

*NONCONTINGENT REINFORCEMENT, ALTERNATIVE REINFORCEMENT, AND
THE MATCHING LAW: A LABORATORY DEMONSTRATION*

CHERYL L. ECOTT

ADVOSERV, INC.

AND

THOMAS S. CRITCHFIELD

ILLINOIS STATE UNIVERSITY

Basic researchers, but not most applied researchers, have assumed that the behavior-decelerating effects of noncontingent reinforcement result at least partly from adventitious reinforcement of competing behaviors. The literature contains only sketchy evidence of these effects because few noncontingent reinforcement studies measure alternative behaviors. A laboratory model is presented in which concurrent schedules of contingent reinforcement were used to establish a “target” and an “alternative” behavior. Imposing noncontingent reinforcement decreased target behavior rates and increased alternative behavior rates, outcomes that were well described by the standard quantitative account of alternative reinforcement, the generalized matching law. These results suggest that adventitious reinforcement of alternative behaviors can occur during noncontingent reinforcement interventions, although the range of conditions under which this occurs remains to be determined in future studies. As an adjunct to applied studies, laboratory models permit easy measurement of alternative behaviors and parametric manipulations needed to answer many research questions.

DESCRIPTORS: adventitious reinforcement, alternative reinforcement, college students, noncontingent reinforcement, response-independent reinforcement

Interventions incorporating noncontingent reinforcement (NCR)¹ are easy to implement, effective in weakening problem behavior, and relatively free of side effects often associated with other decelerative interventions (e.g., Lindberg, Iwata, Roscoe, Wors-

dell, & Hanley, 2003; Vollmer, Marcus, & Ringdahl, 1995). The clear documentation of these effects, however, belies a degree of uncertainty about the behavioral mechanisms that create them. To date, two mechanisms have received considerable attention in the applied behavior analysis literature: (a) NCR is like extinction in that it disrupts the response–reinforcer contingency, and (b) NCR causes satiation by inflating the supply of reinforcers, thereby undermining the establishing operations that support problem behavior (e.g., Kahng, Iwata, Thompson, & Hanley, 2000).

Basic researchers, by contrast, often assume that NCR effects result from adventitious strengthening of alternative behavior, which, under conditions of limited time and effort, competes with, or “crowds out,” the behavior of interest (e.g., Henton & Iversen, 1978; Lattal, 1995; Skinner, 1948). Al-

We thank Mei-Sho Jong for superior computer programming support, Chris Newland and Jim McCoy for suggestions made during the development of the project, Jaime Weaver for help with data collection, and Wayne Fisher for a useful suggestion regarding data presentation. Some of the data for 1 participant (Jim) were presented in a previous report describing our procedure for arranging reinforcers (Critchfield, Schlund, & Ecott, 2000).

Address correspondence to Cheryl L. Ecott, 4185 Kirkwood St. Georges Rd., Bear, Delaware 19701 (e-mail: tallypal@aol.com) or T. Critchfield, Department of Psychology, Illinois State University, Normal, Illinois 61790 (e-mail: tsccrit@ilstu.edu).

¹ Some observers regard the term *noncontingent reinforcement* as conceptually imprecise (e.g., Carr, 1996; Poling & Normand, 1999). We will address this concern after describing data that may be relevant to it.

though at least one applied report has described NCR-related decreases in target behavior accompanied by increases in alternative behavior (Roane, Fisher, & Sgro, 2001), for the most part alternative-reinforcement effects have received little attention from applied researchers. Response competition sometimes has been invoked in applied NCR studies, but not in reference to the alternative-reinforcement hypothesis. For instance, in a study involving children with severe behavior disorders, the investigators observed that problem behavior tended to decrease momentarily while the children interacted with the stimuli used as noncontingent reinforcers (Hagopian, Crockett, van Stone, DeLeon, & Bowman, 2000; for similar effects see Fisher et al., 1999). In this instance, target behavior apparently was weakened via competition with the act of consuming reinforcers, rather than via competition with nonconsumptive behaviors that were adventitiously strengthened by these reinforcers. This is a different sort of response competition than normally is implicated in the alternative-reinforcement hypothesis.

In contemporary behavior analysis, basic and applied efforts are closely coordinated (e.g., Mace, 1994; see also Critchfield, 2002), in part because applied workers have sought to allow theory to guide practice. The divergent interpretations that basic and applied researchers apply to NCR is worrisome in this regard. Whether applied researchers should more systematically consider alternative reinforcement effects depends, however, on the strength of evidence that indicates that such effects really occur. Surprisingly, relevant evidence is in short supply, primarily because most studies of NCR (both basic and applied) have quantified only a single behavior (e.g., Lachter, Cole, & Schoenfeld, 1971; Lattal, 1974; Rachlin & Baum, 1972; Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993). Such studies

may demonstrate that NCR tends to decelerate target behavior, but they leave changes in alternative behavior to the imagination.

Attempts to measure alternative behaviors, when they occur, often are ambiguous because of the complexities of multiple-response environments. For example, in contrast to the Roane et al. (2001) findings mentioned previously, some applied investigators reported searching for, but not finding, systematic evidence of strengthening of alternative behaviors. Such results are difficult to interpret. Given the broad range of alternative behaviors that can occur in applied settings, do negative results reflect the absence of alternative-reinforcement effects or merely a failure to detect them? A similar concern applies to laboratory studies of "superstitious" conditioning (e.g., Skinner, 1948) in which NCR is delivered and a variety of ongoing behaviors are monitored for signs of strengthening. In a typical case, Ono (1987) found adventitious strengthening effects in only 3 of 20 subjects. Did these effects occur in only a few participants, or were they detected in only a few? When the experimental environment permits a wide range of alternative behaviors, there is no guarantee that experimental observations will focus on those that ultimately change due to adventitious strengthening.

All told, the alternative-reinforcement hypothesis has limited empirical support, not because the findings of relevant studies contradict it, but rather because few studies have been designed in a manner that bears directly on it. This brief survey of the literature points to a need for continued research on the mechanisms underlying NCR effects and to two likely features of studies that will prove to be informative. First, experimental procedures are needed that measure multiple behaviors, but, second, the range of possible alternative behaviors must be sufficiently small that experimenters are likely to measure those that are affected by NCR.

NCR and the Matching Law

Consistent with the goal of monitoring multiple responses, some writers have proposed that the effects of NCR interventions be conceptualized in terms of concurrent reinforcement schedules: those that affect target behaviors, and those that affect alternative behaviors (e.g., Fisher et al., 1999; Hagopian et al., 2000; McDowell, 1989). In the laboratory, concurrent schedules of reinforcement can be readily arranged to create a target behavior (e.g., representing a problem behavior that has been marked for deceleration) and a representative alternative behavior. The task can be structured to keep participants quite busy, limiting the range of behaviors available to measure. Under conditions like these, it should be fairly easy to evaluate the effects of NCR on both target and alternative behaviors.

