*IMPULSIVITY IN STUDENTS WITH SERIOUS
EMOTIONAL DISTURBANCE: THE INTERACTIVE EFFECTS OF
REINFORCER RATE, DELAY, AND QUALITY*

NANCY A. NEEF

DEVEREUX INSTITUTE OF CLINICAL TRAINING AND RESEARCH

F. CHARLES MACE

UNIVERSITY OF PENNSYLVANIA

AND

DORAN SHADE

DEVEREUX INSTITUTE OF CLINICAL TRAINING AND RESEARCH

We conducted two studies extending basic matching research on self-control and impulsivity to the investigation of choices of students diagnosed as seriously emotionally disturbed. In Study 1 we examined the interaction between unequal rates of reinforcement and equal versus unequal delays to reinforcer access on performance of concurrently available sets of math problems. The results of a reversal design showed that when delays to reinforcer access were the same for both response alternatives, the time allocated to each was approximately proportional to obtained reinforcement. When the delays to reinforcer access differed between the response alternatives, there was a bias toward the response alternative and schedule with the lower delays, suggesting impulsivity (i.e., immediate reinforcer access overrode the effects of rate of reinforcement). In Study 2 we examined the interactive effects of reinforcer rate, quality, and delay. Conditions involving delayed access to the high-quality reinforcers on the rich schedule (with immediate access to low-quality reinforcers earned on the lean schedule) were alternated with immediate access to low-quality reinforcers on the rich schedule (with delayed access to high-quality reinforcers on the lean schedule) using a reversal design. With 1 student, reinforcer quality overrode the effects of both reinforcer rate and delay to reinforcer access. The other student tended to respond exclusively to the alternative associated with immediate access to reinforcers. The studies demonstrate a methodology based on matching theory for determining influential dimensions of reinforcers governing individuals' choices.

DESCRIPTORS: choice, impulsivity, self-control, matching theory, reinforcer delay

Matching theory conceptualizes all behavior as choice governed by contingent reinforcement relative to all other sources of reinforcement. It also provides a methodological framework for studying choice, via assessment of the confluence or biasing effects of various reinforcement dimensions (e.g., rate, magnitude, duration, immediacy) on the pro-

portional distribution of behavior between concurrently available options. Neef, Mace, Shea, and Shade (1992), for example, examined how 3 special education students allocated their responding across two concurrently available math tasks associated with unequal rates and equal versus unequal qualities of reinforcement. Results showed that when the same reinforcers were available for each of two math task options (and after procedures were introduced to establish sensitivity to the features of variable-interval schedules of reinforcement in effect for each), the students distributed their behavior between the tasks in proportion to the reinforcement obtained from those alternatives; however, when the two response options were associated with qualitatively different reinforcers (as

This research was supported by Grant H023A00027-90A from the U.S. Department of Education to the Devereux Institute of Clinical Training and Research. The opinions expressed herein do not necessarily reflect the position or policy of the U.S. Department of Education. We gratefully acknowledge the support of Steven Pfeiffer and the staff of Gateway School in conducting this study. Reprints may be obtained from Nancy A. Neef, Graduate School of Education, University of Pennsylvania, 3700 Walnut St., Philadelphia, Pennsylvania 19104-6216.

is characteristic of most natural choice situations), there was a bias toward the higher quality reinforcer.

The constructs of self-control and its converse, impulsivity, have been defined according to choices between concurrently available response alternatives associated with large delayed reinforcers versus small immediate reinforcers (Ainslie, 1974; Rachlin, 1974). Choice as a function of variations in reinforcer amount and reinforcer delay has typically been investigated in laboratory environments using either simple concurrent procedures (in which choice responses are directly reinforced according to some schedule) or concurrent chains (in which choice responses in an initial link produce discriminative stimuli for choices correlated with another schedule of reinforcement). Nonhuman subjects' choices between presently available concurrent alternatives in a self-control paradigm have generally been governed more by short reinforcer delays than magnitude of reinforcers (i.e., amount of food) (Green & Snyderman, 1980; Snyderman, 1983). That is, nonhumans generally demonstrate choices characterized as impulsive. By contrast, adult humans have tended to choose the larger reinforcer (usually points exchangeable for money) even when the reinforcers are delayed (Logue, Pena-Correal, Rodriguez, & Kabela, 1986). This pattern of choice has been characterized as self-control.

Many individuals with learning and behavior difficulties tend to exhibit behavior that favors immediate rather than longer term consequences. Horner and Day (1991), for example, reported a study with an adult with autism and severe mental retardation in which handing a card manding "break" to her trainer produced brief escape from the task (reinforcement) after either a 1-s or 20-s delay, and aggression resulted in immediate escape. Results of a reversal design showed that manding a break increased and aggression decreased only when the former produced immediate escape. Thus, as with unequal quality of reinforcers (Neef *et al.*, 1992), differences in delay to delivery of reinforcers between two concurrently available response alternatives may override rate of reinforcement in affecting how some individuals allocate their behavior.

Identifying the most influential parameters of reinforcement and their interactive effects on the allocation of behavior can contribute to the design of interventions to promote beneficial choices.

The purposes of our studies were to extend basic matching research on self-control and impulsivity to the investigation of choices of individuals with learning and behavior difficulties in an educational setting. In Study 1 we examined the interaction between unequal rates of reinforcement and equal versus unequal delays to reinforcer access on performance on concurrently available sets of math problems. Although in most basic research on this topic the concurrent schedules are associated with different amounts (rather than rates) of reinforcement, higher rates also produce greater quantities of reinforcement, and thus similar choices (reflecting either impulsiveness or self-control) would be predicted. We hypothesized that arranging different delays to reinforcer access between the response alternatives would produce a bias toward the response and schedule with the lower delays for students having learning and behavior problems (i.e., that immediacy would override the effects of rate of reinforcement). In Study 2 we examined the interactive effects of reinforcer rate, reinforcer quality, and delay to reinforcer access.

