conditions. Hyperactive children took longer to adapt to a partial reinforcement contingency than normals. The above discrepancies found in the research literature may be due to a variety of reasons such as the use of different response classes across studies. Studies have measured such diverse

responses as the completion of spelling tasks (Pelham et al., 1986), concept-formation tasks (Cunningham & Knights, 1978; Parry & Douglas, 1983) speed/strength of lever pulling (Douglas & Parry, 1994), arithmetic problems (Rapport, Tucker, DuPaul, Merlo, & Stoner, 1986), and motor coordination in response to auditory stimuli (Douglas & Parry, 1983; Firestone & Douglas, 1975). Other reasons for inconclusive results in studies may include the use of different experimental preparations, varying subject characteristics, and the use of different methods of measurement (e.g. Kollins, Lane, & Shapiro, 1997).

It is useful to understand the conceptualization of behavioral inhibition and describe how a child may behave with a deficit in this area. This review demonstrates that it is well established that there are differences in behavioral inhibition between children diagnosed with ADHD and normals. The current data also suggests that these deficits do not seem to stem from attentional processes (e.g., van der Meere & Sergeant, 1988a). Thus, in order to seek explanations of the underlying behavioral mechanisms of ADHD symptomatology, instead of mere descriptions, it seems apparent to focus on the way surrounding contingencies affect the behavior of ADHD children. Research on the construct of sensitivity to reinforcement has demonstrated that the behavior of children diagnosed with ADHD does not track changing contingencies in the same way as the behavior of normal children. Future research examining sensitivity to reinforcement may help to explain this behavior difference better in terms of underlying behavioral mechanisms. Additional research on sensitivity to reinforcement could also be helpful in connecting a theoretical

understanding of ADHD symptomatology to further comprehension of how to reduce these symptoms via interventions such as medication or behavioral therapy.

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Appendix B

Reinforcement Assessment Survey

APPENDIX I.

REINFORCEMENT ASSESSMENT SURVEY

Boys and girls like to get food things. I am going to name things that kids sometimes get in school. I want to know how much you like each of these things. After I name each thing, you tell me if you like it "not at all", "a little", or "a lot". For example, if I say, "going to the supermarket", you mighty say you like it "not at all", but if I say, "going to your favorite movie", you might say you like it "a lot".

(Note: This should be read to participant. Read the whole sentence and offer the 3 alternatives each time.)

Do you like.....	Not at all 1	A little 2	A lot 3
1. Gum	1	2	3
If scores a 3, ask "What kind?" _____			
2. Help a friend with school work	1	2	3
3. Art projects			
4. Certificates, rewards			
5. Your teacher to say "Good job, I like that"			
6. To get out of math			
7. Snack cakes (Ding-Dongs, Twinkies, Granola Bars			
If scores a 3, ask "What kind?" _____			
8. To spend time with a friend at school			
9. To help the teacher			
10. Stickers, stars			
11. Your teacher to say "You're really paying attention"			
12. To put your feet up and relax			
13. Juice, drinks			
If scores a 3, ask "What kind?" _____			
14. A friend to say "Good job, I like that:			
15. To run/jump/dance			
16. Pencils or pens			
17. Your teacher to say "That's right, that's correct"			
18. To get out of or leave the classroom			
19. Pretzels, chips			
If scores a 3, ask "What kind?" _____			
20. A friend to pat you on the back, give you a hug			
21. To read a story or do fun sheets			
22. Markers/highlighters			
23. Your teacher to say "I'm going to let your parents know you're doing a great job"			
24. To get out of reading			
25. Cookies			
If scores a 3, ask "What kind?" _____			
26. To play a game with a friend			
27. To play a computer game/Nintendo			
28. POGS/baseball cards			
29. Your teacher to pat you on the back/hug you			
30. To get out of your seat			
31. Popcorn (Cracker Jack, Crunch-n-Munch)			
If scores a 3, ask "What kind?" _____			
32. To talk with a friend at school			
33. Free time in the library			
34. File folders, pocket folders			
35. Free time with your favorite teacher or aide			
36. To get out of snack time			
37. Candy (Jawbreakers, Snickers, Reese's Peanut Butter Cups)			
If scores a 3, ask "What kind?" _____			
38. A friend to say "You're really doing a good job"			

