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Reducing Pausing at Rich-to-Lean Schedule Transitions: Effects of Variable-Ratio Schedules
and Noncontingent Timeouts

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Reducing Pausing at Rich-to-Lean Schedule Transitions: Effects of Variable-Ratio Schedules
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ABSTRACT**Reducing Pausing at Rich-to-Lean Schedule Transitions: Effects of Variable-Ratio Schedules and Noncontingent Timeouts****Adam T. Brewer**

Transitions from relatively rich to lean conditions of reinforcement often produce extended pausing because this transition is relatively more aversive than other transition types (e.g., rich-rich, lean-lean, and lean-rich). In applied settings, aversive rich-lean transitions may underlie maladaptive aberrant behavior (e.g., self-injury, aggression, and severe stereotypy). Reducing the aversiveness of this critical transition is of basic and applied interest. The length of the pause may be used as an index of the aversive stimulation at rich-lean transitions and as an analog measure of aberrant behavior in clinical settings. Experiment 1 investigated the effects of arranging rich-lean transitions between variable-ratio (VR) schedules or random-ratio (RR) schedules on pausing at rich-lean transitions in four pigeons. Variable- and random-ratio schedules were equally effective at reducing pausing at rich-lean transitions. These results suggest that the aversive stimulation at rich-lean transitions was reduced with variable schedules. The applied implication is that aberrant behavior should be less likely to occur at rich-lean transitions when variable schedules are arranged. In Experiment 2, four transitions were separated by a timeout period imposed between the end of the reinforcer and before the start of the next multiple-schedule component. During the timeout, the response key was darkened and the reinforcement schedule was suspended until the timeout interval had elapsed. Across different timeout durations, ratio sizes, and probes, the timeout produced inconsistent within- and between-subject results. Inconsistent results may be attributable to the timeout reducing the number of transitions completed, performance failing to meet the quantitative and qualitative stability criteria, and insufficient reinforcement in the lean-schedule component. An interesting possibility raised by Experiment 2 is that the multiple schedule may have “chain-like” features (e.g., access to a rich-schedule component), which may maintain responding in the lean component when there is insufficient reinforcement.

General Introduction

The Basic Problem: Pausing on FR Schedules

Fixed-ratio (FR) schedules require that a certain number of responses occur before the reinforcer is delivered for responding (Catania, 2006, p. 169). Performance on this schedule is characterized by a period of nonresponding (a pause) followed by a period of a steady rate of high responding (a “run”) until the response requirement is met and a reinforcer is delivered (e.g., Ferster & Skinner, 1957; for a review, see Lattal, 1991). Pause durations are traditionally measured from the end of the reinforcer delivery to the beginning of the “run” – often the occurrence of the first response. However, animals may sometimes emit a short-latency response after the food delivery and then pause. Conversely, animals may emit several responses followed by long interresponse times (i.e., the time between each response), indicating that the run has not started. Thus, in some cases, pausing may be reasonably measured as the latency to emit several responses instead of the traditional first response (e.g., Shull, 1979).

Pausing always exceeds the time to consume the reinforcer. In the context of a FR schedule, pausing may be considered counterproductive (or maladaptive) because it postpones the receipt of a reinforcer for a food-deprived organism. A host of variables affect pausing on FR schedules; for example, pausing increases as a function of the amount of effort required to complete each response (e.g., Alling & Poling, 1995) and when the reinforcer is omitted (e.g., McMilan, 1971). Conversely, pausing decreases with increases in food deprivation (e.g., Malott, 1966; Sidman & Stebbins, 1954). The most robust finding has been that pausing increases as a function of the size of the ratio (e.g., Felton & Lyon, 1966; Ferster & Skinner, 1957; Powell, 1969).

The effects of reinforcer magnitude on pause durations have been less clear. Some report that pauses were longer after large reinforcers than after small (e.g., Lowe, Davey, & Harzem, 1974), whereas others report that pauses were longer before a small reinforcer than before a large one (e.g., Inman & Cheney, 1974). These mixed results were consistent with literature on reinforcer magnitude manipulations (for a review, see Bonem & Crossman, 1988). Subsequently, two different accounts of pausing were developed that viewed pausing as a postreinforcement or pre-ratio pause. One account argued that pausing should be controlled by the unconditioned inhibitory effects of the past reinforcer magnitude—a postreinforcement pause (Harzem & Harzem, 1981). This account suggested that pauses should be longer after a large reinforcer than after a small one (Lowe et al., 1974). The other account argued that pausing should be controlled by the excitatory properties of the discriminable upcoming reinforcer magnitude—a pre-ratio pause (Shull, 1979). This account suggested that pauses should be shorter before a large reinforcer than before a small one (e.g., Inman & Cheney, 1974).

Perone, Perone, and Baron (1987) proposed that discrepant findings were due to the way the different reinforcer magnitudes (e.g., large, small) were signaled within session. For example, different reinforcer magnitudes were not signaled using a mixed schedule (e.g., Lowe et al., 1974), and the outcome was that pauses were longer for large reinforcers than small ones, which supports the postreinforcement account. Conversely, when different reinforcer magnitudes were signaled using a multiple schedule (e.g., Inman & Cheney, 1974), the opposite outcome occurred; pauses were longer for small reinforcers than for large ones, which supports the pre-ratio account.

To test this, Perone and Courtney (1992) arranged for pigeons to peck lit keys for food according to FR schedules using multiple and mixed schedules. Different reinforcer magnitude

parameters were investigated, but, in general, each reinforcer was either lean (e.g., 1-s access to the food hopper) or rich (e.g., 7-s access), and these reinforcer magnitudes were signaled by the color of the response key (e.g., red = rich, green = lean): a multiple schedule. Each session was composed of 41 multiple-schedule components containing 10 instances of each of four possible transitions between rich and lean reinforcement, that is, rich-rich, rich-lean, lean-lean, and lean-rich transitions. Following signaled transitions from rich to lean, longer pauses (e.g., 35 s) were observed relative to the other transition types (e.g., less than 5 s). When the multiple schedule-correlated stimuli were removed (a mixed schedule), pauses were unaffected by the upcoming reinforcer amount, but were longer after rich than lean reinforcers, which provided support for the control by the past reinforcer magnitude account (Harzem & Harzem, 1981). Under the mixed schedule, pausing never approximated that observed at rich-lean transitions in the multiple schedule.

Increased pausing at signaled rich-lean transitions is not due to increased consumption time or momentary satiation (i.e., long pauses are not observed at rich-rich transitions), nor is it due to the signaled upcoming lean reinforcer (i.e., long pauses are not observed at lean-lean transitions). Instead, longer pauses following signaled rich-lean transitions demonstrated that pausing is under joint control of the past and signaled upcoming schedule conditions, which provided partial support for both accounts (Harzem & Harzem, 1981; Shull, 1979).

Perone (2003) modified Perone and Courtney's (1992) multiple-schedule procedure based on Azrin's (1961) classic study. Azrin tested the counterintuitive notion that a schedule of positive reinforcement contained aversive properties. He provided pigeons with an explicit opportunity to escape on simple FR schedules. A FR schedule was arranged on one key and an escape contingency was arranged on another key. Pecking the escape key darkened both

response keys and suspended the reinforcement schedule; another peck on the escape key returned the FR schedule and its associated stimuli to their original settings. Escape responses occurred during the postreinforcement pause period (i.e., after the end of the reinforcer and before the start of the ratio run) suggesting that this was the most aversive part of the FR schedule.

Additional evidence suggesting that the postreinforcement period contains aversive properties comes from studies of schedule-induced or adjunctive behavior (e.g., aggression, polydipsia, hose-biting). The functional significance of these excessive or compulsive behaviors is unclear (e.g., for a review see Wetherington, 1982), although, some evidence suggests that attack is elicited by aversive stimulation. For example, Ulrich and Azrin (1972) found that aversive stimulation in the form of electric shock elicited fighting in rats. Consistent with escape on simple FR schedules (e.g., Azrin, 1961) and shock-elicited fighting (Ulrich & Azrin), attack on simple FR schedules occurs during the postreinforcement period, suggesting that this period contains aversive properties (e.g., Cherek & Pickens, 1970; Gentry, 1968; Kupfer, Allen, & Malagodi, 2008).

