JOURNAL OF APPLIED BEHAVIOR ANALYSIS 2005, **38,** 135–146 NUMBER 2 (SUMMER 2005)

EVALUATION OF PHARMACOLOGICAL TREATMENT OF IMPULSIVITY IN CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER

NANCY A. NEEF, DAVID F. BICARD, SAYAKA ENDO,
DANIEL L. COURY, AND MICHAEL G. AMAN

THE OHIO STATE UNIVERSITY

We used an assessment that involved competing reinforcer dimensions in a concurrent-schedules arrangement to examine the effects of stimulant medication on impulsivity (i.e., sensitivity of choices to reinforcer immediacy relative to rate, quality, and effort) with 4 students with attention deficit hyperactivity disorder. The assessments were administered in the context of a double-blind, placebo-controlled, counterbalanced reversal design. Reinforcer immediacy was the most influential dimension for 3 of the students and the second most influential dimension for 1 of the students across placebo and medication conditions; medication did not affect these sensitivities.

DESCRIPTORS: attention deficit hyperactivity disorder, self-control, impulsivity, methylphenidate, behavioral pharmacology, concurrent schedules

---

Attention deficit hyperactivity disorder (ADHD) is estimated to affect 3% to 7% of children in the United States, and is one of the most prevalent disorders in the school-aged population (American Psychiatric Association, 2000; Barkley, 1998; Julien, 1995). Although there is no commonly accepted objective method for diagnosing ADHD, Barkley (1997) posits that the disorder is fundamentally a problem of self-control or impaired behavioral inhibition, which manifests "when a delay of a consequence is imposed in a task, when a conflict is confronted between the immediate and delayed consequences of a response" (p. 68). Behaviors (choices) that are more sensitive to (influenced by) immediate than remote consequences suggest temporal discounting, in which the value of a desired consequence diminishes as a function of the delay to that consequence (see Critchfield & Kollins, 2001, for a review). To the extent that children with ADHD discount the value of delayed rewards, treatments that attenuate the characteristics of the disorder might be predicted to have effects on temporal discounting patterns (i.e., reduce these children's sensitivity to delay). Few studies, however, have explicitly examined those relations in children with ADHD (Critchfield & Kollins).

The most common treatment for ADHD is stimulant medication (Barkley, 1998; Purdie, Hattie, & Carroll, 2002). Concurrent with the progressive increase in diagnosis of ADHD, the prescription of stimulant medications for treatment of ADHD has grown dramatically in recent years. Approximately 1.5 million children (2.5% of the school-aged population) are treated with these medications annually (Pincus et al., 1998; Purdie et al.; Safer, Zito, & Fine, 1996), and concerns have been expressed about their use, misuse, or overuse (National Institutes of Health, 1998). The issue remains controversial. Given reports in the research literature that stimulant medication improves impulse control of children with ADHD, some authorities have argued that stimulant medication should be the

This research was supported by a field-initiated research grant (H324C99083) from the U.S. Department of Education, Office of Special Education Programs, and by a grant from the Ohio State University. We gratefully acknowledge the assistance of Marijo Martin with the pharmacological preparations.

Address correspondence to Nancy A. Neef, PAES, College of Education, The Ohio State University, 1945 N. High St., 367 Arps Hall, Columbus, Ohio 43210 (e-mail: neef.2@osu.edu).

doi: 10.1901/jaba.2005.116-02

predominant (if not the sole) treatment for these individuals (Barkley, 1997; The MTA Cooperative Group, 1999). However, research on treatment efficacy has relied principally on indirect informant measures such as behavior rating scales that are limited in a number of respects (see Atkins & Pelham, 1991; Gulley & Northup, 1997; Kollins, Ehrhardt, & Poling, 2000; Stoner, Carey, Ikeda, & Shinn, 1994), particularly with respect to their sensitivity and utility for treatment development and monitoring (Angello et al., 2003). This might have contributed to the large individual differences that have been reported on the effects of pharmacological treatments across children, dosages, behaviors, and environmental contexts (Northup, Gulley, Edwards, & Fountain, 2001; Pelham, Bender, Caddell, Booth, & Moorer, 1985; Rapport, Stoner, DuPaul, Birmingham, & Tucker, 1985; Stoner et al.).

Reliance on medication for the treatment of problems associated with core symptoms of ADHD may have emerged, in part, from a research focus on outcome (treatment efficacy) rather than operation (how treatments act to produce observed outcomes) with this population (for a few elegant exceptions involving methylphenidate, see Northup et al., 1999, who examined interactions with common classroom contingencies, and Murray & Kollins, 2000, who used a matching law analysis).

Understanding the way a drug affects behavior depends on identifying how the environmental variables that typically regulate behavior (e.g., reinforcement processes) interact with or are altered as a result of drug administration (Branch, 1991; Thompson, 1984; Witkin & Katz, 1990). There is evidence that some medications can affect specific behaviors by increasing their sensitivity or responsiveness to certain environmental stimuli (Branch, 1984; Poling, 1986). For example, basic research in behavioral pharmacology has suggested that methylphenidate increases choices considered to demonstrate self-control (Schroeder, Mann-Koepke, Gualtier, Eckerman, & Breese, 1987).

