ASSESSING INFLUENTIAL DIMENSIONS OF REINFORCERS ON CHOICE IN STUDENTS WITH SERIOUS EMOTIONAL DISTURBANCE

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We examined how reinforcer rate, quality, delay, and response effort combined to influence the choices of 6 youths with learning and behavior difficulties, and the viability of an assessment methodology derived from matching theory for determining differential responsiveness to those reinforcer and response dimensions. The students were given two concurrent sets of math problems that were equal on two dimensions but competed on two other dimensions (e.g., one set yielded higher rate and lower quality reinforcement than the other). Competing dimensions were counter-balanced across the six conditions of the initial assessment phase, permitting assessment of each dimension on time allocation. The conditions resulting in the most and least time allocated to one problem set alternative relative to the other were then replicated. Time allocated to each of the problems within sets was differentially affected by the reinforcer and/or response dimensions, with allocation patterns varying across students. The results are discussed in the context of implications for the design of treatments and extrapolations from basic research on matching and behavioral economics.

DESCRIPTORS: assessment, choice, matching theory, reinforcer dimensions, seriously emotionally disturbed students

The matching law (Baum, 1974; Herrnstein, 1961, 1970) has contributed to an understanding of reinforcement effects by making explicit their relativistic properties; that is, it considers the effects of a reinforcer on behavior in the context of other reinforcers for concurrent response options. Because the effect of a reinforcer depends on its relation to other reinforcers, investigations of reinforcer interactions have received increasing emphasis (Green & Freed, 1993).

For example, in previous studies of special ed-

ucation students' response allocation across alternative math tasks on concurrent variable-interval (conc VI VI) schedules of reinforcement, differences between the response options in the quality of reinforcers (Neef, Mace, Shea, & Shade, 1992) or in the delay to reinforcer access (Neef, Mace, & Shade, 1993) produced a preference for the higher quality or more immediate reinforcer that altered the effects produced by rate of reinforcement alone. On the other hand, differences in response effort (represented by problem difficulty) between the task alternatives did not alter the distribution of responding in proportion to the relative rate of reinforcement (Neef, Mace, Shea, & Shade, 1991).

Because response alternatives in applied situations are typically asymmetrical on a number of dimensions (e.g., reinforcer rate, amount, quality, delay, and response effort), consideration of these complexities may aid in understanding, predicting, and managing behavior (Fuqua, 1984; Green & Freed, 1993; Mace & Shea, 1990; Neef et al., 1992; Shull & Fuqua, 1993). The purposes of the

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present study were to determine how reinforcer rate, quality, delay, and response effort combine to influence the choices of individuals with learning and behavior difficulties, and the viability of an assessment methodology derived from matching theory for determining differential responsiveness to various reinforcer dimensions. We therefore sought to conduct a more comprehensive and efficient assessment of the influence of the reinforcer and response dimensions that have been examined separately in previous research.

METHOD

Participants and Setting

Six students in a special education program for youths with serious emotional disturbance and learning difficulties participated in the study. The students were referred by their teachers because of their need for assistance in completing instructional tasks and for practice in arithmetic skills. S1 was a 17-year-old female, S2 was a 17-year-old male, S3 was a 14-year-old male, S4 and S5 were 18-year-old females, and S6 was a 15-year-old male. Each of the students had been diagnosed as seriously emotionally disturbed; S5 and S6 had, in addition, a diagnosis of mild mental retardation, with full-scale Wechsler Intelligence Scale for Children—Revised (WISC-R) IQ scores of 69 and 60, respectively. S1, S3, and S5 were in the borderline range of intellectual functioning, with WISC-R IQ scores of 79, 80, and 79, respectively. S2's IQ score was in the below-average range (86). The Peabody Individualized Achievement Test (PIAT) had been administered to S5 and S6, yielding math scores at the 2.8 and 3.7 grade level, respectively. The study was conducted in a small room in the school building containing a large table and two chairs, with only the student and the experimenter(s) present.