Perone (2003) noted that some animals did not reliably peck the escape key and that animals may escape by moving or turning away from the stimuli correlated with the FR schedule (e.g., Cohen & Campagnoni, 1989; Thompson, 1965), and that such responses during the pause may function as an unauthorized form of escape. Perone demonstrated this possibility when he found that pigeons were more likely to peck an escape key (which turned off all stimuli in the chamber) at signaled rich-lean transitions compared to the other three transition types (e.g., lean-lean, lean-rich, and rich-rich). In a no-escape condition, longer pauses were observed following the signaled rich-lean transition, reproducing the Perone and Courtney (1992) findings. The

pause durations approximated self-imposed escape durations in the escape condition. These results suggest that the stimuli signaling rich-lean transitions are aversive (i.e., the receipt of the rich reinforcer immediately followed by the lean signal) and that extended pausing may function as a form of escape.

Another potential effect of an aversive stimulus is that when a neutral stimulus (e.g., a tone) previously paired with an aversive stimulus (e.g., a shock) is superimposed onto a baseline of operant behavior, this conditioned stimulus may suppress operant behavior by eliciting incompatible emotional behaviors with the operant, such as freezing, a conditioned emotional response (CER) effect (e.g., Estes & Skinner, 1941). Extended pausing at signaled rich-lean transitions may be due to a CER effect.

Another possibility is that at a rich-lean transition, the lean reinforcer is devalued to the extent to which the animal is exposed to an aversive period of extinction because the lean reinforcer is negatively contrasted with the rich reinforcer. As a result, behavior is allocated toward temporarily more-valued activities like grooming or exploratory behaviors, which are incompatible with the operant response (e.g., Derenne & Baron, 2002). In this case, extended pausing at signaled rich-lean transitions may be due to low motivation.

A shortcoming of these accounts is that they do not explain why the animal begins to respond after pausing for extended periods of time. A possibility of why responding resumes is due to the passage of time weakening the control of the past reinforcer and the excitatory properties of the upcoming reinforcer (Shull, 1979). Despite this shortcoming, these accounts may provide a process-level explanation as to why transitions are sometimes rendered aversive and motivate or elicit chronic aberrant behaviors such as self-injury, aggression, and stereotypy for persons with intellectual and developmental disabilities (IDD). Extended pausing at signaled

rich-lean transitions may be considered chronic because it is a long-lasting effect and may be viewed as aberrant because it postpones the receipt of reinforcer for a food-deprived organism.

The Applied Problem: Idiosyncratic Chronic Aberrant Behaviors

Chronic aberrant behaviors (CAB) in persons with intellectual and developmental disabilities (IDD) may interfere with habilitation goals and may pose serious health risks to these individuals or others. Based on a set of reviews, escape from aversive stimulation accounted for the largest proportion of cases of CAB (95% of 20 cases: Edelson, Taubman, & Lovaas, 1983; 38% of 152 cases: Iwata et al., 1994; 31% of 706 cases: Kahng, Iwata, & Lewin, 2002). A puzzling finding from examining the aversive conditions used in these studies was that the aversive conditions were everyday tasks and requests. Predicting when these tasks and requests will generate CAB has been difficult because CAB is often idiosyncratic to individual patients (e.g., Smith, Iwata, Goh, & Shore, 1995). For example, contextual variables, such as the presentation of a particular task (e.g., Weeks & Gaylord-Ross, 1981) or a certain activity at particular time of day (e.g., Bosma & Mulick, 1990; Charlop, Schreibman, Mason, & Vesey, 1983), have been shown to engender CAB in some individuals but not others.

Of course, escape from aversive stimulation is not aberrant; failure to do so would be of clinical concern. Rather, the applied problem here is why a particular stimulus is benign in some contexts but aversive in others? Some general conditions that generate CAB are high rate requirements, large work requirements, a high probability of errors, unpreferred activities, novel tasks, and a lengthy session duration. However, these findings do not provide a process-level explanation of why benign stimuli are rendered aversive in certain contexts in some individuals with IDD.

A longstanding observation (e.g., Durand, 1990) is that transitions from one activity to the next can be aversive for persons with IDD (e.g., transitions to and from school: Kennedy & Itkonen, 1993; Repp & Karsh, 1994; transitions between instructional activities: Sailor, Guess, Rutherford, & Baer, 1968; Sainato, Strain, Lefebvre, & Rapp, 1987). An account of why these transitions are aversive is that unpredictable consequences associated with a transition are aversive (e.g., Flannery & Horner, 1994). Transitions may be unpredictable because the timing of the end of the current activity, the start of the next activity, and/or the nature of the upcoming activity are variable. Based on this account, one may try to answer the applied question by arguing that a transition will be benign when it is predictable, whereas a transition may acquire aversive functions when it is unpredictable. However, evidence in support of this account is scant (Flannery & Horner, 1994).

Bridging Applied Research on CAB and Basic Research on Pausing

Chronic aberrant behavior (e.g., Edelson et al., 1983; Iwata et al., 1994; Kahng et al., 2002) and transition-related pausing (e.g., Perone, 2003; Perone & Courtney 1992) may be the result of aversive stimulation. Perone's animal data showed that all transitions are not equally aversive. For example, a signaled rich-lean transition was relatively more aversive than a signaled lean-lean transition. Because the lean stimulus was rendered more aversive when embedded in a rich-lean transition, these results may provide a process-level explanation as to why a transition will be rendered aversive in certain contexts and benign in others. In applied settings, whether a transition will be rendered aversive may depend on whether a less-preferred activity (e.g., cleaning) is juxtaposed with a previously preferred activity (e.g., shredding paper) in a preferred to less-preferred transition (or, a rich-lean transition). If so, then a low-preferred activity may be rendered aversive and may motivate or elicit CAB in persons with IDD.

Otherwise, if the less-preferred activity is embedded in a different type of transition (e.g., lean-lean), then this activity will not be aversive itself.

To bridge the basic and the applied research on this topic, Williams, Saunders, and Perone (2011) arranged a similar procedure to Perone and Courtney (1992) in which the upcoming reinforcer magnitudes and response requirements were signaled at the beginning of each component. Persons with IDD earned money by pressing colored boxes on a touch-sensitive computer screen. During a rich component (signaled throughout by a particular color), 10 responses were required to earn \$0.25, whereas during a signaled lean trial, 100 responses were required to earn \$0.01. Consistent with Perone and Courtney's results, participants paused longer at the signaled rich-lean transition. This demonstrated that extended pausing at signaled rich-lean transitions was reproduced in the applied population of interest.

DeLeon, Williams, Gregory, and Hagopian (2005) described two participants with IDD and histories of self-injurious behavior who were more likely to engage in hand-flapping, hand-biting, or head-slapping following rich-lean transitions than other transitions when performing the computer task described above. These results suggest that CAB occurs under the same conditions that produced extended pausing at signaled rich-lean transitions.

The stimuli signaling rich-lean transitions have also occasioned or elicited CAB in persons with IDD under more naturalistic conditions. For example, the rate of CAB was higher at the rich-lean transition when using naturally occurring responses and an individual's most-(rich) and least-preferred (lean) activities in a classroom analog setting. Because pausing and CAB may be generated by equivalent behavioral processes (i.e., from the aversive stimuli signaling rich-lean transitions), pausing may be used as an analog measure to CAB in classroom analog settings and vice versa.

The current research project is designed to answer experimental questions within the framework of an ongoing programmatic line of translational research (NICHD RO1 HD044731). Thus far, much of the translational research has focused on the goal of understanding the basic behavioral processes underlying pausing and CAB in persons with IDD at signaled rich-lean transitions and investigating the generality of this phenomenon. The eventual goal of the current program is to use the understanding gained from basic research and bridge studies to develop scientifically based treatments. With this goal in mind, the current research project was designed to investigate variables that remove the aversive stimulation at signaled rich-lean transitions and also have some considerations of use in applied settings.