Assessments that directly and objectively measure behaviors related to a diagnosis of ADHD may allow more precise determination of how these children's behaviors are or are not altered by stimulant medications (Atkins & Pelham, 1991; Broussard & Northup, 1995; Purdie et al., 2002). In behavioral research, self-control and its converse, impulsivity, have been examined in a concurrent-schedules paradigm, which emphasizes the contextual nature of the constructs as depending on the size, quality, and delay of outcomes for competing response alternatives. These constructs are operationally defined as choices between concurrently available response alternatives that produce either delayed reinforcers with relatively high yields (self-control) or immediate reinforcers with smaller yields (impulsivity) (e.g., Neef, Bicard, & Endo, 2001; Neef, Mace, & Shade, 1993; Rachlin, 1974).

Neef et al. (2005) employed these definitions in a brief computer-based assessment of impulsivity and self-control with 58 children. The assessment involved choices between concurrently presented arithmetic problems associated with competing reinforcer dimensions (reinforcer immediacy, rate, quality, and response effort). Results were compared for children with ADHD who were and were not receiving medication and with typically developing children without a diagnosis of ADHD. Impulsivity, when defined as choices between concurrently available response alternatives that produce more immediate but fewer reinforcers, characterized the responding of most of the participants with a diagnosis of ADHD, whether or not they were receiving medication. The choices of children in the non-ADHD group, on the other hand, were influenced principally by reinforcer quality, and the influence of immediacy relative to the other dimensions was not statistically significant. Although the results supported Barkley's (1997) conceptualization of

ADHD as a disorder that is characterized by difficulties with self-control, the finding that reinforcer immediacy was an influential dimension for ADHD participants in both the medication and no-medication groups suggests that medication may have little effect on functionally defined objective measures of impulsivity.

In the current investigation, we extended the Neef et al. (2005) study by conducting a within-subject analysis of the effects of stimulant medication on functionally defined measures of impulsivity with 4 students who had been diagnosed with ADHD. Specifically, we replicated the assessments in the context of a double-blind, placebo-controlled, counter-balanced reversal design to determine (a) the extent to which choices between competing response alternatives were differentially sensitive to immediacy of reinforcement relative to other reinforcer dimensions (demonstrating impulsivity vs. self-control) and (b) the effects of methylphenidate on sensitivity to those dimensions.

METHOD

Participants and Setting

Four children who met the diagnostic criteria for the hyperactive-impulsive subtype of ADHD (American Psychiatric Association, 2000) had been referred by their physicians for participation. Rita was an 11-year-old girl who had been receiving 10 mg of immediate-release methylphenidate twice per day and 5 mg once per day. Al was a 13-year-old boy who had been receiving 20 mg of immediate-release methylphenidate twice per day. Lynn was a 10-year-old girl who had been receiving 10 mg of dextroamphetamine twice per day. Rex was an 8-year-old boy who had been receiving 7.5 mg of immediate-release methylphenidate once per day.

At the request of the children's parents, the study was conducted in the children's homes during the summer months so that any undesirable effects on behavior associated with the withdrawal of medication would not affect the children's performance in school. One or two sessions per day were conducted in a quiet area with only the experimenter and child present.

Assessment

Apparatus. The experimental task was conducted on a laptop computer using a software program similar to one described by Neef et al. (2005). The program provided a menu from which the experimenter selected the specifications for each of two sets of mathematics problems. The specifications consisted of the type (addition, subtraction, multiplication, or division) and level of mathematics problems, the schedules of reinforcement (variable-interval [VI] 30 s, VI 60 s, or VI 90 s), back-up reinforcer delivery schedules (e.g., "today" or "tomorrow"), and back-up reinforcer repositories (Store A and Store B). The computer program was equipped to record (for each problem set) the number of points obtained, the number of problems attempted, the number of problems completed accurately and inaccurately, and the cumulative time spent on each problem set.

Task. The experimental arrangements for the assessment were the same as those described for the initial assessment in Neef et al. (2001, 2005) and Neef and Lutz (2001a, 2001b). During each trial, two different-colored mathematics problems (one from each of two sets) appeared on the monitor (choice screen). The choice screen also displayed under each problem the cumulative number of reinforcers (points) obtained from that problem set, the store from which items could be purchased with the points earned (reinforcer quality), and when those items could be obtained (reinforcer delay). The response effort required for problem completion was evident from the problems displayed. The child selected either the Set 1 or Set 2 mathematics problem using a mouse pointer.

The problem selected by the child was then displayed on the problem screen along with a small clock that showed how much time was left to complete the problem. The problem remained on the screen until the child entered the correct answer from the keyboard, 30 s elapsed with no response, or the child reset the problems, after which the choice screen appeared with two new problems. Following an incorrect response, the words "try again" appeared on the screen, the computer presented the same problem, and the 30-s interval was reset. Different auditory stimuli signaled reinforcer delivery for Set 1 versus Set 2 problems according to the schedule in effect for the problem set. Problems continued to be presented in this manner for the duration of each 10-min session. A sample trial sequence is illustrated in Figure 1. To facilitate discrimination of the schedules of reinforcement associated with the response alternatives, experimental sessions were preceded by a 5-min practice during which the child was required to sample the response alternatives and rates of point delivery for problem completion.