Experimental Conditions and Procedures

Each student participated in two consecutive 10-min sessions per day, 3 to 4 days per week. For S1, S2, S3, and S4, the experimental preparations were the same as those described in Neef *et al.* (1992, 1993) and Mace, Neef, Shade, and Mauro

(1994): Two different-colored stacks of arithmetic problems were placed in front of the student, and designated reinforcers were delivered contingent on correct answers to the arithmetic problems according to a specified conc VI VI schedule. The experimenter deposited the reinforcers in the transparent plastic cup behind the respective stack of problems. Incorrect problems were immediately marked with an "X."

The procedures were automated on a Macintosh® IIfx computer for S5 and S6. During each trial, two different-colored problems appeared on the monitor (choice screen). A choice response (moving the cursor to the problem and pressing the mouse) produced only the selected problem on the monitor (problem screen). The problem could then be calculated by using the mouse to move numbers selected from the bottom of the screen to the appropriate column and row (or to move the pencil pictograph over a number to "erase" it). The problem remained on the screen until (a) the correct answer was entered (signaled by clicking the mouse on the "check answer" box on the screen), (b) 10 s elapsed without entering an answer, unless the pause button was pressed (which restarted the 10-s interval), or (c) the "next problem" box was selected. The next two problem options then appeared (choice screen), initiating the next trial. Following an incorrect response, the words "try again" appeared on the screen, providing an opportunity for the student to change the answer. Reinforcer (point) delivery was signaled by a chime (for problems from one set) or a bell (for problems from the other set) according to the schedule in effect for the problem set. Each time the problem options were presented on the choice screen, the cumulative number of reinforcers (points) obtained under each problem set was displayed under the respective problem, along with the type of back-up reinforcers for which the points from that set could be exchanged ("Store A" or "Store B") and when those reinforcers would be made available (e.g., "today" or "Friday").

The students participated in 4 to 12 preexperimental sessions to familiarize them with the task and (for S5 and S6) operation of the computer.

Variables	BL1/BL2	R/Q		R/E		R/I		Q/E		I/Q		I/E	
	Problem Set 1	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)	High	Low	High	Low	High	Low	Med.	Med.	Med.	Med.	Med.	Med.
Quality of Reinf (Q)	High (Low)	Low	High	High	High	High	High	High	Low	Low	High	High	High
Delay in Access to Reinf (I)	Imm. (Delay)	Imm.	Imm.	Imm.	Imm.	Delay	Imm.	Imm.	Imm.	Imm.	Delay	Imm.	Delay
Response Effort (E)	Low (High)	Med.	Med.	High	Low	Med.	Med.	High	Low	Med.	Med.	High	Low

Figure 1. Dimensions of the response alternatives for each experimental condition. Shaded boxes represent the competing dimensions in the respective condition.

Count-down timers were used initially with S1 through S4 to assist them in discriminating schedule conditions (as described in Neef et al., 1992); timers were discontinued during the final two preexperimental sessions.

During the experimental conditions, the two response alternatives varied binomially along two of four dimensions (reinforcer rate, quality, and delay, and response effort) depending on the condition in effect. The exception was during the baseline phases in which only one set of problems was presented and the dimensions were all at the relatively favorable or unfavorable values (only one set of problems was presented during baseline because identical options would be expected to produce arbitrary or exclusive responding). The conditions are depicted in Figure 1.

Rate of reinforcement refers to the concurrent schedules in effect for the respective sets of problems. VI 30 s was used for the "high" value, VI 60 s for the "medium" value, and VI 90 s for the "low" value.

Reinforcer quality refers to the student's relative preference for the reinforcers associated with the two respective problem sets. For S1 through S4, nickels served as the high-quality reinforcer, and the equivalent in "program money," exchangeable for items and privileges in the school's token economy, served as the low-quality reinforcer. These designations were made on the basis of asking the student at the start of each session which he or

she preferred to earn that day. For S5 and S6, a preference assessment was conducted at the start of each session. Ten items nominated as preferred by the student were displayed (e.g., soda, snack item, cosmetic item, shoe laces, batteries, magazine, etc.). The student was asked to 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 four items. The five selected items were placed on a table labeled "Store A," which served as the high-quality reinforcer. The remaining five items were placed on a table labeled "Store B," which served as the low-quality reinforcer. Points earned on the respective response alternatives could be used to purchase any item(s) from the designated store. Items were identically priced such that one to three items could typically be purchased during a session.