STUDY 1

METHOD

Participants and Setting

Two students in a special education program for youths with severe emotional disturbance or behavior disorders and learning difficulties served as participants. The students, Dee and Leah, were referred by their teachers because of their need for assistance in completing instructional tasks and for practice in arithmetic skills. They were enrolled in the study after we obtained informed consent from the participants and their guardians. Dee had participated in a previous study on the effects of reinforcer rate and reinforcer quality on time allocation (Neef *et al.*, 1992). Dee, aged 19, was diagnosed as functioning within the borderline range

of intelligence and as having "organic mood syndrome." Her math scores on the California Achievement Test yielded a 7.2 grade level. Leah, aged 13, was assessed as functioning within the average range of intelligence, with diagnoses of "posttraumatic stress disorder," "dysthymia," and "atypical pervasive developmental disorder." Her psychoeducational test scores on math were at the 3.2 grade level. Sessions were conducted in a small office at the school, with the experimenter seated across from the participant at a table.

Experimental Conditions and Procedures

We conducted one to three 10-min sessions per day, 3 to 5 days per week, for each participant. During each session, the experimenter placed two stacks of problems, printed on yellow and green index cards, respectively, on top of the table in front of the student. The problems, which were identical in both stacks, consisted of four-digit numbers divided by one-digit numbers for Dee and two-digit by one-digit multiplication for Leah. Thus, each trial consisted of a choice between identical problems. The experimenter gave the student a standard instruction, "You can earn nickels doing these math problems. You may work on either stack of problems as you choose. You may start when I say 'begin.'"

Correct responses to problems on yellow and green cards were reinforced with nickels on concurrent variable-interval (VI) 60-s VI 120-s schedules for Dee and VI 30-s VI 120-s schedules for Leah. Reinforcement was delivered contingent on the first correctly completed problem after the reinforcement interval (signaled to the experimenter by audiotape through an earphone). Following an incorrect response, the experimenter marked the card with an X.

Prebaseline. Preliminary sessions were conducted with Leah to determine her sensitivity to the VI reinforcement schedule under the equal delays to reinforcer access condition described below, and, subsequently, to facilitate discrimination of those contingencies. Procedures were similar to the prebaseline condition described in Neef et al. (1992) (they were not required for Dee because of her

participation in that study). Specifically, after conducting initial sessions in the same manner as in the equal delays to reinforcer access condition, we continued the procedures with a digital kitchen timer placed behind each of the two stacks of problems to signal the remaining time within the respective reinforcement interval. Once Leah consistently allocated her behavior in patterns predicted by the schedules, the timers were removed and the experimental conditions described below were initiated.

Equal delays to reinforcer access. Nickels delivered under the concurrent schedules were deposited within 2 s of a correct response in a transparent plastic cup the same color as, and directly behind, the respective stack of problems. After each session, the student counted the nickels that had been deposited in each cup, recorded in a log the amount in each as well as the total amount earned during the session, and was told that she could take the money with her. The purpose of this condition was to determine the extent of matching when rate of reinforcement differed for the response alternatives and access to reinforcement was immediate for both. This provided a standard against which we could compare the effects of unequal delays to reinforcer access.

Unequal delays to reinforcer access. In addition to the standard instruction, the student was told, "You may earn nickels which you can have now or later. The calculator will show the amount of money to be placed in a savings account for you. You will be given all the nickels in your savings account on [day]." The target date for reinforcer access began with either a 1-, 2-, or 3-week latency, and the same date was specified for all sessions until the nickels were delivered. Thus, the delay to reinforcer access decreased across sessions on successive days, culminating with same-day access on the specified date (identical to the equal delays to reinforcer access condition). For example, if access to nickels earned during sessions on 1 day was scheduled for 7 days later, access to reinforcers earned during sessions the following day would occur 6 days later. The procedure approximated a linear VI schedule, in which the availability of a reinforcer

is stored until the interval is completed (Logue, Rodriguez, Pena-Correal, & Mauro, 1984). For Dee, the first unequal delay to reinforcer access condition began with a 3-week delay, and the subsequent replication of that condition began with a 1-week delay. For Leah, initial implementation of this condition began with a 1-week delay, followed by a second 1-week delay. The replication of that condition began with a 2-week delay, followed by two successive periods beginning with 1-week delays.

Reinforcer delay was applied only to the richer schedule. For each reinforcer delivered under the VI 60-s (Dee) or VI 30-s (Leah) schedule, the experimenter entered 0.05 on a calculator placed behind the stack of yellow card problems, such that the amount accumulated for delivery on the specified date was displayed and visible to the student. This served as the discriminative stimulus for delayed versus immediate access to nickels. At the end of each session, the student was given a receipt (bank deposit slip) for the total amount. All other procedures were identical to the equal delays to reinforcer access condition.

Experimental Design

A reversal design was used to assess the effects of equal versus unequal delays to reinforcer access.

Data Collection and Interobserver Agreement

Data collectors recorded time allocated to each of the response alternatives during continuous 1-min intervals using two stopwatches, one for each stack of problems. The stopwatch was started when, and remained activated while, the student was visually oriented to a problem from that stack. In addition, the number of problems completed correctly and incorrectly for each of the response alternatives was counted at the end of each session. A second observer collected interobserver agreement data on 26% and 25% of the sessions across experimental conditions for Dee and Leah, respectively. An agreement for time allocation was defined as both observers recording the same duration within a 1-min interval plus or minus 2 s. Mean agreement scores

were 100% for Dee and 90.6% for Leah (range, 70% to 100%).

Data were also collected on the number of times reinforcement was delivered. Interobserver agreement (identical recording by independent observers of the number of reinforcer deliveries within intervals) was 100% for Dee and 98.4% for Leah (range, 80% to 100%).

RESULTS

Figure 1 shows the extent of time-allocation matching across equal and unequal delays to reinforcer access conditions for Dee and Leah. These data portray the relation between the percentage of time engaged in responding to the VI 60-s (Dee) or VI 30-s (Leah) reinforcement schedule and the percentage of obtained reinforcement on that schedule. The former represent $T1/(T1 + T2)$ (where $T1$ and $T2$ reflect the total amount of time spent on the task alternative subject to the VI 30-s and VI 120-s schedules, respectively), and the latter represent $r1/(r1 + r2)$ (where $r1$ and $r2$ represent the obtained rates of reinforcement on those alternatives).