Assessment sequence and conditions. A baseline (data not shown) was first conducted in which each pair of math problems differed on only one dimension—rate (R) quality (Q), immediacy (I), or effort (E)—per session. The purpose of this condition was to ensure that the child discriminated the favorable levels of each dimension; this was a condition of continued participation. For example, to determine whether the child discriminated different rates of reinforcement, a VI 30-s schedule was programmed for Set 1 problems and a VI 90-s schedule was programmed for Set 2 problems, while quality, effort, and immediacy were equal for both problem sets. Responding that favored response options associated with the VI 30-s schedule confirmed sensitivity to the favorable level of the rate dimension.

Baseline was followed by an assessment comprised of six conditions (one session per condition), conducted in random order. During each condition, one of the dimensions (R, Q, I, or E) was placed in direct competition with another dimension (the assignment of dimensions to Set 1 or Set 2 problems varied). For example, in the effort versus immediacy (EvI) condition, completion of high-effort problems produced points that could be exchanged for prizes at the conclusion of the session, whereas prizes from points earned for completion of low-effort problems were presented the next day; reinforcer quality (items for which earned points could be exchanged) and rate (VI schedule of point delivery) remained constant across the two problem options. Across the six assessment conditions, all possible pairs of dimensions were presented (RvI, EvI, IvQ, RvQ, RvE, QvE). The conditions are depicted in Figure 2. The RvI, IvE, and IvQ conditions provided an assessment of impulsivity.

Rate refers to the concurrent schedules of reinforcement in effect for the each set of problems. A VI 30-s schedule was used for the high value, a VI 60-s schedule was used for the medium value, and a VI 90-s schedule was used for the low value. The high and low values were used for the respective sets of problems when rate was a competing dimension (RvQ, RvE, and RvI), and the medium value was used during the remaining conditions when rate was held constant across problem sets.

Quality refers to the child's relative preference for the reinforcers associated with the two respective problem sets, based on his or her ranking of available reinforcers during a preference assessment that preceded each session. Available rewards included a wide variety of tangible items (e.g., small toys, snacks, shoelaces, batteries, etc.), coupons for time to engage in a preferred activity (e.g., playing computer games alone), and extra attention (e.g., playing a game with the experimenter, a certificate of task performance designed to evoke praise). During the preference assessment, 10 items were displayed, and the child was asked to