39. Play with toys (legos, dinosaurs, cars)
40. Erasers
41. Your teacher to help you with your work
42. To get out of recess

Which of all of these is your favorite? _____

Is there something else you would like? _____

How much do you like this? Not at all A little A lot

SCORING

Edibles (Sum items 1, 7, 13, 19, 25, 31, 37) ÷ 21 x 100 = %

Peers (Sum items 2, 8, 14, 20, 26, 32, 38) ÷ 21 x 100 = %

Activities (Sum items 3, 9, 15, 21, 27, 33, 39) ÷ 21 x 100 = %

Tangibles (Sum items 4, 10, 16, 22, 28, 34, 40) ÷ 21 x 100 = %

Teacher Attention (Sum items 5, 11, 17, 23, 29, 35, 41) ÷ 21 x 100 = %

Escape (Sum items 6, 12, 18, 24, 30, 36, 42) ÷ 21 x 100 = %

PARENT

Ask parent to give two examples of each category his or her child might like and score 1, 2, or 3.

Edibles _____
Peers _____
Activities _____
Tangibles _____
Teacher Attention _____
Escape _____

Appendix C

Research Protocol Approval

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3899

WESTERN MICHIGAN UNIVERSITY

Date: 18 June 1998

To: Scott Kollins, Principal Investigator
Laura Sauer, Student Investigator

From: Richard Wright, Chair Richard A. Wright

Re: HSIRB Project Number 98-05-07

This letter will serve as confirmation that your research project entitled "Effects of Methylphenidate on the Sensitivity to Reinforcement in Children Diagnosed with Attention Deficit Hyperactivity Disorder: An Application of Matching Law" has been **approved** under the **full** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

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

Approval Termination: 18 June 1999

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3899

WESTERN MICHIGAN UNIVERSITY

Date: 15 September 1998

To: Scott Kollins, Principal Investigator
Laura Sauer, Student Investigator for thesis

From: Sylvia Culp, Chair Sylvia Culp

Re: Changes to HSIRB Project Number 98-05-07

This letter will serve as confirmation that the changes to your research project "Effects of Methylphenidate on the Sensitivity to Reinforcement in Children Diagnosed with Attention Deficit Hyperactivity Disorder: An Application of Matching Law" requested in your memo dated 11 September 1998 have been approved by the Human Subjects Institutional Review Board.

The conditions and the duration of this approval are specified in the Policies of Western Michigan University. *As an additional condition of this approval, sessions are to be scheduled only on weekends or evenings that do not precede a school day.*

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

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

Approval Termination:

College of Arts and Sciences
Department of Psychology

Kalamazoo, Michigan 49008-5052
616 387-8300

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WESTERN MICHIGAN UNIVERSITY

WESTERN MICHIGAN UNIVERSITY
H. S. I. R. B.
Approved for use for one year from this date:
JUN 1 8 1998
x Richard A. Wright
HSIRB Chair

CONSENT FORM

Effects of methylphenidate on the sensitivity to reinforcement in children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD): An application of matching law.

Parent Form

Principal Investigator: Scott H. Kollins, Ph.D.
Research Associate: Laura K. Sauer, B.S.

Laboratory for Child and Adolescent Behavioral Studies
Department of Psychology
Western Michigan University

You and your child have been invited to participate in a research project, conducted through the Laboratory for Child and Adolescent Behavioral Studies. The purpose of this study is to learn more about how children diagnosed with ADHD respond to different amounts of rewards and what effect methylphenidate (Ritalin) has on their behavior. Your child was selected as a possible participant because of his/her age and established diagnosis of ADHD.