The applied literature offers several options for reducing CAB. A consequence-based manipulation, such as extinction of escape-maintained CAB, has been effective at decreasing CAB (e.g., Lalli, Casey, Goh, & Merlino, 1994; Zarcone, Iwata, Hughes, & Vollmer, 1993). However, extinction may not remove the aversive stimulation following the behavior. That is, extinction removes reinforcement for the response, but does not change the aversive stimulation that motivated or elicited CAB in the first place. Thus, the individual is exposed to the aversive stimulation, but has no effective escape or avoidance response available. Treatments that train an acceptable escape or avoidance response – such as asking for a break from a task using a functional communication approach – may be better (e.g., Fisher, Piazza, Cataldo, Harrell, Jefferson, & Conner, 1993), but the practitioner must be prepared for “I do not want to work” responses at rich-lean transitions. Thus, extinction is not likely to alter the aversiveness of a signaled rich-lean transition.

Another tactic to reduce CAB is to use antecedent-based manipulations, such as eliminating the activities that had been identified to generate problem behavior (e.g., Charlop et

al., 1983; DePaepe, Shores, Jack, & Denny, 1996; Dunlap, Kern-Dunlap, Clarke, & Robbins, 1991; Vaughn & Horner, 1997), gradually fading in instructional or task demands (e.g., Zarcone, Iwata, Vollmer, Jagtiani, Smith, & Mazaleski, 1993), tailoring the set of instructions for each individual (e.g., Penno, Frank, & Wacker, 2000), or increasing reinforcement associated with the context in which CAB occurs (e.g., Piazza, Contrucci, Hanley, & Fisher, 1997). Eliminating unpreferred activities may be incompatible with habilitation goals and well-intentioned attempts to increase the reinforcement in problem situations that may create a rich-lean transition between a different set of activities.

Advance-notice procedures have been reported to reduce transition-related problem behavior (e.g., Flannery & Horner, 1994; Flannery, O'Neill, & Horner, 1995; Mace, Shapiro, & Mace, 1998; Schreibman, Whalen, & Stahmer, 2000; Tustin, 1995). These antecedent-based treatments signal the upcoming transition (e.g., a teacher announcing that, in 2 min, recess will be ending and math will be starting) and are designed to make unpredictable transitions predictable and less aversive. However, the results of some recent studies have questioned the effectiveness of this class of procedures (e.g., Cote, Thompson, & McKerchar, 2005; McCord, Thomson, & Iwata, 2001; Waters, Lerman, Hovanetz, 2009; Wilder, Chen, Atwell, Pritchard, & Weinstein, 2006; Wilder, Nicholson, & Allison, 2010; Wilder, Zonneveld, Harris, Marcus, & Reagan, 2007). Although there are some procedural issues with the recent studies (e.g., failing to replicate Tustin's procedure), there is reason to believe that advance-notice procedures may not remove the aversive stimulation at signaled rich-lean transitions. For example, Perone (2003) showed that more escape occurred at rich-lean transitions when the transition was signaled compared to when it was not signaled. Advance notice may simply displace the aversive stimuli to the point when this signal is delivered, that is, during an ongoing rich activity (e.g., recess).

Thus, the applied literature does not appear to offer a potential intervention that may remove the aversive stimulation at signaled rich-lean transitions.

Contrary to the advance-notice literature, the basic literature might suggest that arranging unpredictable transitions using a mixed schedule (i.e., not signaling the nature of the upcoming task) is an effective intervention for reducing the aversive stimulation at rich-lean transitions. However, translating the mixed-schedule procedure to an applied intervention may be impractical because the presentation of an activity can function as a discriminative stimulus, which makes the removal of cues difficult.

Basic research (e.g., Perone & Courtney, 1992; Williams et al., 2011) has already shown that minimizing the disparity (or difference) between rich and lean reinforcer magnitudes reduces extended pausing at signaled rich-lean transitions. For example, extended pausing did not occur in animals when the reinforcer disparity was 5- and 4-s access to grain compared to 7- and 1-s access to grain, nor, did extended pausing occur in humans when the reinforcer magnitude was always \$0.13 at the end of each ratio compared to a quarter versus a point exchangeable for a penny.

Perone (2003) showed that extended pausing at signaled rich-lean transitions increased as a function of the size of the FR schedule. Thus, one way to decrease the aversive stimulation at a signaled rich-lean transition may be to reduce the task variables, such as the response requirement or effort associated with an activity that involves the emission of a discrete number of responses (e.g., reducing the number of math problems). However, this manipulation may run counter to educational or habilitation goals after the goals for learning have increased.

Instead of trying to eliminate or alter the parameters of a signaled rich-lean transition (i.e., reducing the reinforcer disparity or the ratio size), knowledge of variables that remove the

aversive stimulation are of current interest. Variables selected for experimentation met two criteria: (a) their potential effectiveness at removing the schedule interaction between rich- and lean-schedule components, as discussed in the introduction of each experiment, and (b) their potential to be translated into an applied treatment. Because the current grant work from this perspective is aimed more toward understanding than application, pausing was used as an index of the aversiveness of the signaled rich-lean transition in the animal laboratory, where highly controlled experiments are possible.

Experiment 1A: The Effects Variable-Ratio Schedules on Pausing at Rich-Lean Transitions

A common feature of the basic research on extended pausing at rich-lean transitions is that the reinforcers are delivered according to FR schedules (rats: Galuska & Yadon, 2011; Wade-Galuska, Perone, & Wirth, 2005; pigeons: Perone, 2003; Perone & Courtney, 1992; monkeys: Galuska, Wade-Galuska, Woods, & Winger, 2007; humans: Bejarano, Williams, & Perone, 2003; Williams, Saunders, & Perone, 2011) or progressive-ratio schedules (Baron, Mikorski, & Schlund, 1992). Perone (2003) demonstrated that extended pausing and escape is a joint function of the rich-lean transition and the size of the ratio. Thus, decreasing the size of the ratio seems to be an obvious choice for producing shorter pauses. Reducing the pause may suggest that the aversive properties of the stimuli signaling rich-lean transitions have been reduced. However, decreasing the ratio size may run counter to habilitative or educational goals in an applied setting (e.g., decreasing the number of math problems).

An alternative procedure to reducing the ratio is to change the reinforcement schedule to a variable-ratio (VR) schedule. A VR schedule delivers a reinforcer based on an arithmetic mean number of responses (Catania, 2006). The arithmetic mean is derived from a predetermined distribution (e.g., Fleshler & Hoffman, 1962) of different ratio sizes (ranging from small to large)

intended to approximate a constant-probability schedule. Variable-ratio schedules tend to produce a high and constant rate of responding (e.g., Cole, 1999; Peele, Casey, & Silberburg, 1984; Zurriff, 1970). The benefit of arranging an equivalent-sized VR schedule to a FR schedule is that a VR schedule allows for the same number of responses, on average, to be emitted as the FR schedule.

Pausing has been investigated on simple VR schedules (e.g., Crossman, Bonem, & Phelps, 1976; Ferster & Skinner, 1957; Priddle-Higson, Lowe, & Harzem, 1976). For example, Crossman et al. (1987) made within-subject comparisons of pausing between FR and VR schedules across a range of ratio sizes (i.e., 5 to 80) using pigeons. The results revealed no difference in mean pause durations at smaller ratio sizes of 5 and 10 between FR and VR schedules; the pauses were short. At a ratio size of 40, for two of the four subjects, pause durations increased on FR schedules, while pauses on the VR schedule were unaffected by the increase in ratio size. At a ratio size of 80, pause durations reliably increased for all subjects on FR schedules, whereas pauses on VR schedules remained virtually unaffected by the increased ratio. Thus, VR schedules produce shorter pauses at larger ratio sizes compared to equivalent-sized FR schedules.

Schlinger, Derenne, and Baron (2008) suggested that pauses tend to be shorter on a VR schedule compared to a FR schedule of an equivalent size. On a FR schedule, the postreinforcement period reliably signals a period of nonreinforcement (s -delta) because a reinforcer is never delivered until the response requirement is met. This kind of rich-lean transition on simple FR schedules from reinforcement to extinction may produce pausing. On a VR schedule, the response requirement is unpredictable and sometimes the size of the smallest ratio in the VR schedule is small, which prevents the postreinforcement period from acquiring s -

delta properties. Thus, the kind of rich-lean transition from reinforcement to extinction on simple VR schedules should be less aversive than on simple FR schedules. As a result, VR schedules should produce shorter pauses compared to equivalent FR schedules. Arranging rich-lean transitions between VR schedules using the Perone and Courtney (1992) multiple-schedule procedure should eliminate the rich-lean transition inherent on simple schedules (reinforcement to extinction), but it should leave rich-lean transition between reinforcer magnitudes unaffected. Thus, it is unknown whether arranging VR schedules will reduce pausing at rich-lean transitions in the Perone and Courtney procedure.