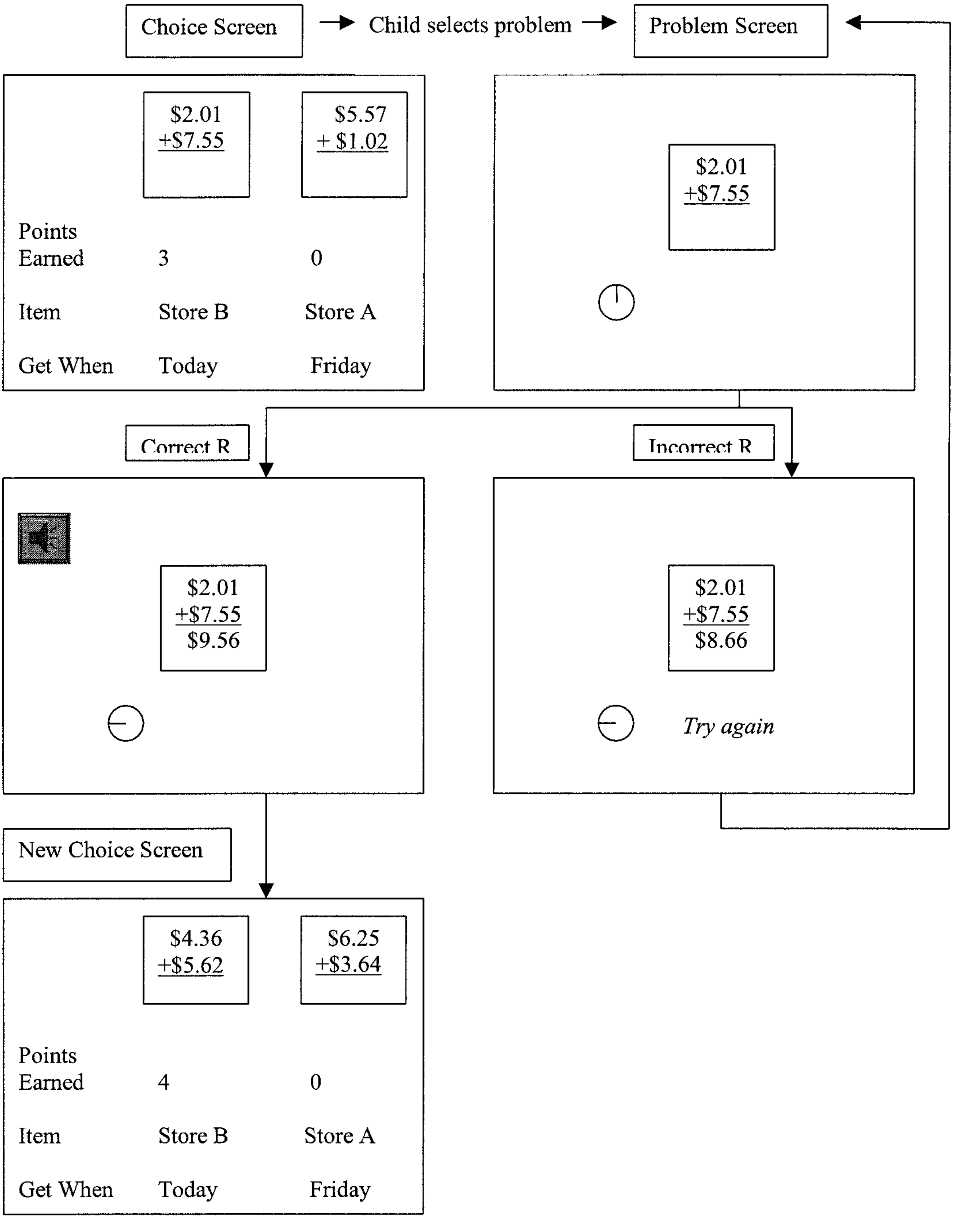

Figure 1. Illustration of a trial sequence.

select the item he or she most wanted to earn that day. That item was then set aside, and the process was repeated for the next nine items. The first to fifth favorite items served as the high-quality reinforcers (Store A). The remaining five items served as the low-quality reinforcers (Store B). When reinforcer quality was not a competing dimension, Stores A and B

Conditions / Dimensions	R v I	E v I	I v Q	R v Q	R v E	Q v E
	Problem Set 1 Set 2	Problem Set 1 Set 2	Problem Set 1 Set 2	Problem Set 1 Set 2	Problem Set 1 Set 2	Problem Set 1 Set 2
Rate of Reinf (R)	*High Low*	Med. Med.	Med. Med.	*High Low*	*High Low*	Med. Med.
Quality of Reinf (Q)	High High	High High	*Low High*	*Low High*	High High	*High Low*
Immediacy of Reinf Access (I)	*Delay Imm.*	*Delay Imm.*	*Imm. Delay*	Imm. Imm.	Imm. Imm.	Imm. Imm.
Response Effort (E)	Med. Med.	*Low High*	Med. Med.	Med. Med.	*High Low*	*High Low*

Figure 2. Response alternatives for each of the assessment conditions.

contained identical sets of five preferred items. During each session, points earned on the respective response alternatives could be used to purchase any items from the designated store. Items were placed in the labeled stores, visible to the student, before each session. Items were identically priced such that one to three items could typically be purchased during a session.

Immediacy refers to whether access to reinforcers earned for the respective set of problems was immediate (at the end of the session) or delayed (immediately preceding the next day's session). If the child earned enough points for the delayed reinforcer, he or she was given a receipt for delayed delivery of the reward.

Effort refers to the relative ease with which arithmetic problems from the respective sets could be completed, as determined by the child's pretest performance (rate and accuracy) on samples of different types of problems (see Neef & Lutz, 2001a, for a description). Easy (fluency level) and difficult (acquisition level) problems were used for the respective sets in which effort was a competing dimension. Medium-level problems were used in conditions in which effort was held constant across the two problem sets.

Dependent Measures

The child's allocation of time to problems associated with competing dimensions allowed determination of the relative influence of each of those dimensions during each administration of the assessment. Data were analyzed for both time allocation (because the VI schedules of reinforcement were based on time allocation) and response allocation (because time allocation might have been affected by more difficult problems that took more time to complete when effort was a competing dimension). A dimension was judged to be most influential if the student allocated the majority of time (responses) to the problem set with the favorable level of that dimension across the three conditions when it competed with any other dimension. For example, if the student allocated the most time (responses) to the alternative associated with immediate reinforcement in the RvI, EvI, and IvQ conditions, immediacy was judged to be the most influential dimension. A dimension was judged to be the second most influential dimension if the student allocated the majority of time (responses) to the problem set with the favorable level of that dimension across all conditions except when it

competed with the most influential dimension. The least influential dimension was determined by allocation of the least amount of time (responses) to the problems associated with that dimension regardless of the competing dimension.

Experimental Design

The assessment was administered four times (to Al, Lynn, and Rex) or two times (to Rita) in the context of a double-blind, placebo-controlled, counterbalanced reversal design (i.e., ABAB or BABA in which A = medication and B = placebo). (Rita received only the first two phases because she moved following a change in custody.) Because the children's physicians had determined that the children's current medications and dosages were therapeutic, these were used during the medication phases of the study. The pharmacist prepared the placebo and medication in identical gelatin capsules with a 1-week supply for each of the four phases. Because of the short half-life of methylphenidate, sessions were conducted within 1 to 3 hr of medication administration when medication effects were predicted to peak. Before each session, the experimenter checked the number of capsules in the prescription bottle for that week and the parent's log of the times the capsules had been given to the child. This information indicated that, for all sessions, the capsules had been given as prescribed.