In evaluating the alternative-reinforcement hypothesis, it is important to determine whether NCR effects are subsumed under a standard account of concurrent-schedule performance, the matching law (see Baum & Rachlin, 1969; Hagopian et al., 2000; McDowell, 1989). The matching law (Baum, 1974) is a quantitative formulation predicting that the allocation of time and effort to Behavior B_1 is a function of the reinforcement that affects both this behavior and others (e.g., B_2) that occur in the same context. The matching relation was first described by Herrnstein (1961) as

$$\frac{B_1}{B_1 + B_2} = \frac{R_1}{R_1 + R_2}, \quad (1)$$

in which the ratio of Behaviors B_1 and B_2 matches the ratio of their associated reinforcement frequencies, R_1 and R_2 . Baum showed that a simple linear function could describe this relation if the terms on either side of the equality were expressed as ratios (rather than proportions) and were trans-

formed as natural logarithms. In Baum's generalized form of the matching law,

$$\log\left(\frac{B_1}{B_2}\right) = a \log\left(\frac{R_1}{R_2}\right) + \log b, \quad (2)$$

the fitted parameter a is the slope of the linear function and is considered to be an estimate of the individual's sensitivity to differences in reinforcement rates for the two behaviors. The fitted parameter $\log b$ is the intercept of the linear function, and it describes any pervasive bias for one of the sources of reinforcement.

For immediate purposes, the details of these quantitative expressions are not as important as the general theme that strengthening one behavior comes at the expense of other behaviors. A number of analyses show the matching law to provide a good account of various nonlaboratory phenomena that involve competing repertoires and contingent reinforcement (e.g., McDowell, 1982, 1989; Myerson & Hale, 1984; Pierce & Epling, 1995; Redmon & Lockwood, 1986; Vollmer & Bourret, 2000). In applying this perspective to NCR, some writers have argued that there is no a priori reason to distinguish between strengthening that results from contingent reinforcement and that which adventitiously results from noncontingent reinforcement (e.g., Baum & Rachlin, 1969; Hagopian et al., 2000; McDowell, 1989). Because the matching law is an explicit alternative-reinforcement account, its success in describing NCR effects speaks directly to the plausibility of the alternative-reinforcement hypothesis of NCR.

At an empirical level, it remains to be seen whether NCR effects in concurrent schedules are anticipated by the matching law. Some concurrent-schedules studies that are widely believed to answer this question (e.g., see McDowell, 1989) have been misinterpreted. Consider a study in which pigeons could stand at either end of a rectangular chamber, where feeders were programmed to

provide food on variable-time schedules (Baum & Rachlin, 1969; for similar procedures, see Brownstein, 1971; Brownstein & Pliskoff, 1968). Although the reinforcement schedules were nominally independent of behavior, food was delivered only at the end where the pigeon's weight was detected by a pressure-sensitive floor panel (the other feeder was disabled at this time). Thus, "non-contingent" food was fully contingent on the responses "standing on the left" and "standing on the right," which were the behaviors predicted in matching-law analyses. A few studies have employed true NCR schedules but in ways that are not informative to the present discussion—for example, too few conditions were completed to support a matching analysis (e.g., Madden & Perone, 2003), or the data were presented in a way that made alternative-behavior effects hard to evaluate (e.g., Lattal & Abreu-Rodrigues, 1997, Experiment 3).

To determine whether alternative-reinforcement effects can occur under NCR, the present study used concurrent reinforcement schedules to mimic some aspects of the "division of labor" between target and other behaviors in natural settings. College students worked for point-based reinforcers in a two-alternative concurrent schedule in which one response was considered the target behavior and the other was considered alternative behavior. Compared to situations in which only the target behavior is under experimental control, this procedure increased the likelihood of detecting alternative-reinforcement effects if they occurred.

Reinforcement was fully response contingent during baseline, and during other conditions reinforcement that had been contingent on the target behavior was converted to NCR. The experimental manipulations followed a parametric design used in several single-operant laboratory studies of NCR (e.g., Bacotti, 1978; Lattal, 1974; Redd, 1969). Across conditions, a percentage of

target-behavior reinforcers was converted to NCR, yielding conditions in which 0% to 100% of the reinforcers were contingent on target behavior. This manipulation is conceptually similar to NCR-plus-extinction interventions (e.g., Hagopian et al., 2000).

Based on previous studies, NCR was expected to reduce rates of the target behavior. Of primary interest was whether this effect would be accompanied by increased rates of the alternative behavior, as predicted by the alternative-reinforcement hypothesis. Note, however, that such an outcome supports the alternative-reinforcement hypothesis only if it is directly related to a redistribution of reinforcement occurring under NCR (i.e., noncontingent money deliveries follow, and strengthen, alternative behavior). We applied analyses based on the generalized matching law to evaluate this possibility.

METHOD

Participants and Apparatus

Participants were 6 undergraduate students. One of the original volunteers was dropped from the study after showing a tendency to make only the target response during sessions (hence, no experimentally measured alternative behavior, and no contact with changing contingencies). The remaining 5 students participated for up to 10 hr, spread across up to five laboratory visits, in exchange for bonus course credit. The amount of course credit nominally depended on duration of participation, according to policies of individual instructors, within Psychology Department guidelines that bonus credit not exceed 2% of the course total. "Participation time" was defined, and accumulated, according to procedures described below.

Each participant worked alone in a small room containing a desk, a VGA color monitor, and a mouse. Speakers in the room played soft instrumental music to help mask

distractions. An IBM-compatible computer in an adjacent room presented experimental stimuli and recorded responses according to a custom program written in the BASIC programming language using QuickBasic®.

Procedure

Reinforcers. Using a technique employed in several previous studies (Critchfield & Magoon, 2001; Innis, Lane, Miller, & Critchfield, 1998; Lane, Clow, Innis, & Critchfield, 1998; Lane & Critchfield, 1998), course credit was linked to the experimental task in a manner designed to establish points as reinforcers. The informed consent agreement indicated that seconds of participation time could be accumulated during experimental tasks, and that messages would indicate when seconds had been awarded. Participants were told further that the duration of participation that would be documented for extra credit purposes depended entirely on the accrual of these seconds. Note that instructors of the students' psychology courses independently set exchange rates (course bonus points earned per hour of participation) within the general guideline that no more than 10 hours of research participation could be converted to bonus credit valued at no more than about 2% of the semester total.

The local Institutional Review Board research protocol actually required that (a) all participants receive credit at least commensurate with time actually spend in the experiment, and (b) any participant who earned fewer seconds than actually spent in the experiment be debriefed immediately. Because of the time-based nature of the experimental schedules, it was possible to predict with reasonable accuracy the rate of accrual of seconds, and all participants earned credit commensurate with their actual time in the experiment. We have found reinforcers created in this way to operate like other, more standard, laboratory reinforcers along

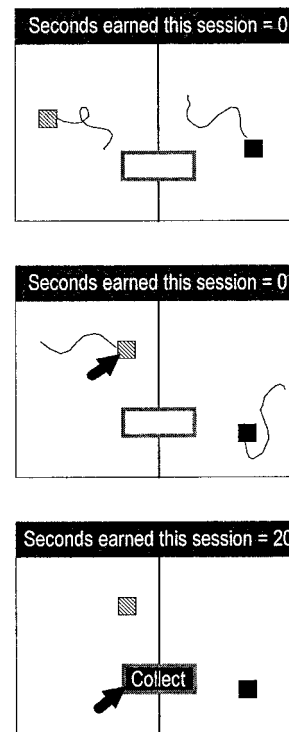


Figure 1. Appearance of subject's computer monitor. See text for details.

several dimensions (Critchfield, Schlund, & Ecott, 2000).