Webbe, DeWeese, and Malagodi (1974) investigated the effects of VR and FR schedules on attack. Pigeons were exposed to a two-component multiple schedule: one component contained a VR schedule, whereas the other contained an equivalent-sized FR schedule. The same reinforcement schedule was arranged for 10 schedule components before alternating to a different reinforcement schedule; sessions ended after 60 schedule components. Between conditions, the ratio size increased from 50 to 125 in step sizes of 25. Pigeons were provided the opportunity to attack a live pigeon that was restrained. Although levels of attack during the postreinforcement pause period tended to increase as a function of the ratio size on the FR schedule, attack also increased on the VR schedule, but was less frequent than on the FR schedule. If attack was elicited by the aversive properties during the postreinforcement period—the transition from reinforcement to extinction (e.g., Azrin, Hutchinson, & Hake, 1966; Hutchinson, Azrin, & Hunt, 1968)—then these results are suggestive that this period on a VR schedule is relatively less aversive than on an equivalent-sized FR schedule.

Several studies investigated preference between VR schedules and FR schedules with a higher rate of reinforcement using a concurrent-chains procedure (e.g., Ahearn, Hinline, &

David; 1992; Andrzejewski, Field, & Himeline, 2001; Field, Tonneau, Ahearn, & Himeline, 1996; Sherman & Thomas, 1968). A concurrent-chains procedure provides subjects a choice between two responses called the initial links of the chain. Each choice produces another schedule that leads to reinforcement. Higher rates of responding on one of the two initial links indicate preference for the schedule produced by that alternative. Field et al. (1996) provided a choice of responding on two fixed-interval 3-s schedule (the initial link) that ended in either a FR 30 or VR 60 schedule. The mean number of choices for the initial link that resulted in the VR 60 schedule tended to be more than for the FR 30 schedule, indicating that the VR was the more preferred reinforcement schedule. These results provide evidence that a larger VR schedule was more preferred than a smaller FR schedule despite the higher rate of reinforcement on the FR. Perhaps preference for a VR schedule is inversely related to its aversive properties.

The convergent results of the effects of simple VR schedules on pausing, attack, and choice may suggest that arranging rich-lean transitions using VR schedules, instead of FR schedules, should reduce the aversive stimulation at rich-lean transitions. Williams et al. (2011) suggested that simple schedules arrange a rich-lean transition from the just-consumed reinforcer to the upcoming requirement: a period in which a reinforcer is never delivered. Extended pausing at rich-lean transitions may be due to a kind of rich-lean interaction inherent in simple FR schedules (i.e., reinforcement to extinction) and the rich-lean schedule interaction involving the transition between rich and lean reinforcer magnitudes in the multiple-schedule arrangement (e.g., Perone & Courtney, 1992). Arranging a VR schedule should reduce the rich-lean interaction inherent on simple FR schedules, but it should also leave the rich-lean interaction between rich and lean reinforcer magnitudes intact. Thus, it is unknown whether a VR schedule will modulate the effects of a rich-lean transition on pausing in multiple schedules.

A study investigating the equivalence between simple VR schedules and FR schedules in a choice procedure may suggest a way that VR schedules may reduce the interaction between rich and lean reinforcer magnitudes in the multiple schedule. For example, Mazur (1986) provided pigeons a choice between a simple VR and FR schedule. Choices on the simple VR schedule decreased the ratio size on the FR schedule. The ratio size of the FR schedule stopped adjusting when the percentage of choice between the FR and VR schedule was equally distributed across the two alternatives (e.g., 50%), suggesting an indifference point at which the two alternatives were subjectively equivalent. The results showed that the subjective value of a larger VR schedule (e.g., VR 60) was equivalent to a smaller FR schedule (FR 30). Pausing at rich-lean transitions has been shown to be a function of the ratio size, despite the disparity in reinforcer magnitude (Perone, 2003). Thus, if pause durations at rich-lean transitions were compared using equivalent-sized large FR to VR schedules, then shorter pauses on the VR schedule might be expected if the VR schedule is subjectively valued as a small FR. Therefore, arranging rich-lean transitions between VR schedules should reduce the aversiveness of the rich-lean transition on simple schedules (reinforcement to extinction) and modulate the effects of the reinforcer magnitude disparity on multiple schedules by arranging subjectively smaller ratio sizes.

Research has suggested that the size of the smallest ratio configured in a VR schedule has a disproportionate effect on pausing compared to other individual ratios configured (e.g., Blakely & Schlinger, 1988; Schlinger, Blakely, & Kaczor, 1990), which may suggest an effective way to reduce pausing at rich-lean transitions in the multiple schedule. For example, Schlinger et al. (1990) arranged a two-component multiple schedule using VR 30 schedules that ended either in 8- or 2-s access to grain; FR schedules were not investigated. The VR schedule was configured

according to an arithmetic progression using 10 individual ratios; this was done to configure a FR 1 as the smallest ratio. The same reinforcer magnitude was arranged for 10 schedule components before alternating to a different reinforcer magnitude; sessions ended after 40 schedule components. Median pauses from two different VR 30 schedule configurations using a FR 1, FR 4, FR 7, or FR 10 as the smallest ratio were compared. Regardless of the smallest ratio, pauses were shorter for the rich reinforcer magnitude than for lean ones. However, pauses were relatively longer (e.g., 12 s) for the lean reinforcer when a FR 10 was the smallest ratio, compared to the FR 1 (e.g., 2 s). These results suggest that the smallest ratio is an important variable for reducing pausing on VR schedules, which may be an effective way to decrease pausing at rich-lean transitions.

The smallest ratio in a VR schedule may also have a disproportionate effect (compared to other individual ratios) on preference for a VR schedule despite a higher rate of reinforcement on a FR schedule. Field, Tonneau, Ahearn, and Hineline (1996) examined the effects of manipulating the smallest ratio in a VR schedule on preference between a VR 60 and FR 30 schedule using a concurrent-chains procedure with pigeons. The VR schedule was configured with four individual ratios. Choice for the VR 60 schedule was greater than the FR 30 schedule when the smallest ratio in the VR schedule was FR 1. Preference for the VR 60 schedule still occurred when the smallest ratio was FR 10, but, for some pigeons, preference for the VR 60 schedule began to decrease. A change in preference to the FR 30 schedule occurred when the smallest ratio in the VR 60 schedule was increased to FR 15. These results suggest that including a FR 1 as the smallest ratio is an important variable for increasing the preference for a VR schedule compared to a FR schedule with a higher rate of reinforcement.

Based on convergent evidence that the postreinforcement period is relatively less aversive on simple VR schedules than FR schedules (e.g., Crossman et al., 1987; Webbe et al., 1974), the goal of the current study was to test whether arranging VR schedules that contain a FR 1 as the smallest ratio, suggested by Field et al. (1996) and Schlinger et al. (1990), would reduce pausing at rich-lean transitions compared to FR schedules. The role of the smallest ratio in the VR schedules on pausing at rich-lean transitions was further examined by comparing it to a VR schedule configuration without a FR 1. A VR schedule with FR 1 as the smallest ratio should be a more effective way to reduce pausing at rich-lean transitions compared to replacing the FR 1 with a larger ratio.

Experiment 1A investigated whether pausing at rich-lean transitions with FR schedules (e.g., *mult* FR 80, 7 pellets; *mult* FR 80, 1 pellet) could be reduced with VR schedules (e.g., *mult* VR 80, 7 pellets; *mult* VR 80, 1 pellet). In addition, the effects of two different VR schedule configurations on pausing at rich-lean transitions were compared: a configuration *with* a FR 1 and another configuration *without* a FR 1. The VR schedule configuration used in the current study were based on Field et al. (1996) schedule configuration.

Method

Subjects

Four homing pigeons (Double 'T' Farm, Glennwood, Iowa, USA) naïve to operant procedures were individually housed in a temperature-controlled colony room with a 12:12 hr light/dark cycle. The pigeons were weighed daily and maintained at approximately 85% of their free-feeding weights by the food earned within session and with post-session feedings (provided 2 hr after a session), as necessary. Health grit and water were continuously available between sessions.