The data for Dee show that the percentage of time allocated to each response alternative closely corresponded to the amount of obtained reinforcement, as predicted by the matching law, when access to earned reinforcers was immediate under both concurrent schedules. The mean percentage of time allocated to the VI 60-s schedule was 66.6%, and the mean percentage of reinforcement obtained on that schedule was 73% (mean difference = 7.9%). During the next condition in which access to reinforcers on the richer (VI 60-s) schedule was delayed for up to 3 weeks and access to reinforcers on the leaner (VI 120-s) schedule was provided at the end of the session, Dee's percentage of time allocation favored the latter, and undermatching occurred. The mean percentage of time allocated to the VI 60-s schedule decreased to 32.8%, and the mean percentage of reinforcement obtained on that schedule was 47.2%, with a mean difference of 14%. Upon reinstatement of the equal delays

Figure 1. Percentages of time allocated to the richer schedule (squares) and obtained reinforcement (Xs) on that schedule across equal and unequal delay conditions for Dee and Leah. Delays indicated on the x axis indicate the number of days to reinforcer access for the respective response alternative. Nonconsecutive delays represent absences or school closings.

to reinforcer access condition, time allocated to the VI 60-s schedule immediately increased to the levels observed in the initial condition ($M = 66.2\%$), corresponding closely to the percentage of obtained reinforcement ($M = 61.6\%$). A reversal to the unequal delays to reinforcer access condition (but beginning with a 1-week delay on the VI 60-s schedule) again resulted in undermatching (mean difference = 12.6%) and an immediate reduction in time allocated to the VI 60-s schedule ($M = 39.9\%$).

A prebaseline condition was conducted with Leah; she allocated between 58% and 73% of her time to problems on the richer schedule ($M = 63.5\%$), whereas the percentage of obtained rein-

forcement on that alternative, as predicted by the schedule, ranged between 74% and 83% ($M = 77.4\%$). After undermatching had occurred for six sessions, timers signaling the VI intervals were made available for two sessions, after which the percentage of time allocation corresponded more closely to the percentage of obtained reinforcement.

As with Dee, Leah's subsequent time allocation ($M = 81.4\%$) was approximately proportional to obtained reinforcement ($M = 79.5\%$) during the equal delays to reinforcer access condition (mean difference = 4.7%). However, the percentages of both time allocation and obtained reinforcement were higher for Leah than Dee, as would be predicted by the matching law given the differences

in their concurrent schedules of reinforcement (a ratio of 1:2 for Dee vs. 1:4 for Leah).

During the subsequent condition, in which access to reinforcers on the VI 30-s schedule was delayed for up to 1 week, percentage of time allocated to that schedule decreased ($M = 45.2\%$), and undermatching occurred to approximately the same extent as with Dee (mean difference = 13.1%). During the 19th session, when the initial 1-week delay period had elapsed (after which she was given access to the reinforcers earned that week on the VI 30-s schedule), her percentage of time allocation approached the levels in the previous condition. During the next session, when the delay interval was longest (1 week), she did not allocate any of her time to that schedule.

Upon reimplementing of equal delays to reinforcer access, percentage of time allocated to the VI 30-s schedule immediately increased ($M = 84.2\%$), to slightly higher levels than the percentage of obtained reinforcement ($M = 82\%$). A return to the unequal delays to reinforcer access condition again disrupted the matching relation, but her pattern of responding differed from her previous performance during that condition. She responded exclusively to the VI 30-s schedule during the sessions immediately preceding access to nickels (i.e., when the delay period was shortest, on Sessions 44 and 45, 56 and 57, and 64). During the sessions immediately following access to nickels (when the delay period was longest on the VI 30-s schedule), she responded exclusively or near-exclusively to the VI 120-s schedule, which produced less, but more immediate access to, reinforcement (Sessions 46 and 47, 58 and 59). Generally, her time allocated to the VI 30-s schedule gradually increased as the delay to access to reinforcers decreased (Sessions 38 through 42, 61 through 63).

The session data for Dee and Leah (time, number of responses, and number of reinforcers obtained for each response alternative, and the corresponding ratios) are reported in the appendix. For both Dee and Leah, the percentage of correctly completed problems on the VI 30-s or VI 60-s schedule (i.e., the number of yellow card problems completed divided by the total number of problems completed) closely paralleled the data on time allocation.

That is, the results were similar in terms of the relation of both response rate and time allocation to obtained reinforcement for the respective response alternatives.

DISCUSSION

The results show that the students' time allocation was sensitive to the relative rate of reinforcement when reinforcer access was immediate for both response alternatives; however, when the response alternatives were associated with unequal delays to reinforcer access, the students demonstrated impulsivity. That is, instead of continuing to allocate their time in ways that would maximize overall quantity of reinforcement (which, under concurrent VI schedules, would coincide with matching), their choices often favored lower rate immediate reinforcement.

Only Leah responded differentially to parametric changes in the delay to reinforcer access, which was most evident in the second unequal delays to reinforcer access condition. She tended to respond exclusively or near-exclusively to the VI 30-s schedule when the delay to reinforcer access was short, and exclusively to the leaner schedule (producing immediate reinforcer access) when the delay to reinforcer access on the richer schedule was longest. Dee, on the other hand, allocated her time consistently in proportions that produced both high-rate delayed and low-rate immediate reinforcers. Her behavior distribution may have been related to establishing operations; her frequent comments that she wanted to earn enough nickels to make a long distance telephone call to her boyfriend suggest that her choices were based on the number of nickels sufficient for that daily purpose. She may also have developed stereotyped response sequences that operated as functional behavioral units (Schwartz, 1986) and that were resistant to change (Nevin, Mandell, & Atak, 1983). Because her behavior allocation did not vary concomitant with the decreasing delays to reinforcer access, it does not conform to predictions of various models of choice (albeit on concurrent-chain schedules) that assume some matching relation between a reinforcer's delay and the resulting reinforcement value (e.g., Baum & Rachlin, 1969; Squires & Fantino, 1971). It

should be noted that most basic studies in this area have used delay values that vary in seconds rather than days, as in this study. (We selected delay values that are typical of those frequently encountered in natural human environments, and to which the students' performance was most likely to be sensitive.) Nevertheless, our results show that unequal delays to reinforcer access can produce biased responding in favor of the more immediate reinforcer which, like reinforcers of unequal quality (Neef et al., 1992), alters the effects produced by rate of reinforcement alone.

STUDY 2

Given the separate biasing effects of immediacy of reinforcer access (Study 1) and reinforcer quality (Neef et al., 1992), the purpose of Study 2 was to determine the influence of each of those parameters relative to the other when combined with a high versus a low rate of reinforcement.