Task. At the beginning of each session, the instruction "Click here to begin" appeared on the screen just above a rectangular box containing the word "Ready." Clicking the box began a task based on one described by Madden and Perone (1999). The screen was divided into two rectangular regions, above which was a point counter with the prompt "TOTAL SECONDS EARNED THIS SESSION" (Figure 1, top). This counter started all sessions at zero, and incremented as points accumulated during each session. Each screen region contained a small, colored square that moved around its screen region in random directions at a rate of 0.5 cm per second. Clicks on these squares registered responses (Figure 1, middle). Clicks that occurred elsewhere were not recorded, thus encouraging sustained attention to the

task and limiting behavior not directed toward the experiment. At the end of each session, the screen was cleared and the message "Session Completed" was displayed. Sessions lasted 8 min, and approximately 9 to 12 sessions were conducted during each 2-hr visit to the laboratory. Participants could take short breaks between sessions.

Schedules and experimental conditions. When appropriate to the point-delivery schedules, a red, flashing prompt ("Collect") appeared inside a box in the center of the screen (Figure 1, bottom). Clicking inside this box caused 20 s to be added to the subject's total. During a baseline consisting entirely of response-contingent reinforcement, point deliveries occurred according to variable-interval (VI) schedules programmed by the method of Fleshler and Hoffman (1962). The target schedule was VI 10 s, and the alternative schedule was VI 30 s. Switching between the two schedules initiated a 2-s changeover delay (COD), during which the VI schedules and the session clock were suspended, and responses, although recorded, were ineffective. A COD prevents the development of response chains incorporating both options, allowing the two reinforcement schedules to exert relatively independent control over behavior (Catania, 1962).

During NCR conditions, the reinforcement schedule for the alternative behavior remained unchanged, while a randomly determined portion of the VI 10-s reinforcers that had been contingent on the target behavior during baseline were now delivered independently of responding. Experimental conditions were defined in terms of the proportion of target-side reinforcers that were converted to noncontingent: 100%, 67%, 33%, or 0%. When a noncontingent reinforcer was scheduled, no response was required and the "Collect" button was activated immediately and independently of responding (with the exception that the COD

was still enforced when applicable). Following experimental designs used by Lattal (1974) and Bacotti (1978), the sequence of conditions was descending (100%, 67%, 33%, and 0% NCR) for 3 participants (Tim, Jim, and Eminem) and ascending (0%, 33%, 67%, and 100% NCR) for 2 participants (Slim and Lem). To the extent that time permitted, conditions then were replicated in the opposite order of the planned initial sequence.

Stability criteria. Conditions lasted until visual inspection of graphed relative response rates (preferred-side responses divided by total responses) showed no systematic trend and a formal stability criterion was met (i.e., the difference between the mean of relative response rates for the most recent two sessions and that for the preceding two sessions constituted less than 10% of the four-session grand mean). Conditions also were terminated in the case of ceiling effects (i.e., three consecutive sessions in which the relative response rate was greater than .9).

Instructions. Prior to the first session, participants read the following instructions:

You will see that the screen is divided into two separate sections, one on the left and one on the right. Two colored squares move about on the screen, but each will stay within its respective section. With the mouse, you may click the left button of the mouse on either square as much or as little as you like. Your screen will show a point counter that will indicate how many points you have received. Points from each square count toward your overall point earnings and can be collected by clicking on the right button of the mouse. The squares pay off differently. It is up to you to decide when, and how often, to click each square. Try to maximize the amount of points you earn in the amount of time you spend working.

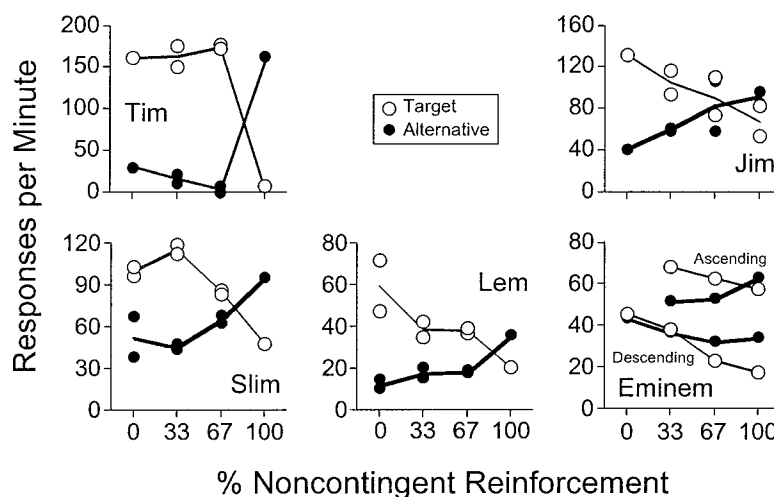


Figure 2. Mean response rates for target and alternative behaviors during terminal sessions of each condition. Note that ordinates are scaled differently for different participants.

RESULTS AND DISCUSSION

Under all conditions, behavior met a rigorous stability criterion in relatively few sessions (median = 5; range, 4 to 10). Analyses were based on the mean of the final four sessions in each condition (three sessions in the case of ceiling effects). It is customary in laboratory studies of concurrent-schedule performance to present parallel analyses that focus on both response rates generated by the individual schedules and the amount of time that subjects spend engaged in the individual schedules. Condition response allocation (ratio of target to alternative response rates) and time allocation were closely correlated (for all participants, $r = .965$ to $.999$); thus, for economy of presentation, we present analyses of response-rate data only.

Effects of NCR on Response Rates

Figure 2 shows response rates for the target and alternative behaviors across conditions, with condition replications plotted separately. For 4 of 5 participants, a single line traces the central tendency across conditions, showing that, as the percentage of NCR increased, target-behavior rate tended to decrease and alternative-behavior rate

tended to increase. Because outcomes were more complex for Eminem, separate functions trace the descending and ascending series of conditions. During the initial (descending) series of conditions, both target- and alternative-response rates generally increased across conditions, suggesting that this individual was still developing mouse-manipulation skills needed to perform the experimental task. During the replication (ascending series), however, outcomes were similar to those of other subjects. Note that, across several studies using the same concurrent-schedules task (e.g., Critchfield & Magoon, 2001; Critchfield, Paletz, MacAleese, & Newland, 2003), we have encountered few college students with poor mouse-control skills, so this participant was unusual. A different kind of task or operandum might be required, however, for other kinds of participants (e.g., some developmentally disabled individuals, or persons with little prior computer experience).