Apparatus

Experimental sessions were conducted in an operant chamber that was 39.4 cm high, 59.7 cm wide, and 62.2 cm deep. The chambers were located on open shelves in the running room. White noise was played into the whole room, and a curtain masked extraneous sounds and light. Two response keys (Coulbourn, Allentown, PA) were located on the front panel of the chamber; the keys were 2.5 cm in diameter and were 16.5 cm apart from the center of the intelligence panel and 19.1 cm from the chamber floor; the left key was never illuminated. A feeder (Coulbourn, Allentown, PA) was outfitted on the back of the intelligence panel with infrared pellet detectors to ensure pellets were delivered (Pinkston, Ratzlaff, Madden, & Fowler, 2008). Forty-five mg food pellets (Bioserve, Frenchtown, NJ) were dispensed into a 6.4 cm x 6.4 cm receptacle located 5.1 cm above the chamber floor. The receptacle was illuminated with a 2-W light during pellet delivery; different amounts of pellets were delivered one at a time. A photocell (Med Associates Inc., St. Albans, VT) was used to detect the pigeon's head-entry and head-removal events from inside the magazine. General illumination was provided by a 28-V houselight that was mounted near the top of the right wall of the chamber, which was adjacent to the right response key. A Med Associates® interface system (St. Albans, VT) controlled the sessions and collected data.

Procedure

Preliminary training. Key pecking on the right key was established using a standard autoshaping procedure (e.g., Brown & Jenkins, 1968). Autoshaping sessions consisted of 100 pairings of an 8-s yellow keylight followed immediately by the offset of the keylight and activation of the food dispenser that delivered a single food pellet. During the autoshaping procedure, food deliveries were scheduled under a variable-time 60-s schedule (i.e., food was

delivered, on average, after 60 s) and the keylight was lit yellow 8-s prior to the food delivery. A keypeck to the illuminated key immediately turned off the keylight and activated the feeder.

After keypecking occurred, autoshaping ended after ten, 100-trial sessions.

Thereafter, pigeons responded on the right yellow-lit key on a simple FR schedule ending in 4 pellets. Sessions ended after 180 min or after 41 ratios were completed. The ratio size was increased, across sessions, from 1 to 20 (in steps of 5) and then in steps of 10. The criterion for increasing the ratio size was contingent upon the pigeon completing all 41 ratios before the 180 min session time limit expired for three consecutive sessions. If a pigeon did not complete all 41 ratios for 3 consecutive sessions, then the size of the FR schedule was decreased until a ratio was found in which the pigeon could complete all 41 ratios within the time limit for three consecutive sessions. Responding was maintained for pigeons 1171 and 57 at FR 80, whereas pigeons 49843 and 51 were maintained at ratios of FR 50 and FR 40, respectively.

Multiple schedule. Following training, pigeons were exposed to a two-component multiple (*mult*) schedule in which the type of reinforcement schedule and the size of the ratio were the same across schedule components, but the reinforcer magnitude differed across schedule components. The multiple schedule was used throughout the remainder of the experiment. The schedule-correlated stimuli were either red or green key colors (counterbalanced across pigeons) that were illuminated at the onset of the schedule component and were turned off once the response requirement was met. Thereafter, a large (7 pellets = rich) or small (1 pellet = lean) amount of food was delivered after the completion of the response requirement in the rich and lean schedule components; the rich reinforcer was delivered over a period of 5.3 s and the lean reinforcer lasted 0.79 s. The onset of the next schedule component occurred once the last pellet was delivered and the pigeon's head was removed from the food receptacle. Pause

durations were timed from after the pigeon had his removed from the hopper for 1 s after the food had been delivered (i.e., when the key was illuminated) to the first response. If a session ended after 180 min rather than after the completion of 41 trials and before a response was emitted, then that pause was not used in the data analysis.

Sequence of schedule components. The sequence of multiple-schedule components arranged within a session was randomly drawn from a pool of 40 different sequences. Each sequence contained either 21 rich- and 20 lean-schedule components (sessions beginning with a rich schedule component), or 20 rich- and 21 lean-schedule components. Each sequence contained 10 of the four possible transitions between multiple-schedule components. That is, 10 times in each session a rich component (7 pellets) was programmed following a rich component (a rich-to-rich transition). Likewise there were 10 rich-lean, 10 lean-lean, and 10 lean-rich transitions. The same type of transition never occurred more than three times in a row.

Variable-ratio schedule configuration with a minimum ratio of FR 1. The mean ratio size used in the VR schedule was yoked to the size of the FR schedule used in the *mult* FR FR condition. Based on Field et al. (1996) VR schedule configuration with four individual ratios, the smallest ratio was set to FR 1, the next largest ratio was half the size of the mean ratio requirement, the next ratio was one and a half times larger than the mean ratio, and the largest ratio was twice the size of the mean (see Table 1). An individual ratio was randomly selected at the start of each schedule component, which equated the overall probability (0.25) of selecting a given ratio at each component change. This random selection method allowed for the same ratio to be selected successively.

Variable-ratio schedule configuration without a FR 1 as the minimum ratio. Variable-ratio schedules of four values were constructed as in the previous condition in which the smallest ratio

was increased to one quarter of the size of the mean ratio, the second and third values remained constant, and the largest decreased proportionately to the increase in the smallest ratio to maintain the same mean ratio size as in the previous configuration (see Table 1).

Subject	Experimental Conditions	Sessions	Programmed Ratio Size	Obtained Ratio Size	VR Schedule Configuration
P57	FR FR	37	80	80	VR w/1:
	VR VR w FR 1	21	80.25	82.01 (0.37)	(1, 40,
	FR FR	30	80	80	120, 160)
	VR VR w FR 1	23	80.25	74.76 (7.18)	VR w/o 1:
	VR VR w/o FR 1	55	80.25	82.48 (11.87)	(20, 40,
	VR VR w FR 1	20	80.25	75.56 (9.65)	120, 141)
P1171	FR FR	38	80	80	VR w/1:
	VR VR w FR 1	20	80.25	83.65 (6.39)	(1, 40,
	FR FR	36	80	80	120, 160)
	VR VR w FR 1	26	80.25	77.66 (3.66)	VR w/o 1:
	VR VR w/o FR 1	60	80.25	68.99 (14.99)	(20, 40,
	VR VR w FR 1	25	80.25	83.45 (9.16)	120, 141)
P49843	FR FR	37	50	50	VR w/1:
	VR VR w FR 1	16	50.25	50.32 (3.79)	(1, 25,
	FR FR	51	50	50	75, 100)
	VR VR w FR 1	26	50.25	49.94 (3.20)	VR w/o 1:
	VR VR w/o FR 1	21	50.25	49.44 (4.55)	(13, 25,
	VR VR w FR 1	20	50.25	49.91 (1.65)	75, 88)
P51	FR FR	34	40	40	VR w/1:
	VR VR w FR 1	21	40.25	41.71 (5.58)	(1, 20,
	FR FR	20	40	40	60, 80)
	VR VR w FR 1	46	40.25	39.14 (4.21)	VR w/o 1:
	VR VR w/o FR 1	13	40.25	42.29 (3.34)	(10, 20,
	VR VR w FR 1	22	40.25	40.34 (4.21)	60, 71)

Table 1. The sequence of experimental conditions, the number of sessions at each condition, the programmed mean and obtained mean ratio sizes (the standard deviation is shown in parentheses), and VR schedule configurations for each pigeon.

Stability criteria. Conditions lasted for a minimum of 10 sessions and until (a) pauses (defined as the latency to the first response) were considered stable when the mean of the final three sessions' median pauses deviated by 5% or less from the preceding three-session mean with no trend observed across the last six sessions, or (b) a maximum of 60 sessions were conducted.

Results and Discussion

The programmed mean VR ratio size and the mean obtained ratio size are shown in Table 1. Because an individual ratio was randomly selected at the beginning of each schedule component in the VR conditions, it was possible that the actual obtained mean ratio size in a session may not have matched the programmed mean ratio size. The potential implication here is that a reduction in pausing may be attributable to a small obtained-ratio size (i.e., short pauses occur on small ratios: Felton & Lyon, 1966) rather than due to the properties of the VR schedule. A two-tailed t-test was conducted to determine if these ratio sizes differed; no significant differences were found. Therefore, any reduction in pausing should not be attributed to a small obtained-mean ratio size.