*Reinforcer delay*¹ refers to whether access to reinforcers earned for the respective set of problems was immediate (at the end of the session) or delayed (the next day). Students were given a receipt and date for delayed reinforcer delivery.

*Response effort*¹ refers to the relative ease with which problems from the respective sets of problems could be completed, as determined by pretest performance on samples of problems ranging from

¹ Our assessment of reinforcer delay and response effort differs from that typically used in basic research, in which delay refers to the time to each reinforcer from the response that produced it and response effort refers to the physical force required to make the response.

1-digit addition and subtraction to 4-digit multiplication and division with regrouping operations. Problems completed at the highest rate with the highest accuracy and confirmed by the classroom teacher as "review" or "fluency" targets were designated as low effort. Problems that were completed at a lower rate with at least 50% accuracy and that were confirmed by the teacher as "acquisition" or "mastery" targets were designated as high effort.

Experimental Design

We used an adaptation of the model for brief functional analysis techniques used by Cooper, Wacker, Sasso, Reimers, and Donn (1990). The baseline phases were used to establish response rates when the independent variables were uniformly favorable or unfavorable. During the initial assessment phase, at least two consecutive sessions were conducted for each experimental condition, with the conditions presented in random order. (If the first two data points during any condition differed substantially, additional sessions were conducted until stability was achieved.) The presentation of the set of experimental conditions allowed three replications of each independent variable at both equal (e.g., high/high) and unequal (e.g., high/low) values across the two response alternatives; competing dimensions were counterbalanced across the six conditions, allowing the effects of each dimension to be examined in relation to every other dimension. During the replication phase, the experimental conditions that resulted in the greatest and lowest percentage of time allocation to the Set 1 alternative, respectively, were reinstituted.

Data Collection and

Interobserver Agreement

For S1 through S4, the experimenter used two stopwatches to record the time allocated to each of the response alternatives (defined as the student being visually oriented to the problem from the respective stack) during continuous 1-min intervals (described in Neef *et al.*, 1992, 1993). A record of the response sequences and reinforcer deliveries during each session was also maintained. This allowed determination of the number of problems

completed correctly and incorrectly for each of the response alternatives, the order in which problems were completed across the two sets, the number of times reinforcement was delivered under each schedule, and which responses produced reinforcement.

A second observer collected interobserver agreement data on 29.4%, 37.9%, 27.0%, and 33.3% of the sessions for S1 through S4, respectively, and generally at least once per experimental condition. Interobserver agreement was assessed in the manner described in Neef *et al.* (1992, 1993). Interval-by-interval comparisons of observers' records for time allocation yielded mean agreement scores of 100% for S1, 94.6% for S2 (range, 80% to 100%), 100% for S3, and 95% for S4 (range, 70% to 100%). Mean agreement scores for reinforcer delivery were 100% for S1, 99.6% for S2, 100% for S3, and 98.6% for S4.

For S5 and S6, a computer-generated summary of the cumulative duration of problem display (as an indication of time allocation), the number of reinforcers obtained, the number of problems attempted, and the number of problems completed correctly for each problem set was obtained for each session.

RESULTS

Figure 2 shows the percentage of time each participant allocated to the Set 1 alternative [$T1/(T1 + T2)$] under each of the experimental conditions (the percentage of time on the Set 2 alternative is the inverse). Time allocation was used as the primary dependent variable because response allocation could reflect the demand characteristics of the experimental situation (i.e., fewer high-effort problems could result from their longer completion time compared with low-effort problems). Baseline data (which served to establish response rates at equal values) are not shown because, with only one response alternative, time allocation to that alternative was always 100%.