The target-behavior data in Figure 2 parallel those of numerous studies that used NCR in the context of a single reinforcement schedule. To illustrate, Figure 3 (based on Lattal, 1995, Figure 2) compares the present target-behavior results with those of

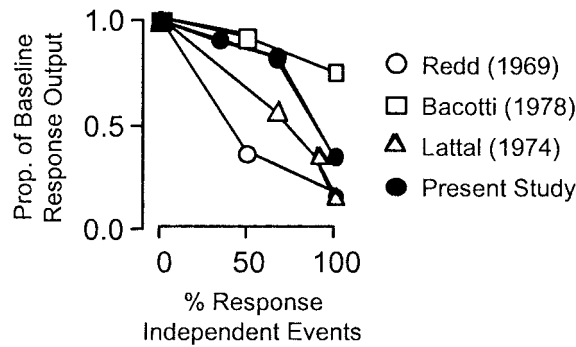


Figure 3. Response rate, as a proportion of a contingent reinforcement baseline, for target behaviors in four studies involving different types of participants, settings, and consequences. Each data point is the mean of all subjects in a study, except that those from the present study exclude Eminem. See text for details.

single-operant studies in which 2 children were presented with candy and praise (Redd, 1969); 5 pigeons were presented with mixed grain (Lattal, 1974); and 3 monkeys were presented with electric shock under conditions in which it appeared to maintain responding as a reinforcer (Bacotti, 1978). For all studies, response output (percentage of observation intervals in Redd; response rate in Bacotti and in Lattal; target-response rate in the present study) under NCR conditions was considered as a proportion of that under contingent reinforcement. Each function in Figure 3 shows mean data for all participants, except that, for the present study, Eminem was excluded due to idiosyncratic patterns described above. The results are strikingly similar across species and types of consequences. Among the studies summarized in Figure 3, however, the present one is unique in revealing concomitant changes in alternative behavior.

Evidence of Alternative Reinforcement Effects

Figure 2 suggests that that alternative-behavior changes were part of a pattern of response competition that resulted in decreased rates of target behavior, but the implications of this outcome for the alternative-reinforcement hypothesis can be evaluated only by determining which point

deliveries in each condition could plausibly have affected the target and alternative behaviors. Table 1 shows rates of point deliveries that occurred while participants were engaged in the two types of behavior. Engagement was defined according to the location of the response that occurred prior to a point delivery, regardless of whether the point delivery was contingent on that response. Overall, the process of converting target-side reinforcement to NCR tended to increase rates of point deliveries associated with the alternative behavior and decrease rates associated with the target behavior, compared to baseline levels, indicating that reinforcement often was tacitly reassigned to the alternative behavior. Figure 4 distinguishes between the contingent and noncontingent point deliveries associated with the two behaviors. As target-side point deliveries were converted to NCR, the number of contingent point deliveries decreased (as programmed), and the number of noncontingent point deliveries tended to increase. For alternative behavior, the number of contingent point deliveries remained relatively constant across conditions (as programmed), and the number of noncontingent point deliveries tended to increase.

Of primary interest was the extent to which the generalized matching law (Equation 2) could parsimoniously summarize the

Table 1
Point Deliveries Contacted While Engaged in Target and Alternative Behavior

Participant		0% NCR		33% NCR		67% NCR		100% NCR	
		Target	Alt	Target	Alt	Target	Alt	Target	Alt
Tim	1st	42.0	3.5	42.3	3.0	45.5	0.8	1.0	58.3
	2nd	41.0	2.5	40.8	4.5	44.5	0.3		
Jim	1st	34.0	8.5	27.0	15.3	23.8	23.0	16.0	42.3
	2nd			35.3	13.8	31.3	14.0	24.0	31.3
Slim	1st	30.3	7.0	35.8	8.3	25.5	20.0	14.3	43.3
	2nd	30.3	11.8	35.8	8.8	25.8	21.3		
Lem	1st	37.3	6.0	31.5	14.5	29.8	14.0	16.3	44.0
	2nd	34.0	4.8	33.8	9.8	34.8	10.8		
Eminem	1st	23.0	9.5	23.5	18.0	17.8	23.5	16	40.5
	2nd			26.3	11.0	24.3	18.8	18.5	38.8

Note. Engagement was defined in terms of the location of the response preceding each reinforcer. Reinforcement rates are a combination of contingent and, when appropriate to the condition, noncontingent reinforcers. Values are means for the terminal sessions of a condition.

relation of point deliveries to target versus alternative behavior allocation. Recall that Equation 2 summarizes the conjoint effects of reinforcement associated with two different behaviors. When contingent reinforcement alone is involved, the typical matching relation, displayed on double logarithmic axes, is strongly linear with a positive slope, for both nonhumans (Baum, 1974) and humans (Kollins, Newland, & Critchfield, 1997). Such a linear function shows that increased strength in one behavior comes at the expense of another behavior (i.e., response competition is explicitly demonstrated).

Figure 5 shows target versus alternative behavior allocation as a function of relative rates of point deliveries, as per the generalized matching law, and evaluates two competing interpretations. Analyses in the left column were based on the assumption that noncontingent point deliveries, whatever their effects, did not directly strengthen either the target or alternative behavior. Recall that in NCR conditions, some point deliveries that previously had been contingent on the target behavior became noncontingent. In any relation A:B, reducing A makes B relatively larger, and thus, even if noncontin-

gent point deliveries are behaviorally inert, preference would be expected to shift toward the alternative behavior. Because such an effect could be readily accommodated by the matching law, the left column of panels in Figure 5 shows the matching relations that result when the R terms of Equation 2 are taken to reflect contingent point deliveries only (noncontingent ones were omitted from the analysis).

Another interpretation is that NCR adventitiously strengthened the responses that it happened to follow. Many laboratory accounts of NCR are grounded in Skinner's (1948) contiguity theory, which assumes that contingency is not required for a post-behavior stimulus change to increase behavior probability. Rather, close temporal contiguity between behavior and reinforcement is held to be sufficient, allowing at least some noncontingent reinforcers to influence behavior as if they were contingent (Henton & Iversen, 1978; Vollmer & Hackenberg, 2001; Vollmer, Ringdahl, Roane, & Marcus, 1997). For example, after imposing noncontingent point deliveries on the behavior of humans working on concurrent reinforcement schedules, Madden and Perone (2003) concluded that preference was better pre-