METHOD

Procedures and Independent Variables

The students from Study 1 served as the participants. Data collection methods and experimental procedures were identical to those described in Study 1, with the exception that both the delay to reinforcer access and the quality of the reinforcer associated with each concurrent schedule varied according to the experimental condition in effect (described below).

Reinforcer rate. As in Study 1, correct responses to problems on yellow and green cards, respectively, were reinforced on concurrent VI 60-s VI 120-s schedules for Dee and VI 30-s VI 120-s schedules for Leah.

Reinforcer quality. For Dee, nickels were designated as the high-quality reinforcer, and their equivalent in "program money" (exchangeable in the school's token economy system for community outings, privileges or special events, and items from the school store) served as the low-quality reinforcer. Each delivery of a chip represented 5 cents in program money. For Leah, program money served as the high-quality reinforcer, and nickels served as

the low-quality reinforcer. High- and low-quality designations were made on the basis of asking the student at the start of each session which of the two she preferred to work for.

Delay to reinforcer access. As in Study 1, access to the reinforcers earned on both or one of the other of the schedules (depending on the experimental condition in effect) was provided at the end of the session (immediate) or on a predetermined date, typically up to 1 (Dee) or 2 weeks (Leah) later (delayed). At the end of the session involving delayed access to reinforcers, students were given a receipt specifying the amount earned and the date those reinforcers would be delivered.

Experimental Conditions

Equal delays and quality. A condition in which both response alternatives were associated with immediate access to the same type of reinforcer served as a baseline. The type of reinforcer was alternated across sessions to establish the students' sensitivity to varying reinforcer rates while holding constant reinforcer quality and delay to reinforcer access across the concurrent schedules. During one condition, low-quality reinforcers with immediate access were used for both VI schedules. During the other condition, high-quality reinforcers with immediate access were used for both VI schedules.

Delayed high-quality reinforcers on rich schedule. The response alternatives consisted of delayed access to high-quality reinforcers on the rich (VI 60 s for Dee and VI 30 s for Leah) schedule, versus immediate access to low-quality reinforcers on the leaner (VI 120 s) schedule.

Immediate low-quality reinforcers on rich schedule. Conditions were identical to the previous phase except that the delay to reinforcer access and reinforcer quality pairings with the VI schedules were reversed (i.e., the richer schedule was associated with immediate access to low-quality reinforcers and vice versa).

Experimental Design

Following baseline (equal delays and quality), the delayed high-quality reinforcer and the immediate low-quality reinforcer conditions were implemented in the context of an ABCBC reversal

design, where A, B, and C conditions represented equal delays and quality, delayed high-quality reinforcers on the rich schedule, and immediate low-quality reinforcers on the rich schedule, respectively. In addition, the reversal of contingencies across the concurrent VI schedules in the delayed high-quality and immediate low-quality reinforcer conditions provided a replication of functional effect.

Data Collection and Interobserver Agreement

Data collection and reliability procedures were the same as those used in Study 1. Interobserver agreement was assessed on 27% and 25% of the sessions for Dee and Leah, respectively. Mean agreement scores on time allocation were 96.2% for Dee (range, 80% to 100%) and 97.6% for Leah (range, 70% to 100%). Mean agreement scores for reinforcer delivery were 99.6% for Dee (range, 90% to 100%) and 100% for Leah.

RESULTS

Figure 2 shows the extent of time allocation matching, represented by the relation between the percentage of time engaged in problems on the rich schedule (VI 60-s and VI 30-s schedules for Dee and Leah, respectively) and the percentage of obtained reinforcement on that schedule, across experimental conditions for the 2 students. (Session data are reported in the appendix.) For both students, the percentage of time allocated to each response alternative closely corresponded to the amount of obtained reinforcement when the quality of the reinforcers and the delay to reinforcer access were the same across the two response alternatives. Dee showed slight undermatching during this condition; the mean difference between the percentage of time allocated to problems on the richer schedule ($M = 68.8\%$) and the percentage of reinforcement obtained on that alternative ($M = 76\%$) was 8.4%. For Leah, the mean percentages of time allocated to and reinforcement obtained from that alternative, respectively, were 84.9% and 84.6%, with a mean difference of 2.9%.

For Dee, high-quality reinforcers overrode the effects of delays to reinforcer access. During the

delayed high-quality reinforcer condition, the mean percentage of time allocated to problems on the richer schedule increased to a mean of 87.7% (range, 67% to 100%), and the mean percentage of obtained reinforcement on that alternative was 93.3%. When the contingencies were reversed in the subsequent immediate low-quality reinforcer condition, there was a corresponding decrease in the percentage of time allocated to problems on the richer schedule to 16.3% (range, 5% to 37%) and in the percentage of obtained reinforcement ($M = 20.9\%$, range, 0% to 50%). A return to the previous condition produced an immediate increase in the percentage of time allocated to problems on the richer schedule, associated with delayed reinforcer access but the higher quality reinforcer. The mean percentages of time allocation and obtained reinforcement on that alternative, respectively, were 90% (range, 80% to 100%) and 91.9% (range, 86% to 100%). A reversal resulted in percentages of time allocation and obtained reinforcement similar to the previous immediate low-quality reinforcer condition ($M = 12.6\%$ and 19.8%, respectively).

Leah's choices, on the other hand, were controlled more by delay to reinforcer access than by reinforcer rate and quality. Except for the second session in the first delayed high-quality reinforcer condition, she allocated all, or almost all, of her time to the alternative yielding lower rate and quality of reinforcers but immediate access to them. Mean percentages of time allocation to and obtained reinforcement on the rich schedule were 13.4% and 15%, respectively.

When the contingencies were reversed during the immediate low-quality reinforcer condition, she responded exclusively or near-exclusively to problems on the richer schedule, except during the sessions immediately preceding scheduled access to reinforcers accumulated for problems on the leaner schedule (Sessions 23 and 24, 29 and 30). Upon return to the delayed high-quality reinforcer condition, she began by responding exclusively to problems on the leaner schedule (associated with immediate reinforcer access). When scheduled access to reinforcers on the richer schedule was imminent,

Figure 2. Percentages of time allocated to the richer schedule (triangles) and obtained reinforcement (Xs) on that schedule across experimental conditions for Dee and Leah. Closed and open triangles within the equal delay condition represent time allocation when high- and low-quality reinforcers, respectively, were used. Delays along the x axis indicate the number of days to reinforcer access. Where delays to zero carry across conditions, the number represents both the delay to access reinforcers on the lean schedule in that condition and to access reinforcers on the rich schedule during the previous condition. Nonconsecutive delays represent absences or school closings.

she showed preference reversal, responding exclusively to that alternative (Sessions 37 through 41). During the next sessions, when delay to reinforcer access on the richer schedule was longest, she again responded exclusively to problems on the leaner schedule (Sessions 42 and 43).