During the initial assessment, S1 allocated the greatest percentage of time to the Set 1 alternative

Figure 2. Percentage of time allocated to Set 1 arithmetic problem options across experimental conditions for S1 through S6.

in the quality versus effort (Q/E) ($M = 73.6\%$), rate versus effort (R/E) ($M = 93.1\%$), and immediacy versus effort (I/E) conditions ($M = 86.8\%$). In each of these conditions, Set 1 alternatives were associated with high-quality reinforcers, high or medium rates of reinforcement, immediate access to reinforcers, and high response effort. When rate competed with quality of reinforcement (R/Q condition), S1 allocated an average of only 32.9% of her time to the alternative associated with the higher rate but lower quality reinforcer. When immediacy competed with quality of the reinforcer (I/Q condition), she allocated little time to the problems associated with the lower quality but more immediate reinforcers ($M = 10.0\%$). When rate competed with immediacy of reinforcement (R/I condition), she allocated an average of only 19.3% of her time to problems yielding higher rate but delayed reinforcement. Thus, the results of the initial assessment suggest that S1's choices were most influenced by the quality of the reinforcers, and were more sensitive to immediacy than rate of reinforcement. It could not be determined whether high-effort problems were favored or simply failed to override other variables. These results were confirmed in the replication phase, in which the I/Q condition produced the least time allocated ($M = 10\%$) and the R/E and I/E conditions the most time allocated to the Set 1 alternative ($M = 95\%$ and 72.7% , respectively).

S2 allocated a mean of 58.8% of the time to the problems producing higher rate but lower quality reinforcement (R/Q condition). The problems producing a higher rate of reinforcement were also favored in the R/E condition when they competed with low-effort problems ($M = 87.1\%$) and in the R/I condition when they competed with more immediate access to reinforcement ($M = 78.7\%$). In the Q/E condition, S2 allocated most of her time to the high-effort problems that produced higher quality reinforcers ($M = 91.6\%$). The percentage of time on Set 1 problems decreased to a mean of 19.8% when they were associated with lower quality reinforcers, even though access to those reinforcers was more immediate (I/Q condition). However, when rate and quality of reinforcement were

equal (I/E condition), high-effort problems that produced immediate reinforcement were favored ($M = 70.7\%$), although performance was variable (range, 31.1% to 92.0%). Replication of the R/E and I/Q conditions produced results similar to those in the initial assessment ($M = 89.6\%$ and 44.8% , respectively); the Q/E condition was not reinstituted because the student transferred to another program. Taken together, these results suggest that the choices of S2 were most influenced by rate and quality of reinforcement.

S3 allocated a mean of 69.6% of his time to the problem alternative associated with high effort and a high rate of reinforcement (R/E condition). High-effort problems were also favored when they were associated with immediate access to the reinforcers in the I/E condition ($M = 93.9\%$). When the response options competed with respect to rate versus immediacy of reinforcement (R/I condition), the student responded exclusively to Set 1 or Set 2 problems on an alternating basis, reflecting indifference. Subsequently he responded exclusively to the problems associated with higher quality reinforcers when they competed with rate of reinforcement (Set 2 problems in the R/Q condition), low response effort (Set 1 problems in the Q/E condition), or more immediate access to reinforcers (Set 2 problems in the I/Q condition). Identical results were obtained during replication of the Q/E, R/Q, and I/Q conditions. These data indicate that S3's choices were more sensitive to quality than to rate or immediacy of reinforcement.

S4 allocated an average of 94.9% of her time in the R/E condition to the problems associated with the higher rate of reinforcement and higher effort. In the Q/E condition, she allocated most of her time to the high-effort alternative, which yielded higher quality reinforcers ($M = 88.1\%$). When, in the R/Q condition, Set 1 problems were associated with lower quality but a higher rate of reinforcement than Set 2 problems, S4 allocated all her time to the latter. In the I/E condition, she responded exclusively to Set 1 problems, which were higher effort but produced immediate access to reinforcers. When reinforcer quality competed with immediate access to reinforcers (I/Q condi-