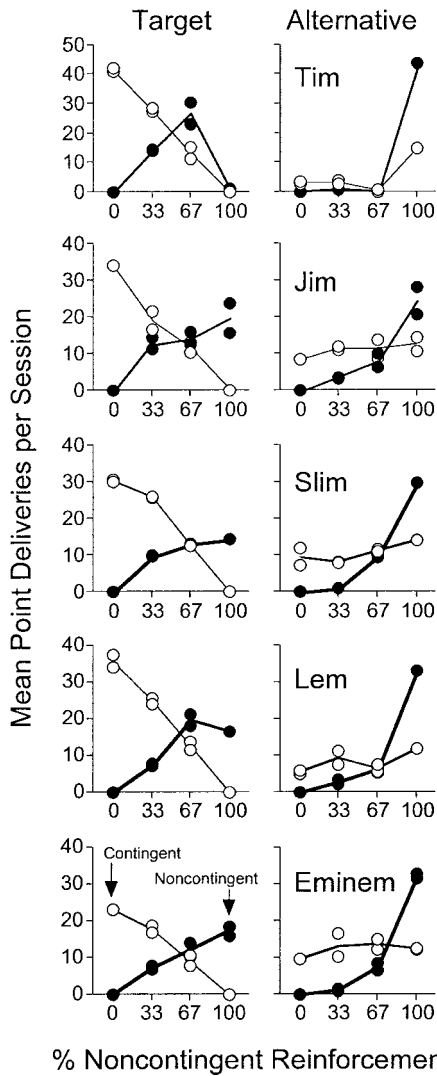


Figure 4. Mean number of contingent and noncontingent point deliveries per session during terminal sessions of each condition. Note that ordinates are scaled differently for different participants.

dicted by considering both contingent and noncontingent point deliveries than by assuming that behavior was affected by contingent point deliveries alone. Consistent with the approach of Madden and Perone, the right column of panels in Figure 5 shows the matching relations that result when the R terms of Equation 2 are taken to reflect the sum of all potential experimentally programmed reinforcers (contingent point de-

liveries plus noncontingent point deliveries that were preceded by that type of response).

The competing accounts can be compared in two ways. First, each panel in Figure 5 shows the percentage of variance in a subject's behavioral data that was accounted for by a least squares linear regression fit of Equation 2. When 100% of the variance is accounted for, the equation predicts behavior exactly. All of the functions approximated linearity to some extent, but for all participants, more variance was accounted for by considering noncontingent point deliveries in the analysis ($M = 86.3\%$) than by ignoring them ($M = 74.2\%$).

Second, the a parameter of Equation 2, which is the slope of the lines of best fit in Figure 5, traditionally is viewed as an estimate of an individual's sensitivity to (or discrimination of) the differences in reinforcement received from two concurrent behaviors (Baum, 1974; Davison & Nevin, 1999). A slope of 1 indicates perfect sensitivity, although slopes less than 1 are the norm (Baum; Kollins et al., 1997). In the present study, if noncontingent point deliveries were behaviorally inert, then sensitivity estimates would be closer to ideal when only contingent point deliveries were used in the matching analysis. Figure 5 shows, however, that values of the a parameter were higher for all participants when noncontingent point deliveries were considered in the analysis ($M = .65$) than when they were omitted ($M = .31$).

On both critical dimensions, the matching law provided a better account of the present data when noncontingent point deliveries were included in the analysis. Of course, it does not follow that *all* noncontingent point deliveries strengthened behavior. Contiguity theory assumes that any delay that occurs between behavior and response-independent events degrades the capacity of the latter to function as reinforcers, but does not specify what duration of re-

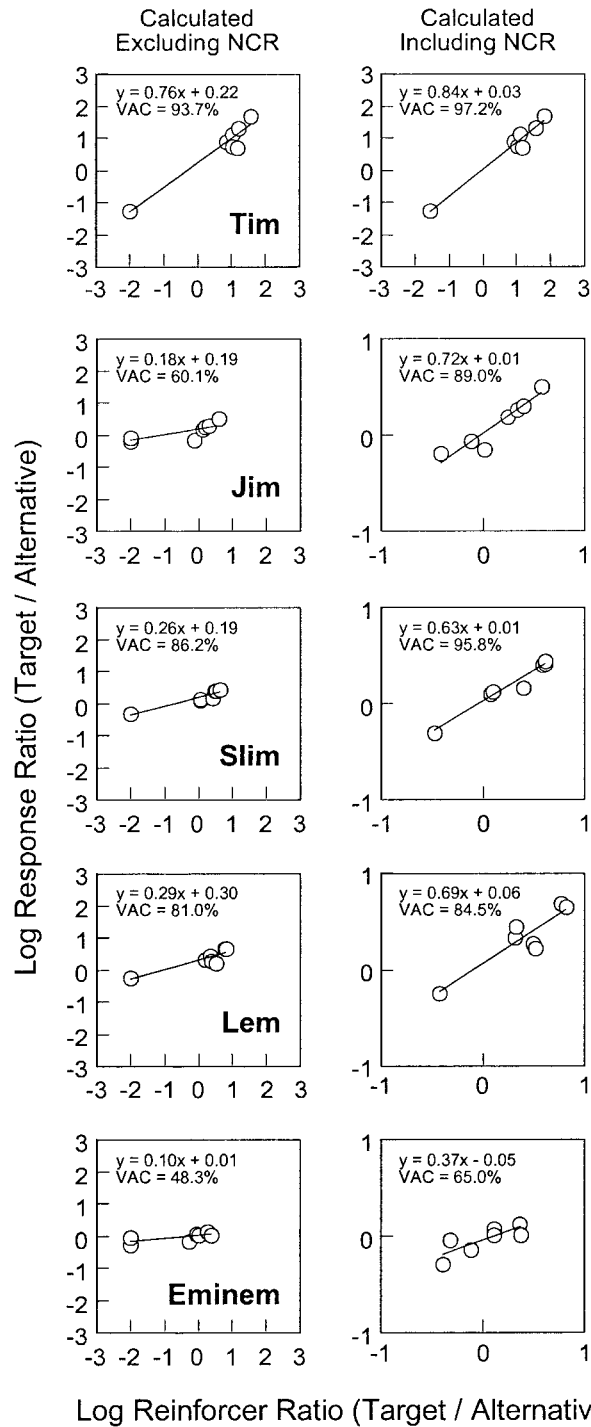


Figure 5. Matching of behavior ratios (natural logarithm of target to alternative) to reinforcement ratios (natural logarithm of target to alternative), calculated using contingent point deliveries only (left) and contingent plus noncontingent point deliveries (right). Some conditions were omitted from the analysis; see the Appendix for details of data preparation prior to analysis. Lines of best fit, described by the inset in each panel, were determined using least squares linear regression. Axes are scaled to suit the range of data in each panel. VAC = percentage of variance accounted for by a least squares linear regression fit of Equation 2.

sponse–consequence interval is too long. The present data provide no answer to that question.

To summarize, consistent with the predictions of Hagopian et al. (2000), McDowell (1989), and others, the matching law provided a good description of the interplay between NCR and contingent reinforcement schedules. This was true even for Eminem, whose raw response-rate patterns appeared to be unlike those of other subjects (Figure 2). Overall, the data make the most sense if it is assumed that NCR can adventitiously strengthen both target and alternative behaviors (e.g., see Vollmer et al., 1997), and thus that reductions in target behavior under NCR (e.g., Figure 2) were, in part, related to changes in reinforcement of alternative behavior.