RESULTS

Figure 3 shows the percentage of time allocation to problems with competing dimensions for assessments conducted across medication and placebo phases for each of the participants. Rita's time allocation (top panel) was most sensitive to reinforcer immediacy, followed by quality, rate, and effort. Specifically, during the first three conditions of the assessments in both medication and placebo phases, Rita allocated more time to the problem alternatives that produced immediate access to reinforcers, even though that alternative resulted in a lower rate of reinforcement (RvI), more difficult problems (EvI), and lower quality of reinforcement (IvQ). When reinforcer immediacy was held constant across the problem alternatives in the last three conditions of each of the assessments (i.e., when it was not a competing dimension), she allocated the majority of time to the response alternatives that produced higher quality (more preferred) reinforcers (striped bars in the RvQ and QvE conditions). She consistently allocated the least time to the low-effort problems when high-effort problems resulted in more immediate, higher quality, or a higher rate of reinforcement.

Al (second panel) demonstrated a similar pattern. His choices were most influenced by reinforcer immediacy, followed by quality, rate, and effort across both placebo and medication phases (although the influence of rate and quality were more similar in the first assessment with placebo than in subsequent replications).

Although reinforcer immediacy also was an influential dimension for Lynn (third panel), her choices were usually more sensitive to reinforcer quality across medication and placebo assessments. She allocated the majority of her time to the response alternative associated with high-quality reinforcers, even though the problems associated with preferred reinforcers required more effort (QvE), produced a lower rate of reinforcement (RvQ), and delayed receipt of the reinforcers (IvQ) relative to the response alternative associated with less preferred reinforcers. (In the first placebo assessment, however, reinforcer immediacy and quality appeared to be equally influential.) When quality was held constant across the response alternatives, Lynn's choices favored the response associated with immediate reinforcement relative to a higher rate of reinforcement (RvI) and easier problems (EvI). Rate of reinforcement was an influential dimension only when it competed with response effort, which least affected her choices.

As with Rita and Al, Rex's choices (bottom panel) consistently favored the alternatives that