tion), she allocated an average of 33.8% of her time to the Set 1 alternative yielding immediate access to low-quality reinforcers. When immediate access to reinforcers competed with rate of reinforcement (R/I condition), she allocated a greater percentage of time to the alternative producing higher rate but more delayed access to reinforcement ($M = 67.0\%$). Alternation of the conditions producing the lowest (R/Q and I/Q) and highest percentages of time allocation to Set 1 problems (I/E and R/E) in the context of a reversal design replicated the findings of the initial assessment. The mean percentage of time allocated to Set 1 problems was 1.6%, 88.2%, 45.7%, and 77.7% for the R/Q, I/E, I/Q, and R/E conditions, respectively. These data indicate that the choices of S4 were influenced most by quality of reinforcers, and more by rate of reinforcement than by immediate access to reinforcers. As with S1, S2, and S3, S4 rarely spent time on low-effort problems in lieu of those producing more favorable consequences on the other reinforcer dimensions; however, the possibility that high-effort problems were preferred cannot be ruled out.

S5 allocated her time exclusively to one or the other set of problems on all but two sessions. Her time allocation favored problems yielding higher quality reinforcers (Set 2) versus a higher rate of reinforcement (R/Q condition); more immediate access to reinforcers (Set 2) versus a higher rate of reinforcement (R/I condition); higher quality reinforcers (Set 1) versus lower effort (Q/E condition); lower effort (Set 2) versus a higher rate of reinforcement (R/E condition); immediate access to reinforcers (Set 1) versus lower effort (I/E condition); and immediate access to reinforcers (Set 1) versus higher quality reinforcers (I/Q condition). Replication of the R/Q, I/Q, R/E, and I/E conditions produced results identical to those in the initial assessment (0%, 100%, 0%, and 100% time allocation to Set 1 problems, respectively). Thus, results for S5 indicate that immediate access to reinforcers was the most influential dimension, reinforcer quality was more influential than response effort, and rate of reinforcement least affected her time allocation.

Similar results were obtained for S6. His time allocation also favored problems yielding higher quality reinforcers versus a higher rate of reinforcement ($M = 4.0\%$ in the R/Q condition); more immediate access to reinforcers versus a higher rate of reinforcement ($M = 0\%$ in the R/I condition); more immediate access to reinforcers versus lower effort ($M = 100\%$ in the I/E condition); higher quality reinforcers versus lower effort ($M = 96\%$ in the Q/E condition); and lower effort versus a higher rate of reinforcement ($M = 4.5\%$ in the R/E condition). When the two most influential dimensions (reinforcer quality and immediate access to reinforcers) competed (I/Q condition), S6 responded exclusively to Set 2 problems on three sessions and exclusively to Set 1 problems on one initial assessment and the one replication session, suggesting indifference. The remaining conditions implemented in the replication phase produced results identical to the initial assessment phase: 100% in I/E, 0% in R/I, and 0% in R/Q. Thus, the results for S6 indicate that time allocation was most affected by the quality and immediacy of the reinforcers, and least affected by the rate of reinforcement.

DISCUSSION

Our results extend previous investigations on the separate effects of reinforcer quality (Neef et al., 1992), reinforcer delay (Neef et al., 1993), reinforcer rate (Mace et al., 1994), and response effort (Neef et al., 1991) by examining how each of the dimensions combine to influence behavior allocation. The responding of each of the students was differentially affected by the reinforcer dimensions, confirming that choice is an orderly phenomenon governed by the relativistic properties of response alternatives.

This study contributes a methodology derived from matching theory for assessing individual responsiveness to variables that collectively affect the value of reinforcers. This methodology adds to the research on functional analyses in two ways. First, it extends the focus on single reinforcement contingencies for a behavior to concurrent contingencies

for competing behavior alternatives, thereby taking into account that the effect of a particular reinforcer is always context dependent. Second, it extends the analyses of types of reinforcement contingencies that maintain behavior to assessment of the reinforcement dimensions that are most influential. The profiles yielded by this assessment differed across the 6 subjects.