A return to the immediate low-quality reinforcer condition produced a reversal in Leah's time allocation and a functional replication of the effects of the previous condition; that is, she responded exclusively to the alternative that produced more immediate reinforcement (problems on the richer schedule) during the first five sessions. She then

shifted her time allocation as the delay to the higher quality reinforcers (associated with the leaner schedule) decreased, culminating in exclusive responding to problems on the leaner schedule when access to those reinforcers was also immediate.

DISCUSSION

The data for Leah indicate continued impulsivity; she tended to respond exclusively to the alternative associated with immediate access to the reinforcers. When both alternatives were associated with immediate access to reinforcers but competed with respect to rate and quality (i.e., Sessions 23

and 24, 29 and 30, and 51 and 52, in the immediate low-quality reinforcer conditions), her time allocation initially corresponded closely to the relative rate of reinforcement, but thereafter favored higher quality over the higher rate reinforcers. It was not feasible to conduct a complete parametric investigation of the interaction between the three reinforcer dimensions; thus, it cannot be determined whether and at what values of the independent variables preference reversal (i.e., self-control) might have been established. However, in Leah's case, the clinical utility of such information would be limited because more potent generalized reinforcers and a higher rate of reinforcement than used in our experimental conditions would not be practical in most applied settings. Leah's results suggest that to compete effectively with reinforcers for less desirable choices, access to reinforcers should be relatively immediate. Alternatively, self-control might be developed by gradually lengthening (rather than decreasing) the delay interval. Results of studies by Mazur and Logue (1978) and Logue *et al.* (1984) suggest that fading procedures can improve sensitivity to delayed reinforcement (i.e., improve self-control).

For Dee, however, reinforcer quality overrode the effects of both reinforcer rate and delay to reinforcer access. Given that her choices were governed less by immediate access to reinforcers and were less likely to be exclusive, her behavior might be characterized as less impulsive than Leah's. However, because, with concurrent VI VI schedules, matching is consistent with reinforcement maximization, deviations from matching typically result in less overall reinforcement received. Thus, in the unequal reinforcer delay and quality conditions, both subjects' choices produced decreases in the total amount of reinforcement received even though this sacrifice did not increase the number of preferred reinforcers (either immediate or high quality) they could obtain by matching. This suggests that one measure of either impulsive behavior or the value of a reinforcer may be the "price" an individual is willing to pay (in total number of reinforcers) for "certainty" in obtaining the maximum number of preferred reinforcers available.

GENERAL DISCUSSION

Although early findings derived from basic research suggested a matching relation between responses in a two-choice situation and variables such as frequency (Herrnstein, 1961), amounts (Catania, 1963), and immediacy of reinforcement (Chung & Herrnstein, 1967), subsequent investigations of combinations of variables have indicated that these dimensions are not functionally equivalent, and that their effects are not uniformly described by the matching law (Davison & McCarthy, 1988; Green & Snyderman, 1980; Snyderman, 1983). As our study also indicates, the relative effects of different reinforcement dimensions on the distribution of behavior between concurrently available alternatives differ across individuals. A worthwhile goal, then, is to determine the relative influence of the dimensions that, collectively, affect the value of reinforcers for individuals, as measured by relative responding in choice situations.

Our results suggest that extending functional analyses of the type of reinforcement *contingencies* that maintain behaviors (Cooper, Wacker, Sasso, Reimers, & Donn, 1990; Iwata, Dorsey, Slifer, Bauman, & Richman, 1982) to an assessment of individual sensitivities to different reinforcement *dimensions* may be useful in further informing the design of effective treatment programs. Horner and Day (1991) conducted functional assessments of the variables maintaining problem behaviors of 3 individuals with disabilities; they subsequently established a more appropriate alternative response that was functionally equivalent to the problem behavior (i.e., that produced the same effect) and that was more "efficient" in terms of physical effort, schedule of reinforcement, or the delay between presentation of the discriminative stimulus and reinforcer delivery.

Determination of the relative potency of different dimensions, as well as the effects of parametric changes in their values, should suggest how variables could be combined or manipulated strategically to influence the choices of individuals toward more adaptive repertoires. For individuals who demonstrate impulsivity, these analyses may sug-

gest the maximum delay to reinforcer access that would allow consequences for desirable behavior to compete effectively with the prevailing contingencies for less desirable behavior (as appropriate in Leah's case). These analyses may also indicate other potentially influential dimensions (e.g., quality), and the levels at which those dimensions might compensate for immediate access to reinforcers in the development of self-control (as appropriate in Dee's case). Our studies demonstrate the viability of a conceptual and methodological framework based on matching theory to further that goal.