Your consent for your child to participate in this study means that the researchers will ask your child, yourself, and another significant adult to complete several questionnaires regarding his/her behavior. Once this information is obtained, your child and you may be asked to continue participation. Your child's physician will be contacted to agree that this study is in your child's best interest. Your child's physician will be asked to prescribe pills with their normal Ritalin dosage and placebos, that look identical but contain no active medication. A local pharmacist from the Sindecuse Health Center will fill all prescriptions needed. The researchers will pay for these prescriptions and will let you know when you may pick them up from the Sindecuse Health Center. Participation in this study will consist of twelve sessions on different days lasting approximately two hours each. The phases of this study and the activities in which yourself and your child will be asked to participate in are described in the following timeline.

Second Screening Session: During this phase, you are required to bring your child to Western Michigan University's lab without receiving his/her normal dosage of Ritalin. Your child will complete a reward survey and perform some trials on sample math worksheets to be sure the problems are easy for him/her. These tasks will each be separated with a ten-minute break. During this time, you will be in an adjacent room completing various questionnaires.

Phase I: During this phase, you will be required to bring your child to the lab on two different occasions with him/her receiving no pills/medication. During these sessions, your child will complete math problems to earn tokens for approximately ten minutes at a time. Each ten-minute work session will be followed by a ten-minute break when he/she can cash in their tokens for rewards. There will be a total of four work sessions, each session.

Phase II. During this phase, you will be required to bring your child to the lab on eight different occasions. Prior to each session, a researcher will telephone at a particular predetermined time to remind you which pill to give to your child. You will arrive at the LCABS 45 minutes after administering a pill to your child. Your child will then complete math problems to earn tokens for 10 minutes and then be given a 10 minute break when they can "cash in" their tokens for rewards. Again, each day will consist of four work sessions.

Potential Benefits of Participating in this study: Your child will have an opportunity to earn rewards each session for completing math problems. These rewards will all be given prior approval by each individual's parents and may include such things as edible items, toys, and time on Nintendo. In addition, after completion of all twelve sessions, you will have the option to participate in one of two services offered through the Western Michigan University Psychology training clinic. The two opportunities include 4-6 sessions of parent management training or 4-6 sessions of social skills training for your child. These services are provided by doctoral students in Western Michigan University's clinical psychology training program. In addition to the daily rewards and service compensation for your child's participation, several other benefits are available. First, the procedure used in this study allows us to determine how children diagnosed with ADHD perform on school work while gaining different amounts of rewards. It also examines what effect Ritalin has on this performance. This relays valuable information about how your child performs academically while free of medication and with his/her normal dosage of Ritalin. Such information could be very important in helping us understand more about the nature ADHD and how to more effectively manage it. If you wish, you may also be provided with an interpretation of your child's behavior patterns while on Ritalin versus free of medication. We will be available to answer any questions you may have about this information. Should you and your child discontinue participation at any time, rewards earned to that point may be retained. The clinical services may only be collected if the study is completed.

Risks of Participation in this study: There are minimal risks to your child in this study. He/She may experience some behavioral difficulties and/or frustrations on those days that he/she does not receive their normal dosage of Ritalin. He/She may also experience some frustration from the nature of the task. The task is designed to change the rate at which your child earns rewards with the completion of math problems. However, it is not expected that this frustration would exceed that experienced throughout the course of a normal day.

As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or additional treatment will be made available to the subject except as otherwise stated in this consent form.

Confidentiality of Data: Any information obtained in connection with this study that can be identified with yourself or your child will remain confidential. If the information from his/her data becomes part of a publication in a professional journal or a conference presentation, it will be anonymous so as to ensure the confidentiality of you and your child.

Your decision whether or not to participate will not jeopardize your future relations with Western Michigan University. Furthermore, you may discontinue participation at any time without penalty. If you decide to withdraw from the study, you may also withdraw any information which has been collected on your child. Your child may withdraw or refuse to participate in this study at any time.

We invite you to ask any questions you may have. If you have additional questions later, Laura Sauer (387-4497) or Dr. Kollins (387-4482) will be happy to answer them. You may also contact the Chair, Human Subjects Institutional Review Board (387-8293) or the Vice President for Research (387-8298) if questions or problems arise during the course of the study. You will be given a copy of this form to keep.