Implications

Applied implications. The present study suggests a strategy through which NCR effects might be modeled in the laboratory, using concurrent reinforcement schedules, to facilitate both systematic measurement of alternative behavior and parametric variation of important features of NCR. Of course, any number of procedural differences between the present model and a given applied situation can be identified. For instance, our subjects were verbally capable college students, whereas many applied studies have focused on language-disabled individuals with intellectual limitations; our procedure employed a generalized conditioned reinforcer (course credit), but many applied studies use primary (e.g., edible items) or tangible reinforcers; and our noncontingent reinforcer was the same consequence that maintained both target and alternative behaviors, whereas some interventions use qualitatively different consequences. The goal of the present study was not to recapitulate the features of any specific applied environment but rather to use laboratory procedures to isolate vari-

ables that might operate in those environments.

Although the present results suggest that the alternative-reinforcement hypothesis deserves more serious consideration than it has received to date in applied studies of NCR, an obvious point of departure for future studies is to define the range of conditions under which NCR produces adventitious strengthening (of either target or alternative behaviors). It remains possible that these conditions rarely arise in applied settings—that is, perhaps applied researchers may have said little about alternative reinforcement because it occurs only weakly in most treatment environments.

Vollmer et al. (1997) suggested that adventitious strengthening is a joint function of the baseline rate of behavior and the rate at which noncontingent reinforcers are delivered—that is, the more frequent the behavior and the more frequent the NCR, the greater the likelihood that the two will occur in close temporal proximity. From this perspective, the high-rate alternative behaviors of the present study (>10 responses per minute in all baseline conditions) may have been ideally suited to profit from adventitious strengthening. Across behaviors, noncontingent point deliveries usually occurred within 2 s of a response, an outcome that might not be replicated with all problem behaviors or treatment schedules of NCR. A useful next step will be to determine the extent to which adventitious strengthening occurs with lower rate behaviors. Factors like response rate and reinforcement rate can be manipulated in applied settings, but they are more easily controlled in the laboratory (Vollmer & Hackenberg, 2001).

A related issue concerns the number of alternative behaviors. For purposes of the present investigation, we employed a single alternative behavior because two-alternative concurrent schedules are convenient to work with, and evidence from the laboratory sug-

gests that, where contingent reinforcement is concerned, adding more alternatives to concurrent schedules does not alter the lessons to be derived about response allocation (Davison & Hunter, 1976; Luce, 1959; Miller & Loveland, 1974; Pliskoff & Brown, 1976). Whether the same holds when NCR is involved is an open question that only new studies can answer. As the number of concurrent operants under investigation increases, so too should the value of laboratory models, in which measurement usually is effortless and exact.

The present procedure, in which reinforcement that had been contingent on target behavior was converted to NCR, is reminiscent of the intervention strategy known as NCR plus extinction. Some interventions, however, simply superimpose NCR on existing contingencies (NCR without extinction; e.g., Fischer, Iwata, & Mazaleski, 1997). Comparing these two procedures in applied settings is challenging, because relative-efficacy assessments are most straightforward when different treatments are applied to the same types of behaviors in the same individuals. Laboratory procedures, in which arbitrary responses can be constructed and deconstructed at will, are well suited to such comparisons.

Overall, the most important feature of procedures like those employed here is that they can be readily adapted to address a variety of questions of interest to applied researchers. Other factors worthy of investigation in laboratory models include rates of reinforcement that maintain the behaviors of interest (Hagopian, Fisher, & Legacy, 1994; Ringdahl, Vollmer, Borrero, & Connell, 2001); types of reinforcers that maintain the behaviors of interest (Carr, Bailey, Ecott, Lucker, & Weil, 1998; Ecott, Foate, Taylor, & Critchfield, 1999; Fisher, O'Connor, Kurtz, DeLeon, & Gotjen, 2000); and fixed versus variable scheduling of NCR (Carr, Kellum, & Chong, 2001). In addition, the

familiar laboratory technology of concurrent schedules may be a convenient environment in which to examine variables, such as the economic relation between different types of reinforcers (e.g., Madden, 2000), that are known to influence response allocation in multiple-operant situations, but that have not been examined in previous NCR investigations.

Implications for basic principles. Vollmer and Hackenberg (2001) argued that it is possible to design studies that simultaneously inform both theory and applied research. Although the present study was undertaken with applied concerns in mind, the basic-research context into which it fits should not be ignored. Basic researchers have long assumed that NCR-associated weakening of one behavior is accompanied by adventitious strengthening of others (e.g., Skinner, 1948), but rarely have systematic alternative-strengthening effects been described. Despite this paucity of evidence, interpretative writings have assumed that NCR operates within an alternative-reinforcement framework generally (e.g., Skinner, 1953), and more specifically within this framework as described by the matching law (e.g., McDowell, 1989).

To our knowledge, only one laboratory study has provided unambiguous, systematic evidence of alternative-reinforcement effects of NCR in concurrent schedules. During Madden and Perone's (2003) baseline conditions, human subjects were allowed to move a joystick in any of four directions, with these movements producing money reinforcers on separate schedules. The most preferred joystick movement was then labeled as the target behavior, and the remaining movements were considered to be alternative behaviors. When a variable-time schedule of money delivery was superimposed on the existing contingencies, 2 of 3 subjects showed decreases in the amount of time devoted to target responding and in-

creases in time devoted to alternative responding. Unfortunately, however, too few conditions were completed to allow an analysis in terms of the generalized matching law. It is interesting to note that, although Madden and Perone used NCR without extinction of the target behavior and the present study used NCR with extinction of the target behavior (in the 100% conditions), the findings of the two studies both point toward alternative reinforcement, suggesting a measure of generality in the effects.

The present report extends the work of Madden and Perone (2003) by providing the first empirical demonstration of the matching relation involving truly noncontingent reinforcement. The explicit alternative-strengthening precepts of the matching law, and the finding that matching was closer to ideal when noncontingent reinforcement was considered than when it was ignored (Figure 5), make our data the clearest evidence available to date that noncontingent reinforcement can weaken one behavior by adventitiously strengthening another.

Consequently, the present results have implications for how we speak about the operations that generated them. In describing the “response-independent delivery of stimuli with known reinforcing properties” (Vollmer et al., 1993, p. 10), some observers have objected to use of the term *noncontingent reinforcement* on the grounds that *reinforcement* necessarily incorporates contingency (e.g., Carr, 1996; Poling & Normand, 1999). If a reinforcer is a stimulus that strengthens the behavior that produced it (Catania, 1998), then the term *noncontingent reinforcement* is nonsensical—there can be no reinforcement without contingency, and NCR is known primarily for its capacity to weaken target behaviors (Carr). In relating target-behavior weakening to the strengthening of alternative behavior, and suggesting that the strengthening resulted from adventitious reinforcement due to non-

contingent point deliveries, the present data support the perspective of contiguity theory (Skinner, 1948), which defines reinforcement as the strengthening of behavior by the events that follow it (no contingency is assumed). According to this definition, NCR, under at least some circumstances, qualifies as noncontingent *reinforcement*.