REFERENCES

- Ainslie, G. W. (1974). Impulse control in pigeons. *Journal of the Experimental Analysis of Behavior*, 21, 485-489.
- Baum, W. M., & Rachlin, H. C. (1969). Choice as time allocation. *Journal of the Experimental Analysis of Behavior*, 12, 861-874.
- Catania, A. C. (1963). Concurrent performances: A baseline for the study of reinforcement magnitude. *Journal of the Experimental Analysis of Behavior*, 6, 299-300.
- Chung, S. H., & Herrnstein, R. J. (1967). Choice and delay of reinforcement. *Journal of the Experimental Analysis of Behavior*, 10, 67-74.
- Cooper, L. J., Wacker, D. P., Sasso, G. M., Reimers, T. M., & Donn, L. K. (1990). Using parents as therapists to evaluate appropriate behavior of their children: Application to a tertiary diagnostic clinic. *Journal of Applied Behavior Analysis*, 23, 285-296.
- Davison, M., & McCarthy, D. (1988). *The matching law: A research review*. Hillsdale, NJ: Erlbaum.
- Green, L., & Snyderman, M. (1980). Choice between rewards differing in amount and delay: Toward a choice model of self control. *Journal of the Experimental Analysis of Behavior*, 34, 135-147.
- Herrnstein, R. J. (1961). Relative and absolute strength of a response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior*, 4, 267-272.
- Horner, R. H., & Day, H. M. (1991). The effects of response efficiency on functionally equivalent competing behaviors. *Journal of Applied Behavior Analysis*, 24, 719-732.
- Iwata, B. A., Dorsey, M. F., Slifer, K., Bauman, K. E., & Richman, G. S. (1982). Toward a functional analysis of self-injury. *Analysis and Intervention in Developmental Disabilities*, 2, 3-20.
- Logue, A. W., Pena-Correal, T. E., Rodriguez, M. L., & Kabela, E. (1986). Self-control in adult humans: Variation in positive reinforcer amount and delay. *Journal of the Experimental Analysis of Behavior*, 46, 159-173.
- Logue, A. W., Rodriguez, M. L., Pena-Correal, T. E., & Mauro, B. C. (1984). Choice in a self-control paradigm: Quantification of experience-based differences. *Journal of the Experimental Analysis of Behavior*, 41, 53-67.
- Mazur, J. E., & Logue, A. W. (1978). Choice on a "self-control" paradigm: Effects of a fading procedure. *Journal of the Experimental Analysis of Behavior*, 30, 11-17.
- Neef, N. A., Mace, F. C., Shea, M., & Shade, D. B. (1992). Effects of reinforcer rate and reinforcer quality on time allocation: Extensions of matching theory to educational settings. *Journal of Applied Behavior Analysis*, 25, 691-699.
- Nevin, J. A., Mandell, C., & Atak, J. R. (1983). Choice as time allocation. *Journal of the Experimental Analysis of Behavior*, 39, 49-59.
- Rachlin, H. (1974). Self-control. *Behaviorism*, 2, 94-107.
- Schwartz, B. (1986). Allocation of complex, sequential operants on multiple and concurrent schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 45, 283-295.
- Snyderman, M. (1983). Delay and amount of reward in a concurrent chain. *Journal of the Experimental Analysis of Behavior*, 39, 437-447.
- Squires, N., & Fantino, E. (1971). A model for choice in simple concurrent and concurrent-chain schedules. *Journal of the Experimental Analysis of Behavior*, 15, 27-38.

Received February 2, 1992

Initial editorial decision April 20, 1992

Revision received August 7, 1992

Final acceptance August 13, 1992

Action Editor, David Wacker

APPENDIX
Session Data

Subject	Condition	Session	Rich schedule			Lean schedule			Ratio		
			Time (sec- onds)	Respon- ses	Rein- forcers	Time (sec- onds)	Respon- ses	Rein- forcers	% Time	% Re- sponses	% SR +
Study 1											
Dee	ED	1	472	43	10	128	10	2	78.6	81.1	83.3
		2	532	48	9	68	9	1	88.6	84.2	90.0
		3	468	46	11	132	12	0	78.0	79.3	100
		4	523	55	10	77	6	0	87.1	90.1	100
		5	463	54	10	137	6	2	77.1	90.0	83.3
		6	402	35	9	198	16	5	67.0	68.6	64.3
		7	333	33	10	267	25	5	55.5	56.8	66.6
		8	366	42	11	234	18	3	61.0	70.0	78.5
		9	488	47	10	112	13	6	81.3	78.3	62.5
		10	440	37	10	160	17	5	73.3	68.5	66.6
		11	410	43	12	190	18	6	68.3	70.4	66.6
		12	399	40	9	201	18	5	66.5	68.9	64.2
		13	398	41	11	202	21	4	66.3	66.1	73.3
		14	398	47	10	202	21	5	66.3	69.1	66.6
		15	362	35	10	238	23	2	60.3	60.3	83.3
		16	346	34	9	254	23	5	57.6	59.6	64.2
		17	382	38	9	218	24	4	63.6	61.2	69.2
		18	364	40	10	236	22	3	60.6	64.5	76.9
		19	397	43	10	203	15	5	66.1	74.1	66.1
		20	352	46	5	248	35	3	58.6	56.7	62.5
		21	391	45	12	209	28	2	65.1	61.6	85.7
		22	393	49	9	207	26	5	65.5	65.3	64.2
		23	383	49	6	217	35	4	63.8	58.3	60.0
		24	425	54	9	175	27	3	70.8	66.6	75.0
		25	429	53	10	131	24	3	71.5	68.8	76.9
		26	378	49	9	222	36	4	63.0	57.6	69.2
		27	351	40	7	249	32	3	58.5	48.7	70.0
		28	337	44	7	263	32	3	56.1	57.8	70.0
		29	400	50	8	200	27	3	66.6	64.9	72.7
		30	372	50	8	228	38	3	62.0	56.8	72.7
		31	384	57	9	216	33	3	64.0	63.3	75.0
	UD	32	228	28	5	372	46	5	38.0	37.8	50.0
		33	209	23	3	391	43	5	34.8	34.8	37.5
		34	202	26	6	398	50	5	33.6	34.2	54.5
		35	193	22	3	407	49	5	32.1	30.9	37.5
		36	186	26	4	414	47	6	31.0	35.6	40.0
		37	132	21	4	468	62	5	22.0	25.3	44.4
		38	162	21	3	438	57	5	27.0	26.9	37.5
		39	268	32	4	332	50	5	44.6	39.0	44.4
		40	181	24	4	419	59	6	30.1	28.9	40.0
		41	255	30	5	345	51	4	42.5	37.0	55.5
		42	171	28	6	429	62	6	28.5	31.1	50.0
		43	197	28	4	403	52	5	32.8	35.0	44.4
		44	200	29	5	400	46	4	33.3	38.6	55.5
		45	183	21	4	417	63	6	30.5	25.0	40.0
		46	217	22	6	383	56	6	36.1	28.2	50.0
		47	182	23	4	418	61	4	30.3	27.3	50.0
		48	227	33	6	373	57	6	37.8	36.6	50.0
		49	195	28	4	405	54	6	32.5	34.1	40.0
		50	211	35	7	389	56	3	35.1	38.4	70.0

APPENDIX
(Continued)