Figure 1 shows two different ways to measure the pause duration at rich-lean transitions: pausing measured as the latency to the first response or the latency from the first to the fifth response. When the pause was measured to the emission of the fifth response, pause durations from the FR 1 schedule in the *mult* VR VR with the FR 1 condition were excluded from the analysis. Data from the same condition were averaged together. In the *mult* FR FR and *mult* VR VR without the FR 1 conditions, the latency to the first response was longer than to the fifth response. However, when the VR schedule contained a FR 1, the latency from first to the fifth response was longer than the latency to the first response. After the fifth response, the interresponse times (IRTs) were essentially constant and very short (e.g., approximately .3 s). That is, after the fifth response, high constant rates of responding without pauses occurred. Longer latencies between the first to fifth response results suggest that the location of the pause was relocated to between the first to the fifth response when the VR schedule contained a FR 1. Therefore, in subsequent figures, these latency measures were transformed into pause durations

that measured the pause as the latency to the fifth response. This transformation allowed pause durations to be compared across conditions, regardless of whether the pauses were located before the emission of the first or between the emission of the first to fifth response. The pause definition was changed from the latency to the first response to the latency to the fifth response after the entire experiment had been conducted.

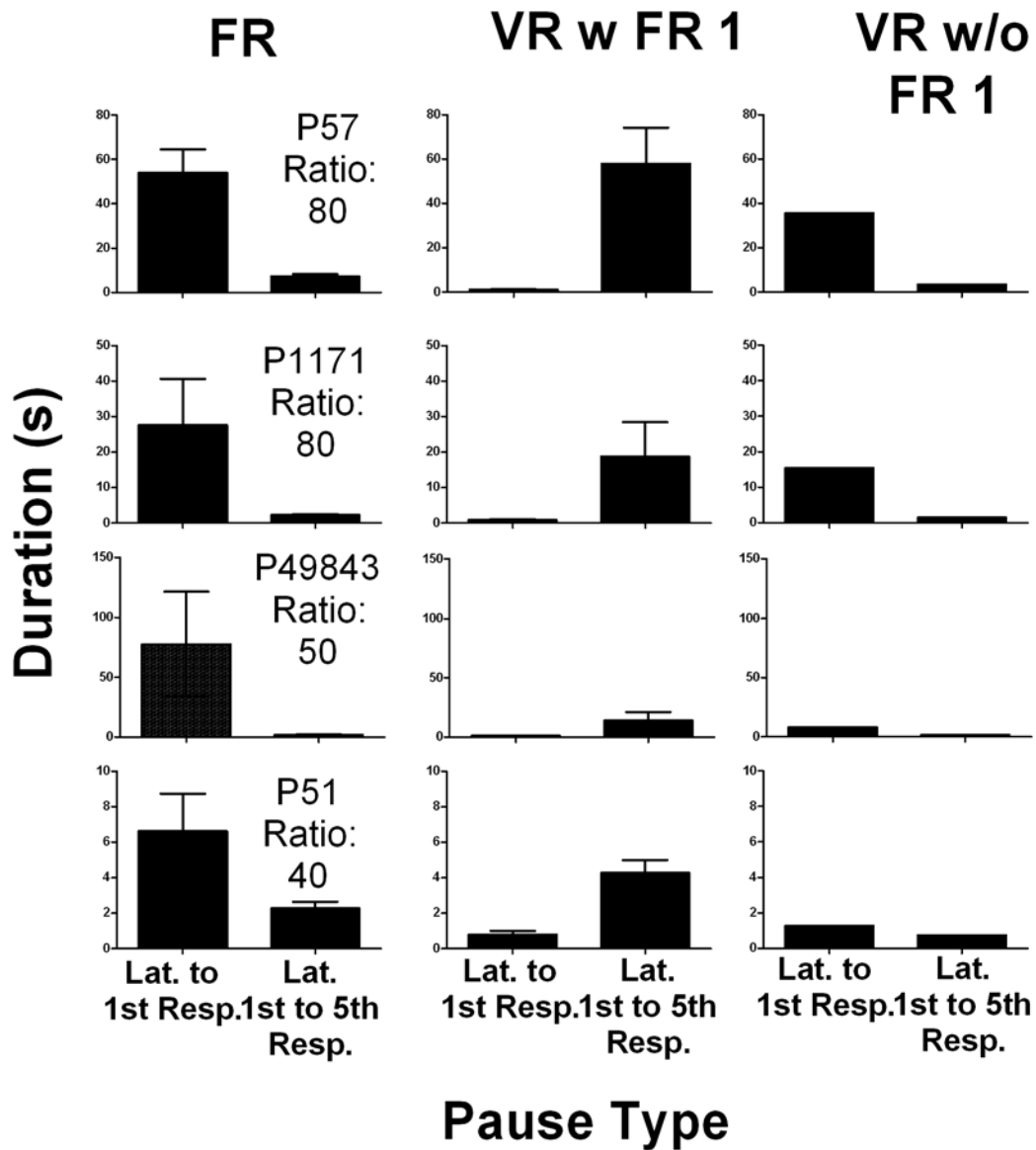


Figure 1. Latency to the emission of the first response and the latency from the first response to the fifth response at rich-lean transitions across for the *mult* FR FR, (left column) *mult* VR VR with FR 1 (center columns), and *mult* VR VR without FR1 (right column). Pauses when the ratio was FR 1 in the *mult* VR VR with the FR 1 condition were excluded from the analysis.

Figure 2 shows median pause durations (i.e., latency to the fifth response) at each transition type across the entire condition. The median was based on pauses collected from a block of three consecutive sessions. In both of the *mult* FR FR conditions, pause durations (e.g., ranging from 6.55 s for P51 to 446.06 s for P49843) at rich-lean transitions were considerably longer than at three other transition types in all pigeons (i.e., pauses were short at the other transitions: less than 5 s). Differentiation between pauses at rich-lean transitions and lean-lean transitions also occurred in the *mult* VR VR with and without the FR 1 conditions, albeit to a much smaller extent than in the *mult* FR FR conditions. These results reproduced Perone and Courtney's (1992) results of extended pausing at rich-lean transitions.