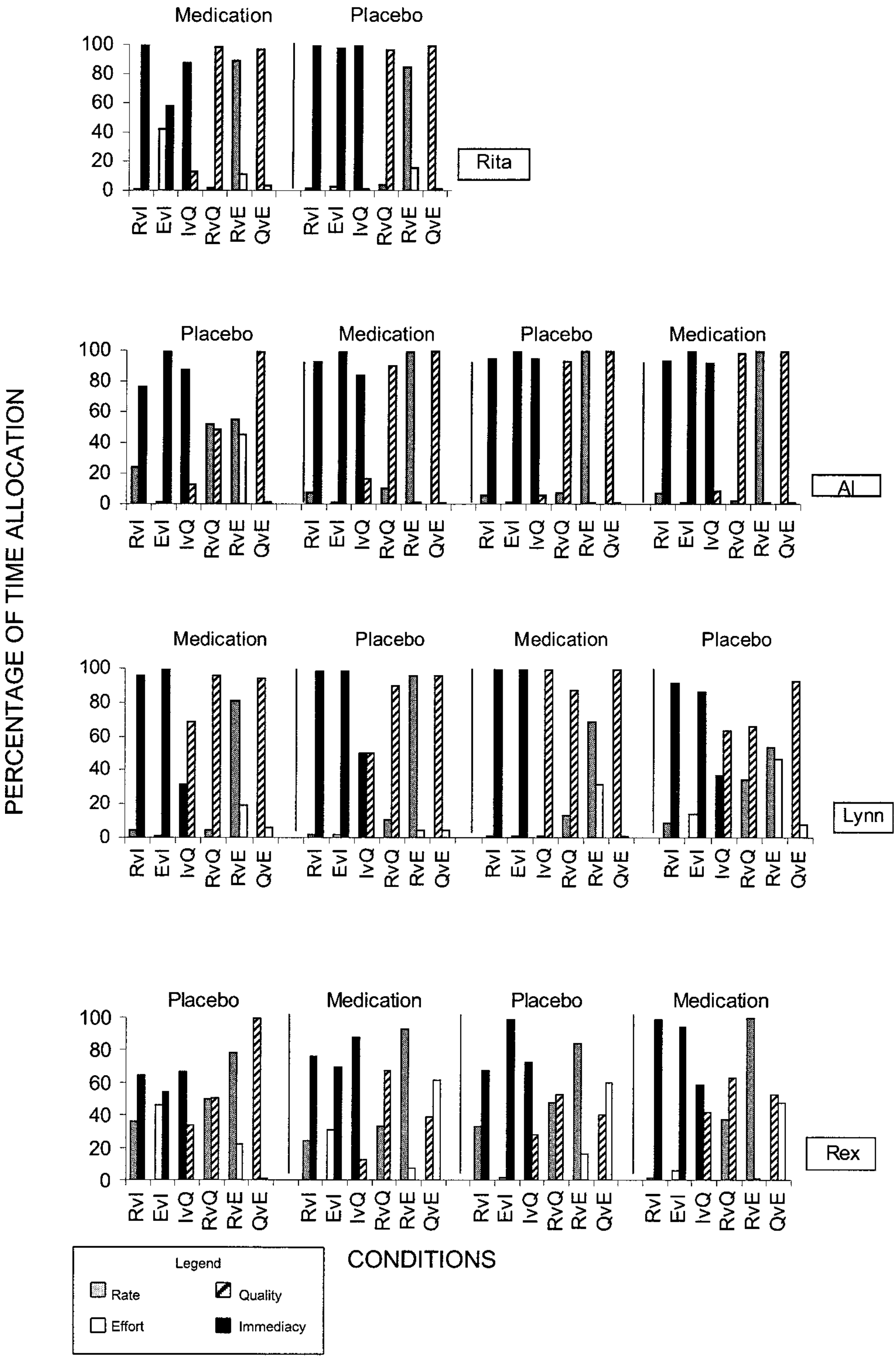

Figure 3. The percentage of time allocation to problems associated with competing reinforcer dimensions across assessment conditions during medication and placebo phases for Rita, Al, Lynn, and Rex.

produced immediate reinforcement. However, the influence of rate and effort differed when they competed with quality, and reinforcer immediacy was not a competing dimension. This may be because the higher quality reinforcers available were more preferred during some sessions than others. In the RvE condition (i.e., when both quality and immediacy were held constant), Rex allocated the majority of his time to the response alternative associated with the higher rate of reinforcement.

With the exception of Rex, the influence of each of the reinforcer dimensions was consistent across all medication and placebo phases (and the difference for Rex did not appear to be a function of medication status). The results for response allocation (data not shown) mirrored those for time allocation, with a few exceptions: For Al, reinforcer rate was the second most influential dimension in the first placebo assessment condition as measured by response allocation, whereas quality was the second most influential dimension in this phase as measured by time allocation. Rate (as opposed to effort) was the least influential dimension in both of the medication phases for Lynn and in the first placebo phase for Rex.

Table 1 shows the mean number of problems attempted, percentage correct, and work duration per session across medication and placebo assessments for each of the participants. With the exception of Rita, there were no consistent differences across medication and placebo phases with respect to the number of problems attempted, the duration of work engagement (range, 7.6 to 8.7 min), or the mean percentage of correct responses (range, 82% to 99%). Rita attempted more problems, but spent less time on them and had proportionally fewer correct in the medication assessment than in the placebo assessment, but conclusions are limited because her withdrawal from the study as a result of moving precluded replication of the phases. Thus, these changes might have been a result of loss of interest in the task over time (as appeared to be the case with Rex), or experience that led to a change in strategies (as with Al, who in the latter two phases discriminated that reinforcement was time based and waited until the last moment of each trial to record his answer).

DISCUSSION

The results of the study indicated that the allocation patterns of all 4 children favored problem alternatives that produced immediate reinforcement when immediacy competed with

Table 1

Mean Number of Problems Attempted, Percentage Correct, and Work Duration Per Session (in Minutes) Across Medication (M) and Placebo (P) Assessments

Participant	Condition			
Rita	M	P		
Mean number attempted	139	70		
Mean percentage correct	72	89		
Mean duration	6.7	8.0		
Al	P	M	P	M
Mean number attempted	104	89	77	78
Mean percentage correct	97	99	96	96
Mean duration	7.9	8.5	8.7	8.5
Lynn	M	P	M	P
Mean number attempted	85	90	102	103
Mean percentage correct	88	86	87	91
Mean duration	8.5	8.6	8.6	8.2
Rex	P	M	P	M
Mean number attempted	33	24	18	18
Mean percentage correct	90	97	82	93
Mean duration	7.6	8.6	8.6	8.2

reinforcer rate, response effort, and (except for Lynn) reinforcer quality, across medication and placebo conditions. As in Neef et al. (2005), the finding that immediacy of reinforcement influenced the choices of children with ADHD is consistent with a diagnostic criterion for ADHD and supports Barkley's assertion that ADHD is fundamentally a problem of self-control, which manifests in behavior that is "less likely to be aimed at maximizing net future outcomes over immediate ones" (1997, p. 258). The finding that reinforcer immediacy was an influential dimension for ADHD participants across both placebo and medication assessments supports the results of the between-groups (medication and no medication) comparison in Neef et al., and suggests that medication may have little effect on functionally defined objective measures of impulsivity. In addition, there did not appear to be a relation between medication status and the number of problems attempted, the percentage of problems correct, or the time spent completing problems across assessments, with the possible exception of Rita. In general, these data are consistent with previous research, which has failed to show that stimulant medication has an effect on academic performance or learning (see Purdie et al., 2002).