REFERENCES

- Bacotti, A. V. (1978). Responding under schedules combining response-dependent and response-independent shock delivery. *Journal of the Experimental Analysis of Behavior*, *29*, 267–272.
- Baum, W. M. (1974). On two types of deviation from the matching law: Bias and undermatching. *Journal of the Experimental Analysis of Behavior*, *22*, 231–242.
- Baum, W. M., & Rachlin, H. C. (1969). Choice as time allocation. *Journal of the Experimental Analysis of Behavior*, *12*, 861–874.
- Brownstein, A. J. (1971). Concurrent schedules of response-independent reinforcement: Duration of a reinforcing stimulus. *Journal of the Experimental Analysis of Behavior*, *15*, 211–214.
- Brownstein, A. J., & Pliskoff, S. S. (1968). Some effects of relative reinforcement rate and change-over delay in response-independent concurrent schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, *11*, 683–688.
- Carr, J. E. (1996). On the use of the term “noncontingent reinforcement.” *Journal of Behavior Analysis and Therapy*, *1*, 33–37.
- Carr, J. E., Bailey, J. S., Ecott, C. L., Lucker, K. D., & Weil, T. M. (1998). On the effects of noncontingent delivery of differing magnitudes of reinforcement. *Journal of Applied Behavior Analysis*, *31*, 313–321.
- Carr, J. E., Kellum, K. K., & Chong, I. M. (2001). The reductive effects of noncontingent reinforcement: Fixed-time versus variable-time schedules. *Journal of Applied Behavior Analysis*, *34*, 505–509.
- Catania, A. C. (1962). Independence of concurrent responding maintained by interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, *5*, 175–184.
- Catania, A. C. (1998). *Learning* (4th ed.). Upper Saddle River, NJ: Prentice Hall.
- Critchfield, T. S. (2002). Evaluating the function of applied behavior analysis: A bibliometric analysis. *Journal of Applied Behavior Analysis*, *35*, 423–426.
- Critchfield, T. S., & Magoon, M. A. (2001). On the differential impact of positive and negative reinforcement. *Experimental Analysis of Human Behavior Bulletin*, *19*, 16–18.

- Critchfield, T. S., Paletz, E. M., MacAleese, K., & Newland, M. C. (2003). Punishment in human choice: Direct or competitive suppression? *Journal of the Experimental Analysis of Behavior*, *80*, 1–27.
- Critchfield, T. S., Schlund, M., & Ecott, C. L. (2000). A procedure for using bonus course credit to establish points as reinforcers for human subjects. *Experimental Analysis of Human Behavior Bulletin*, *18*, 15–18.
- Davison, M., & Hunter, I. W. (1976). Performance on variable-interval schedules arranged singly and concurrently. *Journal of the Experimental Analysis of Behavior*, *32*, 233–242.
- Davison, M., & Nevin, J. A. (1999). Stimuli, reinforcers, and behavior: An integration. *Journal of the Experimental Analysis of Behavior*, *71*, 439–482.
- Ecott, C. L., Foate, B. A. L., Taylor, B., & Critchfield, T. S. (1999). Further evaluation of reinforcer magnitude effects in noncontingent schedules. *Journal of Applied Behavior Analysis*, *32*, 529–532.
- Fischer, S. M., Iwata, B. A., & Mazaleski, J. L. (1997). Noncontingent delivery of arbitrary reinforcers as treatment for self-injurious behavior. *Journal of Applied Behavior Analysis*, *30*, 239–249.
- Fisher, W. W., O'Connor, J. T., Kurtz, P. F., DeLeon, I. G., & Gotjen, D. L. (2000). The effects of noncontingent delivery of high- and low-preference stimuli on attention-maintained destructive behavior. *Journal of Applied Behavior Analysis*, *33*, 79–83.
- Fisher, W. W., Thompson, R. H., DeLeon, I. G., Piazza, C. C., Kuhn, D. E., Rodriguez-Catter, V., et al. (1999). Noncontingent reinforcement: Effects of satiation versus choice responding. *Research in Developmental Disabilities*, *20*, 411–427.
- Fleshler, M., & Hoffman, H. S. (1962). A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior*, *5*, 529–530.
- Hagopian, L. P., Crockett, J. L., van Stone, M., DeLeon, I., & Bowman, L. (2000). Effects of noncontingent reinforcement on problem behavior and stimulus engagement: The role of satiation, extinction, and alternative reinforcement. *Journal of Applied Behavior Analysis*, *33*, 433–449.
- Hagopian, L. P., Fisher, W. W., & Legacy, S. M. (1994). Schedule effects of noncontingent reinforcement on attention-maintained destructive behavior in identical quadruplets. *Journal of Applied Behavior Analysis*, *27*, 317–325.
- Henton, W. W., & Iversen, I. H. (1978). *Classical conditioning and operant conditioning*. New York: Springer-Verlag.
- Herrnstein, R. J. (1961). Relative and absolute strength of response as a function of frequency of reinforcement. *Journal of the Experimental Analysis of Behavior*, *4*, 267–272.
- Innis, A., Lane, S. D., Miller, E. R., & Critchfield, T. S. (1998). Stimulus equivalence: Effects of a default-response option on emergence of untrained stimulus relations. *Journal of the Experimental Analysis of Behavior*, *70*, 87–102.
- Kahng, S., Iwata, B. A., Thompson, R. H., & Hanley, G. P. (2000). A method for identifying satiation versus extinction effects under noncontingent reinforcement schedules. *Journal of Applied Behavior Analysis*, *33*, 419–432.
- Kollins, S. H., Newland, M. C., & Critchfield, T. S. (1997). Human sensitivity to reinforcement in operant choice: How much do consequences matter? *Psychonomic Bulletin & Review*, *4*, 208–220. Erratum: *Psychonomic Bulletin & Review*, *4*, 431.
- Lachter, G. D., Cole, B. K., & Schoenfeld, W. N. (1971). Response rate under varying frequency of non-contingent reinforcement. *Journal of the Experimental Analysis of Behavior*, *15*, 233–236.
- Lane, S. D., Clow, J. K., Innis, A., & Critchfield, T. S. (1998). Generalization of crossmodal stimulus equivalence classes: Operant processes as components in human category formation. *Journal of the Experimental Analysis of Behavior*, *70*, 267–279.
- Lane, S. D., & Critchfield, T. S. (1998). Increasing the generativity of identity-based procedures for establishing arbitrary conditional relations. *The Psychological Record*, *48*, 457–479.
- Lattal, K. A. (1974). Combinations of response-reinforcer dependence and independence. *Journal of the Experimental Analysis of Behavior*, *22*, 357–362.
- Lattal, K. A. (1995). Contingency and behavior analysis. *The Behavior Analyst*, *18*, 209–224.
- Lattal, K. A., & Abreu-Rodrigues, J. (1997). Response-independent events in the behavior stream. *Journal of the Experimental Analysis of Behavior*, *68*, 375–398.
- Lattal, K. A., & Doepke, K. J. (2001). Correspondence as conditional stimulus control: Insights from experiments with pigeons. *Journal of Applied Behavior Analysis*, *34*, 127–144.
- Lindberg, J. S., Iwata, B. A., Roscoe, E. M., Worsdell, A. S., & Hanley, G. P. (2003). Treatment efficacy of noncontingent reinforcement during brief and extended application. *Journal of Applied Behavior Analysis*, *36*, 1–19.
- Luce, R. D. (1959). *Individual choice behavior: A theoretical analysis*. New York: Wiley.
- Mace, F. C. (1994). Basic research needed for stimulating the development of behavioral technologies. *Journal of the Experimental Analysis of Behavior*, *61*, 529–550.
- Madden, G. J. (2000). A behavioral economics primer. In W. K. Bickel & R. E. Vuchinich (Eds.), *Reframing health behavior change with behavioral economics* (pp. 3–26). Mahwah, NJ: Erlbaum.
- Madden, G. J., & Perone, M. (1999). Human sensitivity to concurrent schedules of reinforcement: Effects of observing schedule-correlated stimuli.