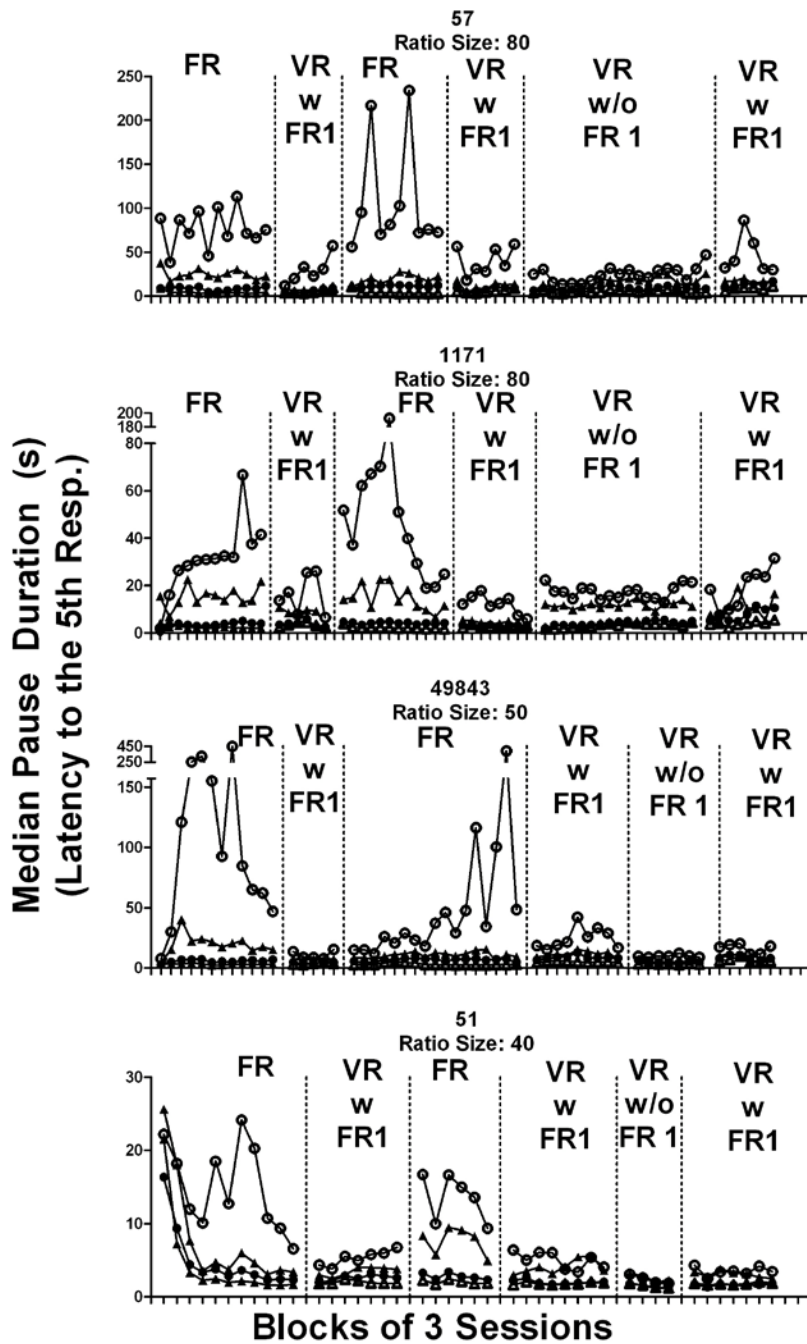


Figure 2. Median pause durations (latency to the fifth response) at rich-rich (closed circles), rich-lean (open circles), lean-lean (closed triangles), and lean-rich (open triangles) transitions across conditions. Each data point represents the median pause duration based on pauses collected across a block of three sessions.

Figure 3 shows the percent difference in the median pause durations (measured to the fifth response) at rich-lean transitions from the *mult* VR VR with the FR 1 condition compared to an individual pigeon's *mult* FR FR condition (see Table 2 for absolute values). Data from the last six sessions of the same condition were averaged together. The percent difference score was calculated by subtracting the median pause duration of the *mult* FR FR condition from the median pause duration of the *mult* VR VR with the FR 1 condition and dividing the result by the median pause duration from the *mult* FR FR condition. Compared to the *mult* FR FR condition, pauses at rich-lean transitions were reduced for all pigeons (e.g., ranging from a decrease of 48% for P51 to 80.67% for P49843) when the VR schedule was configured with a FR 1. Thus, the *mult* VR VR schedule with the FR 1 reduced pausing at rich-lean transitions, which should reduce the aversiveness of the stimuli signaling the rich-lean transition.

Pigeon	Condition	Median Pause at Rich-Lean Transitions
P57	FR	70.88 (51.34, 94.48)
	VR w FR 1	33.98 (11.35, 72.86)
	FR	73.30 (39.59, 180.60)
	VR w FR 1	52.84 (27.83, 88.60)
	VR w/o FR 1	37.68 (23.25, 65.19)
	VR w FR 1	30.89 (20.76, 68.03)
P1171	FR	38.37 (21.94, 71.53)
	VR w FR 1	14.8 (5.03, 33.06)
	FR	21.31 (18.31, 35.16)
	VR w FR 1	5.88 (2.09, 18.32)
	VR w/o FR 1	21.20 (16.72, 29.95)
	VR w FR 1	27.10 (17.82, 34.26)
P49843	FR	49.97 (20.06, 428.10)
	VR w FR 1	10.28 (7.00, 20.62)
	FR	136.60 (20.66, 644.30)
	VR w FR 1	15.17 (24.72, 62.56)
	VR w/o FR 1	9.40 (8.21, 12.36)
	VR w FR 1	14.58 (11.78, 18.59)
P51	FR	7.23 (5.99, 9.76)
	VR w FR 1	6.17 (4.88, 7.96)
	FR	11.18 (8.54, 14.57)
	VR w FR 1	4.73 (3.17, 7.52)
	VR w/o FR 1	1.93 (1.56, 2.24)
	VR w FR 1	3.92 (3.14, 5.34)

Table 2. Absolute values for median pause durations (with 25th and 75th interquartile ranges) across *mult* FR FR, *mult* VR VR with FR 1, and *mult* VR VR without FR 1 conditions.

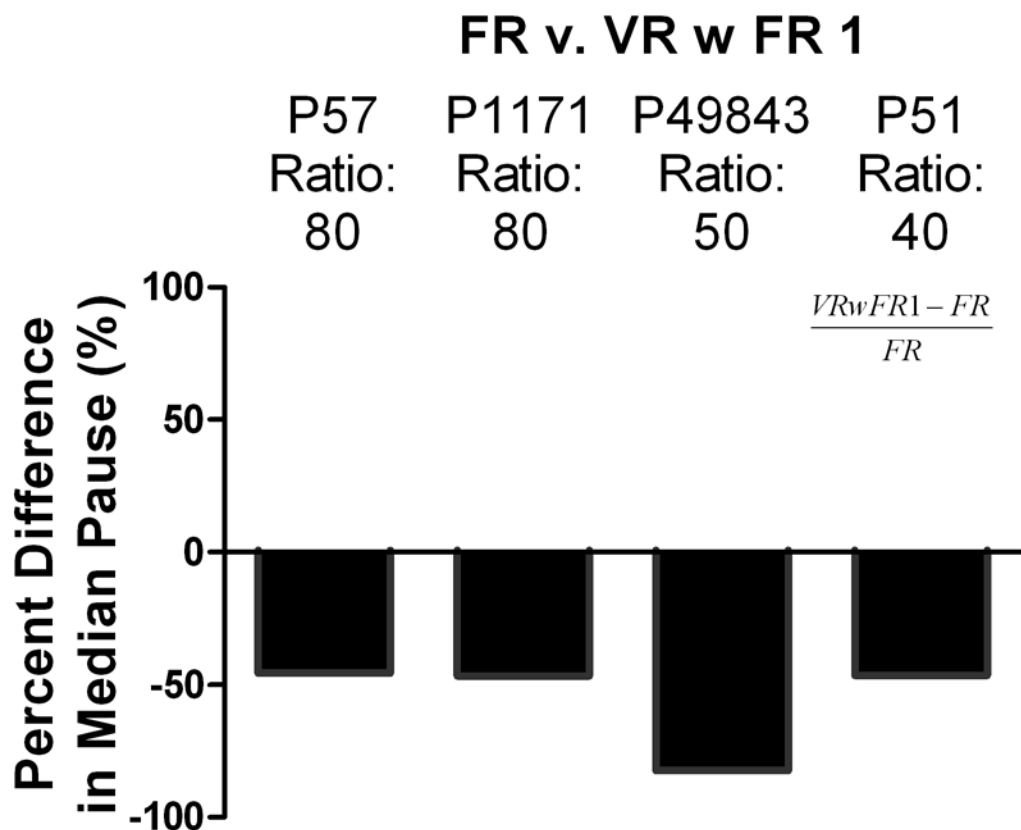


Figure 3. Percent difference (%) in median pause durations at rich-lean transitions from the *mult* VR VR with the FR 1 condition compared to the *mult* FR FR condition. The percent difference score was calculated by subtracting the median pause duration of the *mult* FR FR condition from the median pause duration of the *mult* VR VR with the FR 1 condition and dividing that result by the median pause duration from the *mult* FR FR condition.

Figure 4 shows the percent change in the median pause durations at rich-lean transitions from the *mult* VR VR with the FR 1 condition and the *mult* VR VR without the FR 1 condition compared to the *mult* FR FR condition. Data from the last six sessions of each condition were averaged together. For pigeon 1171, the *mult* VR VR with the FR 1 schedule was more effective

at reducing pausing at rich-lean transitions than the *mult* VR VR without the FR 1 schedule. One might argue that it may be difficult to attribute the reduction in pausing at rich-lean transitions to the FR 1 because both the smallest and largest ratio sizes were adjusted simultaneously. Arguing against this, in the VR schedule *with* a FR 1, the size of the largest ratio was relatively larger (e.g., 160) than when the FR 1 was removed (e.g., 141). A larger ratio size should produce longer pauses, which pitted the pause-reducing effects of the *mult* VR VR *with* a FR 1 schedule configuration against itself. Pigeon 51 showed the opposite effect—the *mult* VR VR without the FR 1 schedule was more effective than *mult* VR VR with the FR 1 at reducing pausing. Both VR schedule configurations were equally effective at reducing pausing at rich-lean transitions for pigeons 57 and 49843. Thus, contrary to predictions, setting a FR 1 as the smallest ratio was not a more effective way to configure a VR schedule for the purpose of reducing pausing at rich-lean transitions.