It is unclear from this study whether or not medication might affect impulsivity. Conclusions are limited by the small number of participants, and additional replications are needed to determine their external validity. Several possible explanations for the results remain to be investigated through further research: First, it may be that the dosage was insufficient to affect impulsivity. We did not titrate the dosage; however, the fact that the physicians and parents had previously judged the dosages to be therapeutic was supported by the parents' reports when they were asked whether they thought their child was receiving placebo or medication (in all cases, their observations matched the conditions when the blind was broken). These judgments suggest that medication had an effect, but we did not compare results with other, more traditional measures. A second possibility, therefore, is that the dosage was sufficient to affect behavior topographies associated with a diagnosis of ADHD that are often included on rating scales (e.g., activity level, calling out, interrupting others) but not impulsivity as defined in this study. Other assessment paradigms may be required to capture all aspects of the construct as used clinically. It should be noted, however, that even when improvements in typical measures of impulsivity and related behavioral outcomes have been reported with stimulant medication, they have been relatively weak, typically remaining one standard deviation above the norm (Purdie et al., 2002).

Third, our assessment instrument may not have provided a sensitive measure of impulsivity. Consistent with the results of Neef et al. (2001, 2005), impulsivity did characterize the choices of children with ADHD to some extent when using a delay that might be considered socially significant (24 hr). However, medication may have an effect on self-control at shorter delay intervals. Indeed, with temporal discounting, the value of a reinforcer decreases as delay duration increases (i.e., the delay "discounts" the effectiveness of the reinforcer). To determine whether medication affects self-control in children with ADHD at shorter delay intervals, an adjusting delay procedure (Mazur, 1987, 1988) might be used with the assessment task; the indifference points (i.e., the delay value at which allocation occurs equally to the two response alternatives) could be compared across medication and placebo conditions.

Finally, it is possible that medication does not affect impulsivity to a meaningful degree. At the least, the results (albeit preliminary) suggest that current assumptions regarding the basis for the effects of stimulant medication on the constructs associated with ADHD warrant further scrutiny. If medication alone is determined to

be undesirable or insufficient for the development of self-control for some children with ADHD, the assessment of influential reinforcer dimensions might be useful in designing effective behavioral interventions. For example, Neef et al. (2001) demonstrated the development of self-control of children with ADHD in an analogue situation when the delay to reinforcement for a response alternative associated with a higher rate or quality reinforcer (whichever was identified by an assessment as an influential dimension) was progressively increased.

Clarification of the relations between behaviors associated with ADHD and temporal discounting could have numerous benefits in advancing the conceptualization of the disorder and in informing effective intervention, paralleling those of functional analyses (see Critchfield & Kollins, 2001). Perhaps the main contribution of the study is to demonstrate a methodology, employing functional, operational definitions of impulsivity and self-control that can be used to address these issues more definitively in subsequent applied research.

REFERENCES

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington DC: Author.

Angello, L. M., Volpe, R. J., DiPerna, J. C., Gureasko-Moore, S. P., Gureasko-Moore, D. P., Nebrig, M. R., et al. (2003). Assessment of attention-deficit/hyperactivity disorder: An evaluation of six published rating scales. *School Psychology Review*, *32*, 241–262.

Atkins, M. S., & Pelham, W. E. (1991). School-based assessment of attention deficit-hyperactivity disorder. *Journal of Learning Disabilities*, *24*, 197–225.

Barkley, R. A. (1997). *ADHD and the nature of self-control.* New York: Guilford.

Barkley, R. A. (1998). *Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment* (2nd ed.). New York: Guilford.

Branch, M. N. (1984). Rate dependency, behavioral mechanism, and behavioral pharamacology. *Journal of the Experimental Analysis of Behavior*, *42*, 511–522.

Branch, M. N. (1991). Behavioral pharmacology. In I. Iverson & K. A. Lattal (Eds.), *Experimental analysis of behavior* (Part 2, pp. 21–77). Amsterdam: Elsevier Science Publishers.

Broussard, C., & Northup, J. (1995). An approach to functional assessment and analysis of disruptive behavior in regular education classrooms. *School Psychology Quarterly*, *10*, 151–164.

Critchfield, T. S., & Kollins, S. H. (2001). Temporal discounting: Basic research and the analysis of socially important behavior. *Journal of Applied Behavior Analysis*, *34*, 101–122.

Gulley, V., & Northup, J. (1997). Comprehensive school-based assessment of the effects of methylphenidate. *Journal of Applied Behavior Analysis*, *30*, 627–638.

Julien, R. M. (1995). *A primer of drug action: A concise, nontechnical guide to the actions, uses, and side effects of psychoactive drugs* (7th ed.). New York: Freeman.

Kollins, S. H., Ehrhardt, K., & Poling, A. (2000). Clinical drug assessment. In A. Poling & T. Byrne (Eds.), *Introduction to behavioral pharmacology* (pp. 191–218). Reno, NV: Context Press.

Mazur, J. E. (1987). An adjusting procedure for studying delayed reinforcement. In M. L. Commons, J. Mazur, J. A. Nevin & H. Rachlin (Eds.), *The effect of delay and of intervening events on reinforcement value* (pp. 53–73). Hillsdale, NJ: Erlbaum.

Mazur, J. E. (1988). Estimation of indifference points with an adjusting-delay procedure. *Journal of the Experimental Analysis of Behavior*, *49*, 37–47.