Examination of the relative influence of different reinforcer dimensions may be helpful in determining the extent to which alternative reinforcers are interchangeable or, based on economic principles, the relationship between commodities. The substitutability of reinforcers is evaluated according to the degree to which consumption of one commodity (or reinforcement obtained from one schedule) changes as the value of another commodity (or rate of reinforcement obtained from the alternative schedule) is changed. On a continuum of interactions, altering the price of one reinforcer in a pair may produce (a) a joint increase or decrease in consumption of both (if they are complementary), (b) no effect on consumption of the other (if they are independent), or (c) a decrease in consumption of one and a compensatory increase in the other (if they are substitutable) (Green & Freed, 1993). Qualitative differences between the reinforcers was an influential dimension for all 6 students in our study, and the data suggest that, in at least some cases, the reinforcers were independent. For example, despite a decrease in the price of one type of reinforcer (R1) in the rate versus quality condition (i.e., a higher rate of reinforcement for an equivalent response), S3 and S6 responded almost exclusively to the other (R2) reinforcer. Similar results were obtained in the quality versus effort condition, in which the price (responses per reinforcer) was made relatively low for R2 by decreasing the response requirement per reinforcer unit (i.e., there were fewer responses in the chain for low-effort problems), and near-exclusive responding occurred to R1. The results for S4 and S5 differed from those for S3 and S6 because an increase in another dimension (delay to reinforcer access) did produce decreased responding to that reinforcer in the immediacy versus quality condition. Thus, these

data provide preliminary information as to the conditions under which qualitatively different reinforcers may (or may not) be (or become) substitutable.

The information yielded by this assessment has potentially important implications for treatment by suggesting which reinforcer or response dimensions should be altered, and to what extent. The assessment profiles for S5 and S6, for example, suggest that even a large differential in the rate of reinforcement could fail to produce desired changes in behavior if the particular reinforcer maintaining the undesirable behavior was different from, and non-substitutable for, the reinforcer for a more desirable alternative response. For these students, the indicated treatment would involve arranging for the desirable behavior to produce more immediate reinforcement (S5) or reinforcers that are as immediate but more highly preferred than those produced by the undesirable behavior (S5 and S6).

Our results must be interpreted cautiously in view of several limitations. First, conclusions regarding the extent to which an individual's behavior is differentially affected by particular reinforcer and response dimensions are limited to the specific values of the independent variables that were used. In order to enhance the social relevance and prescriptive utility of the findings, we selected values of the independent variables that the students would normally encounter in their day-to-day environments (e.g., "program money" was used in the comparison of quality of reinforcers for the 4 students for whom the token economy was a central feature of the school program). Although determining the generality of the findings for individual students (as well as determining the substitutability of various reinforcers) would require replication of the experimental conditions at different values of the independent variables (e.g., different rates of reinforcement), the potential usefulness of additional analyses must be considered in relation to their practicality and efficiency.

A second limitation of the study is that exclusive responding to one alternative precluded contact with differential contingencies on dimensions that might otherwise control behavior allocation. This is es-

pecially problematic in interpreting the results of unequal schedules of reinforcement that, unlike the other dimensions, could be discriminated only by sampling both response alternatives. This might account for the fact that the choices of S5 and S6 (which were often exclusive) were least influenced by rate of reinforcement. It might therefore be helpful to require subjects to sample each of the response alternatives before beginning the condition. In addition, it would be instructive to solicit participants' descriptions of the performance rules they applied in distributing their behavior between the concurrent alternatives to determine the extent to which the relevant reinforcement contingencies were discerned.

Subsequent investigations might examine the viability of our assessment procedure for other purposes. For example, given that impulsivity is commonly associated with attention deficit hyperactivity disorder, it might be expected that a significant proportion of that population of children would demonstrate extreme responsiveness to immediacy of reinforcement; if so, the assessment might prove to be useful as a diagnostic tool, as well as a means of evaluating the effectiveness of stimulant medication (e.g., methylphenidate) in attenuating behavioral sensitivity to that dimension (i.e., facilitating self-control). It remains for future research to determine the usefulness of this type of assessment in guiding and predicting the results of treatment efforts, and the applicability of basic research findings on variables that may alter these relations.

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