Subject	Condition	Session	Rich schedule			Lean schedule			Ratio		
			Time (sec- onds)	Respon- ses	Rein- forcers	Time (sec- onds)	Respon- ses	Rein- forcers	% Time	% Re- sponses	% SR +
Leah	ED	51	208	27	5	392	48	4	34.6	36.0	55.5
		52	212	29	5	388	59	6	35.3	32.9	45.4
		53	136	16	3	464	45	5	22.6	26.2	37.5
		54	202	35	4	398	56	6	33.6	38.4	40.0
		55	181	27	3	419	55	6	30.1	32.9	33.3
		56	112	23	3	488	63	6	18.6	26.7	33.3
		57	148	26	3	452	45	6	24.6	36.6	33.3
		58	224	35	7	376	49	2	37.3	41.6	77.7
		59	302	45	6	298	46	2	50.3	49.4	75.0
		60	383	45	9	217	35	3	63.8	56.2	75.0
		61	439	55	9	161	22	2	73.1	71.4	81.8
		62	374	51	9	226	32	5	62.3	61.4	64.2
		63	382	40	7	218	26	1	63.6	60.6	87.5
		64	391	52	7	209	36	4	65.1	59.0	63.6
		65	418	47	9	182	30	4	69.6	61.0	69.2
	UD	66	255	24	7	345	42	6	42.5	36.3	33.8
		67	182	18	5	418	47	6	30.3	27.6	45.4
		68	260	23	5	340	46	5	43.3	33.3	50.0
		69	216	18	6	384	51	6	36.0	26.0	50.0
		70	232	19	5	368	28	6	38.6	40.4	45.4
		71	296	24	8	304	29	4	49.3	45.2	66.6
		72	276	22	5	324	33	4	46.0	40.0	55.5
		73	202	20	7	398	37	6	33.6	35.0	53.8
	ED	1	239	22	14	76	8	4	75.8	77.7	73.3
		2	309	41	13	75	11	4	80.4	76.4	78.8
		3	455	70	18	17	3	3	96.3	85.7	95.8
		4	258	30	16	39	5	4	86.8	80.0	85.7
		5	443	39	15	104	4	3	80.9	83.3	90.6
		6	399	19	12	201	9	4	79.3	75.0	67.8
		7	388	37	15	152	8	4	71.8	78.9	82.2
		8	412	36	16	109	8	4	79.0	80.0	81.8
		9	427	25	15	87	11	4	85.0	78.9	69.4
	UD	10	46	8	7	56	6	4	45.0	63.6	57.1
		11	61	12	5	158	23	4	27.8	55.5	34.2
		12	118	18	10	38	8	4	75.6	71.4	69.2
		13	127	20	9	160	21	5	44.2	64.2	48.7
		14	180	23	13	109	11	4	62.2	76.4	67.6
		15	92	12	6	181	15	5	33.6	54.5	44.4
		16	111	10	7	50	5	3	68.9	70.0	66.6
		17	58	4	3	88	10	3	39.7	50.0	28.5
		18	88	14	11	72	9	5	55.0	68.7	60.8
		19	310	46	17	113	19	5	73.2	77.2	70.7
		20	0	0	0	151	29	4	0	0	0
		21	34	4	2	125	15	5	21.3	28.5	21.0
		22	42	7	5	75	10	5	35.8	50.0	41.1
		23	62	6	5	37	7	5	62.6	50.0	46.1
		24	26	6	6	54	10	4	32.5	60.0	37.5
	ED	25	238	26	17	103	17	4	69.7	80.9	60.4
		26	139	15	14	46	5	4	75.1	77.7	75.0
		27	271	49	16	34	6	4	88.8	80.0	89.0

APPENDIX
(Continued)

Subject	Condition	Session	Rich schedule			Lean schedule			Ratio		
			Time (sec-onds)	Respon- ses	Rein- forc- ers	Time (sec-onds)	Respon- ses	Rein- forc- ers	% Time	% Re- spon- ses	% SR +
Study 1	UD	28	333	40	16	87	12	4	79.2	80.0	76.9
		29	454	71	20	44	5	3	91.1	86.9	93.4
		30	407	62	20	67	8	4	85.5	83.3	88.5
		31	203	24	13	33	4	3	86.0	81.2	85.7
		32	502	72	20	26	5	4	95.0	83.3	93.5
		33	156	13	11	23	2	2	87.1	84.6	86.6
		34	508	59	22	0	0	0	100	100	100
		35	396	30	17	5	1	0	98.7	100	96.7
		36	0	0	0	31	2	2	0	0	0
		37	0	0	0	0	0	0	0	0	0
		38	50	6	5	106	19	4	32.0	55.5	24.0
		39	51	7	6	101	12	4	33.5	60.0	36.8
		40	101	15	11	44	7	4	69.6	73.3	68.1
		41	19	4	3	106	14	4	7.2	42.8	22.2
		42	250	36	16	10	1	1	96.1	94.1	97.2
		43	436	43	18	0	0	0	100	100	100
		44	360	44	18	0	0	0	100	100	100
		45	266	27	16	0	0	0	100	100	100
		46	0	0	0	0	0	0	0	0	0
		47	0	0	0	0	0	0	0	0	0
		48	0	0	0	0	0	0	0	0	0
		49	0	0	0	0	0	0	0	0	0
		50	0	0	0	0	0	0	0	0	0
		51	0	0	0	0	0	0	0	0	0
		52	410	31	19	30	2	2	93.1	90.4	93.9
		53	160	13	9	78	10	4	67.2	69.2	56.5
		54	0	0	0	0	0	0	0	0	0
		55	0	0	0	73	4	3	0	0	0
		56	163	18	13	0	0	0	100	100	100
		57	98	10	8	0	0	0	100	100	100
		58	36	2	1	115	13	4	23.8	20.0	13.3
		59	0	0	0	114	21	4	0	0	0
		60	0	0	0	54	9	4	0	0	0
		61	22	2	2	168	23	5	11.5	28.5	8.0
		62	321	26	15	114	18	4	73.7	78.9	59.0
		63	236	24	14	39	7	4	85.8	77.7	77.4
		64	121	12	11	0	0	0	100	100	100
		65	212	16	14	28	7	4	88.3	77.7	69.5
Study 2 Dee	ED	1	391	35	9	209	18	3	65.1	75.0	66.0
		2	418	37	9	182	14	2	69.6	81.8	72.5
		3	421	39	11	179	14	3	70.1	78.5	73.5
		4	441	46	9	159	14	2	73.5	81.8	76.6
		5	424	38	8	176	18	2	70.6	80.0	67.8
		6	435	39	9	165	17	4	72.5	69.2	69.6
		7	393	39	7	207	22	4	65.5	63.6	63.9
		8	383	51	7	217	27	2	63.8	77.7	65.3
	DHQ	9	405	39	10	195	20	3	67.5	76.9	66.1
		10	446	40	10	154	14	0	74.3	100	74.0
		11	421	46	10	179	18	2	70.1	83.3	71.8