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE. YOUR SIGNATURE INDICATES THAT YOU HAVE DECIDED TO PARTICIPATE HAVING READ THE INFORMATION PROVIDED ABOVE.

_____

Date Time

_____

Signature of Parent/Guardian

_____

Signature of Investigator

College of Arts and Sciences
Department of Psychology

Kalamazoo, Michigan 49008-5052
616 387-8300

WESTERN MICHIGAN UNIVERSITY

ASSENT FORM

Effects of methylphenidate on the sensitivity to reinforcement in children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD): An application of Matching Law

Participant Form

Principal Investigator: Scott H. Kollins, Ph.D.
Research Associate: Laura K. Sauer, B.S.

Laboratory for Child and Adolescent Behavioral Studies
Department of Psychology
Western Michigan University

You have been invited to participate in a research project to learn more about how kids with ADHD act when they get different amounts of rewards. We are also looking at how Ritalin effects the behavior of kids with ADHD. You were chosen to be in this study because you have been diagnosed with ADHD and take Ritalin.

If you agree to be in this study, you will come to Western Michigan University on different days to work with some people. First, you will be marking off what you like best for rewards. Then, you will be doing some math problems to earn tokens. You will have to work on math problems for a while and then you get a break when you can "cash in" your tokens you earned for different rewards that you said you liked.

This study will not hurt you, and it may teach you and your parents more about your behavior in school. Also, any information about you will be kept away from other people not helping with the study so no one will know that you were in the study. If you start this project and later decide that you want to drop out of the study, you can do so without getting into trouble.

If you have any questions about the study, you can talk to your parents and call Laura Sauer at 387-4497 or Scott Kollins at 387-4482.

Due to the requirement that participants are verbal, non-assent will be determined by the child verbally saying "no".

PHYSICIAN AGREEMENT TO PARTICIPATE

TO: Scott H. Kollins, Ph.D. & Laura K. Sauer, B.S.

FROM:

RE: Consent to Participate

I, _____, agree to participate in the study entitled "Effects of methylphenidate on the sensitivity to reinforcement in children diagnosed with attention deficit hyperactivity disorder (ADHD): An application of matching law." The study design has been described to me and I agree to provide a prescription of Ritalin and placebo pills that are identical in appearance. I understand that a local pharmacist will fill all prescriptions for the study. I further understand that I will assist in monitoring any side effects that may occur when the child receives or does not receive his/her normal dosage of Ritalin. I will also provide information to parents and children regarding potential side effects. I agree to immediately discontinue (name)_____'s participation if he/she appears to be experiencing any significant adverse medical problems during the course of the study, whether or not those problems are related in any way to the study itself.

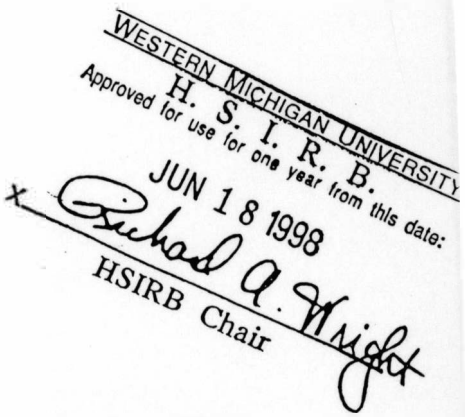
_____ _____

Physician Name *Date*

_____ _____

Experimenter *Date*

PARENT CONSENT TO PHYSICIAN
(Copy to be given to physician)



TO:

FROM:

RE: Consent to Participate

I, _____, have agreed to participate in the study entitled "Effects of methylphenidate on the sensitivity to reinforcement in children diagnosed with attention deficit hyperactivity disorder: An application of matching law." As such I agree for my child's physician, _____, to prescribe his/her normal dosage of Ritalin and placebo pills that are identical in appearance. I understand that my child's physician will be consulted regularly throughout the study and will make any relevant medical recommendations, including discontinuation from the study, as a result of side effects from medication or other medical complications that may arise.

_____ _____
Parent Name *Date*

_____ _____
Experimenter *Date*

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