The MTA Cooperative Group. (1999). A 14-month randomized trial of treatment strategies for attention deficit hyperactivity disorder. *Archives of General Psychiatry*, *56*, 1073–1086.

Murray, L. K., & Kollins, S. H. (2000). Effects of methylphenidate on sensitivity to reinforcement in children diagnosed with attention deficit hyperactivity disorder: An application of the matching law. *Journal of Applied Behavior Analysis*, *33*, 573–591.

National Institutes of Health. (1998). Diagnosis and treatment of attention deficit hyperactivity disorder. *NIH Consensus Development Statement*, *16(2)*, 1–37.

Neef, N. A., Bicard, D. F., & Endo, S. (2001). Assessment of impulsivity and the development of self-control by students with attention deficit hyperactivity disorder. *Journal of Applied Behavior Analysis*, *34*, 397–408.

Neef, N. A., & Lutz, M. (2001a). Assessment of variables affecting choice and application to classroom interventions. *School Psychology Quarterly*, *16*, 239–252.

Neef, N. A., & Lutz, M. N. (2001b). A brief computer-based assessment of reinforcer dimensions affecting choice. *Journal of Applied Behavior Analysis*, *34*, 57–60.

Neef, N. A., Mace, F. C., & Shade, D. (1993). Impulsivity in students with serious emotional disturbance: The interactive effects of reinforcer rate, delay, and quality. *Journal of Applied Behavior Analysis*, *26*, 37–52.

Neef, N. A., Marckel, J., Ferreri, S. J., Bicard, D. F., Endo, S., Aman, M. G., et al. (2005). Behavioral assessment of impulsivity: A comparison of children

with and without attention deficit hyperactivity disorder. *Journal of Applied Behavior Analysis*, *38*, 23–37.

Northup, J., Fusilier, I., Swanson, V., Huete, J., Bruce, T., Freeland, J., et al. (1999). Further analysis of the separate and interactive effects of methylphenidate and common classroom contingencies. *Journal of Applied Behavior Analysis*, *32*, 35–50.

Northup, J., Gulley, V., Edwards, S., & Fountain, L. (2001). The effects of methylphenidate in the classroom: What dosage, for which children, for what problems? *School Psychology Quarterly*, *16*, 303–323.

Pelham, W., Bender, M., Caddell, J., Booth, S., & Moorer, S. (1985). Methylphenidate and children with attention deficit disorder. *Archives of General Psychiatry*, *42*, 948–952.

Pincus, H. A., Tanielian, T., Marcus, S., Olfson, M., Zarin, D., Tompson, J., et al. (1998). Prescribing trends in psychotropic medications. *Journal of the American Medical Association*, *279*, 526–531.

Poling, A. (1986). *A primer of human behavioral pharmacology*. New York: Plenum.

Purdie, N., Hattie, J., & Carroll, A. (2002). A review of the research on interventions for attention deficit hyperactivity disorder: What works best? *Review of Educational Research*, *72*, 61–99.

Rachlin, H. (1974). Self-control. *Behaviorism*, *2*, 64–107.

Rapport, M., Stoner, G., DuPaul, G., Birmingham, B., & Tucker, S. (1985). Methylphenidate in hyperactive children: Differential effects of dose on academic, learning, and social behavior. *Journal of Abnormal Child Psychology*, *13*, 227–244.

Safer, D. J., Zito, J. M., & Fine, E. M. (1996). Increased methylphenidate usage for ADD in the 1990s. *Pediatrics*, *98*, 1084–1088.

Schroeder, S. R., Mann-Koepke, K., Gualtier, C. T., Eckerman, D. A., & Breese, G. R. (1987). Methylphenidate affects strategic choice behavior in normal adult humans. *Pharmacology Biochemistry & Behavior*, *28*, 213–217.

Stoner, G., Carey, S. P., Ikeda, M. J., & Shinn, M. R. (1994). The utility of curriculum-based measurement for evaluating the effects of methylphenidate on academic performance. *Journal of Applied Behavior Analysis*, *27*, 101–113.

Thompson, T. (1984). Behavioral mechanisms of drug dependence. *Advances in Behavioral Pharmacology*, *4*, 1–37.

Witkin, J. M., & Katz, J. L. (1990). Analysis of behavioral effects of drugs. *Drug Development Research*, *20*, 389–409.

Received August 30, 2002
Final acceptance January 18, 2005
Action Editor, John Northup

STUDY QUESTIONS

1. What is temporal discounting, and how might it relate to the treatment of ADHD?

2. Briefly describe the experimental task.

3. What procedures comprised the baseline, and what was its purpose?

4. What manipulations were made during the six assessment conditions, and which ones were relevant to the assessment of impulsivity?

5. What were the main independent variables, and what experimental designs were used to evaluate their effects?

6. Summarize the general findings with respect to (a) reinforcer dimension and (b) medication on participants' response allocation.

7. What factors temper the conclusion that methylphenidate may have little effect on the impulsivity of children with ADHD?

8. How might the specific values manipulated within a dimension of reinforcement have determined the extent to which that dimension influenced response allocation?

Questions prepared by Jessica L. Thomason and Jennifer L. Hammond, University of Florida