APPENDIX
(Continued)

Subject	Condition	Session	Rich schedule			Lean schedule			Ratio		
			Time (sec- onds)	Respon- ses	Rein- forcers	Time (sec- onds)	Respon- ses	Rein- forcers	% Time	% Re- sponses	% SR +
		12	455	45	9	145	17	2	75.8	81.8	72.5
		13	600	55	12	0	0	0	100	100	100
		14	600	64	12	0	0	0	100	100	100
		15	570	58	12	30	3	0	95.0	100	95.0
		16	492	51	11	108	11	2	82.0	84.6	82.2
		17	600	68	12	0	0	0	100	100	100
		18	600	63	12	0	0	0	100	100	100
		19	600	65	12	0	0	0	100	100	100
	ILQ	20	77	54	1	523	12	6	12.8	14.2	81.8
		21	31	7	0	569	70	6	5.1	0	9.0
		22	109	13	2	491	66	6	18.1	25.0	16.4
		23	125	15	4	475	56	6	20.8	40.0	21.1
		24	157	20	1	443	45	4	26.1	20.0	30.7
		25	221	24	5	379	46	5	36.8	50.0	34.2
		26	86	11	2	514	61	6	14.3	25.0	15.2
		27	381	4	1	562	68	6	6.3	14.2	5.5
	DHQ	28	41	4	0	559	65	6	6.8	0	5.7
		29	600	69	12	0	0	0	100	100	100
		30	600	59	12	0	0	0	100	100	100
		31	549	68	12	51	5	2	91.5	85.7	93.1
		32	523	63	12	77	11	1	87.1	92.3	85.1
		33	565	69	12	35	4	2	94.1	85.7	94.5
		34	498	55	12	102	13	2	83.0	85.7	80.8
		35	478	52	10	122	14	0	79.6	100	78.7
	ILQ	36	506	56	12	94	12	2	84.3	85.7	82.3
		37	72	9	2	528	57	6	12.0	25.0	13.6
		38	0	0	0	600	61	6	0	0	0
		39	169	23	2	431	55	5	28.1	28.5	29.4
		40	0	0	0	600	68	6	0	0	0
		41	0	0	0	600	63	6	0	0	0
		42	158	20	5	442	52	6	26.3	45.4	27.7
		43	189	24	5	411	49	5	31.5	50.0	32.8
		44	69	8	1	531	57	5	11.5	16.6	12.3
		45	224	27	8	376	43	4	37.3	66.6	38.5
		46	727	11	2	528	66	6	12.0	25.0	14.2
		47	28	3	0	572	60	6	4.6	0	4.7
		48	0	0	0	600	70	6	0	0	0
		49	0	0	0	600	68	6	0	0	0
Leah	ED	1	339	28	17	58	3	3	85.3	85.0	90.3
		2	220	12	12	38	2	2	85.2	85.7	85.7
		3	83	7	6	0	0	0	100	100	100
		4	362	28	19	49	5	4	88.0	82.6	84.8
		5	301	25	17	41	3	3	88.0	85.0	89.2
		6	15	1	1	44	4	2	25.4	33.3	20.0
		7	387	36	18	47	4	3	89.1	85.7	90.0
		8	68	5	5	4	0	0	94.4	100	100
		9	278	27	13	13	1	1	95.5	92.8	96.4
		10	715	5	5	0	0	0	100	100	100
		11	352	37	21	70	6	5	83.4	80.7	86.0

APPENDIX
(Continued)

Subject	Condition	Session	Rich schedule			Lean schedule			Ratio		
			Time (sec- onds)	Respon- ses	Rein- forcers	Time (sec- onds)	Respon- ses	Rein- forcers	% Time	% Re- sponses	% SR +
	DHQ	12	0	0	0	29	3	2	0	0	0
		13	74	5	5	0	0	0	100	100	100
		14	0	0	0	73	6	5	0	0	0
		15	0	0	0	92	6	5	0	0	0
		16	12	1	1	158	5	4	7.0	20.0	16.6
		17	0	0	0	160	15	4	0	0	0
		18	0	0	0	169	17	5	0	0	0
	ILQ	19	0	0	0	168	15	6	0	0	0
		20	78	6	6	0	0	0	100	100	100
		21	231	22	14	0	0	0	100	100	100
		22	295	25	13	0	0	0	100	100	100
		23	293	27	14	69	6	4	80.9	77.7	81.8
		24	188	18	12	54	4	4	77.6	75.0	81.8
		25	178	16	10	0	0	0	100	100	100
		26	348	31	15	0	0	0	100	100	100
		27	103	8	8	0	0	0	100	100	100
		28	51	5	5	0	0	0	100	100	100
		29	169	18	12	82	7	4	67.3	75.0	72.0
		30	93	7	6	140	12	5	39.9	54.5	36.8
		31	106	11	8	0	0	0	100	100	100
		32	139	12	10	20	2	2	87.4	83.3	85.7
	DHQ	33	0	0	0	66	5	5	0	0	0
		34	0	0	0	79	5	4	0	0	0
		35	0	0	0	74	5	4	0	0	0
		36	0	0	0	76	5	5	0	0	0
		37	90	5	5	0	0	0	100	100	100
		38	103	5	5	0	0	0	100	100	100
		39	265	23	15	0	0	0	100	100	100
		40	246	15	10	0	0	0	100	100	100
		41	240	11	10	0	0	0	100	100	100
		42	0	0	0	67	5	5	0	0	0
	ILQ	43	0	0	0	69	5	4	0	0	0
		44	87	6	6	0	0	0	100	100	100
		45	94	5	5	0	0	0	100	100	100
		46	280	14	12	0	0	0	100	100	100
		47	97	5	5	0	0	0	100	100	100
		48	80	6	6	0	0	0	100	100	100
		49	49	4	4	29	3	3	62.8	57.1	57.1
		50	47	5	5	30	3	3	61.0	62.5	62.5
		51	0	0	0	107	11	4	0	0	0
		52	410	0	0	114	9	5	0	0	0