- Journal of the Experimental Analysis of Behavior*, 71, 303–318.
- Madden, G. J., & Perone, M. (2003). Effects of alternative reinforcement on human behavior: The source does matter. *Journal of the Experimental Analysis of Behavior*, 79, 193–206.
- McDowell, J. J. (1982). The importance of Herrnstein's mathematical statement of the law of effect for behavior therapy. *American Psychologist*, 37, 771–779.
- McDowell, J. J. (1989). Matching theory in natural human environments. *The Behavior Analyst*, 11, 95–108.
- Miller, H. L., & Loveland, D. H. (1974). Matching when the number of response alternatives is large. *Animal Learning & Behavior*, 2, 106–110.
- Myerson, J., & Hale, S. (1984). Practical implications of the matching law. *Journal of Applied Behavior Analysis*, 17, 367–380.
- Ono, K. (1987). Superstitious behavior in humans. *Journal of the Experimental Analysis of Behavior*, 47, 261–271.
- Pierce, W. D., & Epling, W. F. (1995). The applied importance of research on the matching law. *Journal of Applied Behavior Analysis*, 28, 237–241.
- Pliskoff, S. S., & Brown, T. G. (1976). Matching with a trio of concurrent variable-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 25, 69–73.
- Poling, A., & Normand, M. (1999). Noncontingent reinforcement: An inappropriate description of time-based schedules that reduce behavior. *Journal of Applied Behavior Analysis*, 32, 237–238.
- Rachlin, H., & Baum, W. M. (1972). Effects of alternative reinforcement: Does the source matter? *Journal of the Experimental Analysis of Behavior*, 18, 231–241.
- Redd, W. H. (1969). Effects of mixed reinforcement contingencies on adults' control of children's behavior. *Journal of Applied Behavior Analysis*, 2, 249–254.
- Redmon, W. K., & Lockwood, K. (1986). The matching law and organizational behavior. *Journal of Organizational Behavior Management*, 8, 57–72.
- Ringdahl, J. E., Vollmer, T. R., Borrero, J. C., & Connell, J. E. (2001). Fixed-time schedule effects as a function of baseline reinforcement rate. *Journal of Applied Behavior Analysis*, 34, 1–15.
- Roane, H. S., Fisher, W. W., & Sgro, G. M. (2001). Effects of a fixed-time schedule on aberrant and adaptive behavior. *Journal of Applied Behavior Analysis*, 34, 333–336.
- Skinner, B. F. (1948). "Superstition" in the pigeon. *Journal of Experimental Psychology*, 38, 168–172.
- Skinner, B. F. (1953). *Science and human behavior*. New York: Macmillan.
- Vollmer, T. R., & Bourret, J. (2000). An application of the matching law to evaluate the allocation of two- and three-point shots by college basketball players. *Journal of Applied Behavior Analysis*, 33, 137–150.
- Vollmer, T. R., & Hackenberg, T. D. (2001). Reinforcement contingencies and social reinforcement: Some reciprocal relations between basic and applied research. *Journal of Applied Behavior Analysis*, 34, 241–253.
- Vollmer, T. R., Iwata, B. A., Zarcone, J. R., Smith, R. G., & Mazaleski, J. L. (1993). The role of attention in the treatment of attention-maintained self-injurious behavior: Noncontingent reinforcement and differential reinforcement of other behavior. *Journal of Applied Behavior Analysis*, 26, 9–21.
- Vollmer, T. R., Marcus, B. A., & Ringdahl, J. E. (1995). Noncontingent escape as treatment for self-injurious behavior maintained by negative reinforcement. *Journal of Applied Behavior Analysis*, 28, 15–26.
- Vollmer, T. R., Ringdahl, J. E., Roane, H. S., & Marcus, B. A. (1997). Negative side effects of noncontingent reinforcement. *Journal of Applied Behavior Analysis*, 30, 161–164.

Received June 6, 2003

Final acceptance May 18, 2004

Action Editor, Richard Smith

APPENDIX

In several cases, obtained reinforcement rates for one response option in a condition were zero. This could happen for at least two reasons. First, if response rate (and associated time allocation) was low but not zero, it was possible, given the interval programming of the point deliveries, for no point deliveries (either contingent or noncontingent) to be delivered during terminal sessions, even though the reinforcement schedules had been contacted in earlier sessions. Second, in analyses focusing on contingent point deliveries only, the number of programmed events could be zero (e.g., in the 0% NCR conditions). Such outcomes are problematic because analyses employing the generalized matching law (Equation 2) are possible only when reinforcement and response rates for all behavior options are greater than zero (only positive values can be logarithmically transformed).

One strategy for dealing with this problem is to drop the relevant conditions from

analysis. This solution is unsatisfying because potentially interesting data are lost. It proved to be especially unsuitable for the analyses summarized in Figure 5 because it sometimes yielded different numbers of conditions for the contingent reinforcement and contingent-plus-noncontingent reinforcement analyses that were being compared.

An alternative strategy is to add a small constant to all data values in all conditions to correct for zero values (e.g., see Critch-

field et al., 2003). A small constant added to both terms in a preference ratio shifts the ratio slightly towards indifference, but the conditions are retained for analysis. Before performing the analyses upon which Figure 5 is based, we added 0.01 times the condition total obtained reinforcement rate (target plus alternative schedule) to both the target- and alternative-schedule reinforcement rates. For consistency, this correction was performed for all conditions for all subjects.

STUDY QUESTIONS

1. What are two common explanations for response reduction under noncontingent reinforcement (NCR)? What other explanation was offered by the authors?
2. Stated generally, what is the prediction made by the matching law?
3. Briefly describe (a) the experimental task and (b) the contingencies in place during baseline.
4. What procedures were in effect during the NCR conditions?
5. What was the general effect of NCR on target- and alternative-response rates?
6. What do the data in Figure 4 show, and how were these data interpreted?
7. What do the data in Figure 5 suggest about the influence of NCR on behavior?
8. Describe the basis for the authors' conclusion about the accuracy of the term *noncontingent reinforcement*.

Questions prepared by Leah Koehler and Stephen North, University of Florida