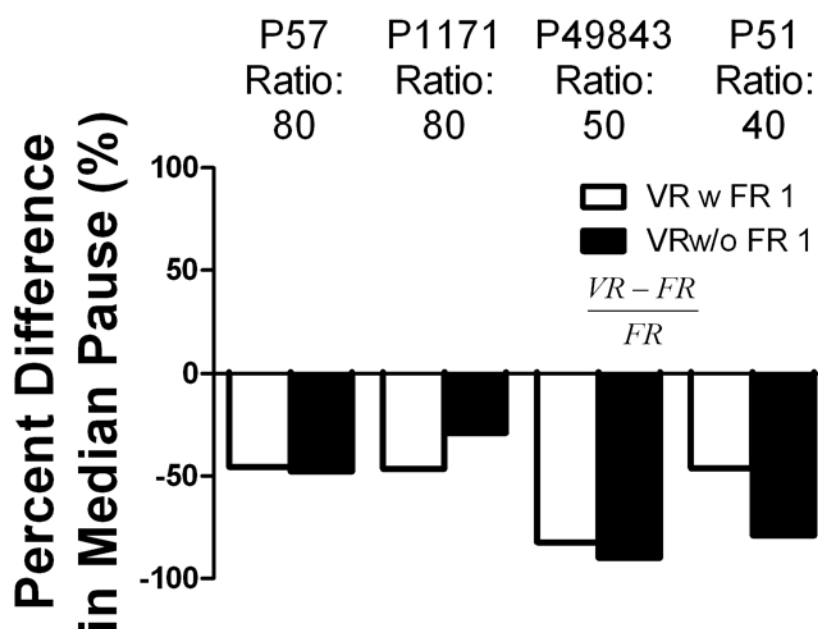


Figure 4. Percent change (%) in median pause durations at rich-lean transitions from either the *mult* VR VR with the FR 1 (open bars) or the *mult* VR VR without the FR 1 (closed bars) compared to the *mult* FR FR condition. The percent difference score was calculated by subtracting the median pause duration of the *mult* FR FR condition from the median pause duration of the given *mult* VR VR condition and dividing the result by the median pause duration from the *mult* FR FR condition.

The results of Experiment 1A revealed relatively long latencies from the first to the fifth response occurred on the *mult* VR VR with the FR 1 conditions, but not in the *mult* FR FR and the *mult* VR VR without the FR 1 condition for all pigeons. These results suggested that the location of the pause in the *mult* VR VR with the FR 1 conditions was relocated to after the first response. This pause relocation was likely attributable to the atypical 4-valued VR schedule.

From an applied perspective, relocating a period of aversive stimulation at rich-lean transitions from before the emission of the first response to after the first response may not be considered an effective potential treatment. The applied implication of this displacement is that instead of CAB at rich-lean transitions occurring before the first response on the lean task, CAB would be displaced to after the task had already started—which are both equally disruptive.

The VR schedule with four individual ratios used in Experiment 1 is not the typical way VR schedules are arranged. Typical VR schedules tend to use distributions that better approximate a constant probability of reinforcement for each response or at least that minimize the discriminability of the individual ratios. One commonly used distribution was described in Fleshler and Hoffman's (1962) progression for arranging a distribution of ratios such that the probability of a given ratio was less discriminable and produced smoother rates of responding. Typical VR schedules do not successively present the same individual ratio. Instead, typical VR schedules cycle through all individual ratios before the same ratio can be selected again. Variable-ratio schedules were designed to approximate a constant-probability schedule in which each response had an equal probability of being reinforced. A convenient way to arrange a constant-probability of reinforcement schedule is to use a random-ratio (RR) schedule. A RR schedule arranges a probability of reinforcement that is independent of the number of responses since the last reinforcer (Catania, 2006). Performance on simple RR schedules is characterized by short pauses and relatively short and uniform IRT durations (Mazur, 1983). Thus, there is reason to believe that arranging a *mult* RR RR schedule would reduce pausing at rich-lean transitions compared to a *mult* FR FR schedule.

Experiment 1B: The Effects of Random-Ratio Schedules on Pausing at Rich-Lean Transitions

Using a *mult* RR RR schedule should reduce pausing at rich-lean transitions compared to a *mult* FR FR schedule because the upcoming ratio on the RR schedule is unpredictable and can be small, which should eliminate any s-delta properties of the postreinforcement period. A RR schedule should not relocate the pause period to after the first response because the probability of reinforcement after each response is independent of the number of responses since the last reinforcer, which should make it difficult to discriminate individual ratios on RR schedules compared to the previous study's four-value VR schedule that arranged a long period of nonreinforcement between individual ratios. Another study was conducted to determine whether arranging a *mult* RR RR schedule would reduce pausing at rich-lean transitions compared to *mult* FR FR schedules without relocating the pause.

Method

The pigeons, apparatus, procedures, and stability criteria were the same as in Experiment 1A, unless otherwise noted. Table 3 shows the order of experimental conditions. To produce an average ratio size on the RR schedule that was equivalent to the one used in the *mult* FR FR conditions, the probability of reinforcement for each response on a RR 80 schedule was set to 0.0125 (1/80), a RR 50 was set to 0.02 (1/50), and a RR 40 schedule was set to 0.025 (1/40). The Med-PC computer program implemented a random-probability gate after each response to determine if a reinforcer was to be delivered.

Subject	Experimental Conditions	Sessions	Programmed Ratio Size	Obtained Ratio Size
P57	FR FR	60	80	80
	RR RR	31	80	69.53 (5.39)*
	FR FR	60	80	80
	RR RR	21	80	83.60 (6.86)
P1771	FR FR	58	80	80
	RR RR	34	80	87.24 (18.09)
	FR FR	35	80	80
	RR RR	23	80	81.11 (11.94)
P49843	FR FR	25	50	50
	RR RR	20	50	52.46 (7.11)
	FR FR	60	50	50
	RR RR	20	50	52.19 (8.20)
P51	FR FR	22	40	40
	RR RR	20	40	34.08 (4.94)*
	FR FR	60	40	40
	RR RR	20	40	34.77 (2.78)*

Table 3. The sequence of experimental conditions, the number of sessions in each condition, programmed and mean obtained ratio sizes (the standard deviation is shown in parentheses). Significant differences are indicated with an asterisk.

Results and Discussion

The programmed mean RR ratio size and the obtained ratio size are shown in Table 2. A two-tailed t-test was conducted to determine if these ratio sizes differed; some significant differences were obtained, as indicated in Table 3. For pigeons 57 and 51, the obtained ratio in the RR schedule were 10 or 6 responses less than the programmed mean. Such deviations have been reported when using RR schedules. For example, in Table 2 of Crossman et al.'s (1987) study, the actual value of a programmed RR 80 was a RR 64.73—a deviation of about 15 responses. One might argue that in the current study the difference in pausing between that

generated by a FR 34 and FR 40 for pigeon 51 may be negligible. As for pigeon 57, the difference between the programmed mean RR ratio size and the obtained ratio was statistically significant for only one of the *mult* RR RR conditions; no difference in pausing occurred between the two conditions.

Figure 5 shows two different ways to measure the pause duration at rich-lean transitions: pausing measured as latency to the first response or as the latency between the first to the fifth response. When the pause was measured as the latency from the first to fifth response, pause durations from the FR 1 schedule in the *mult* VR VR schedule were excluded from the analysis. Data from the same condition were averaged together. In the both the *mult* FR FR and *mult* RR RR conditions, the latency to the first response was longer than the latency from the first to fifth response. Thus, the RR schedule did not relocate pausing to after the first response.

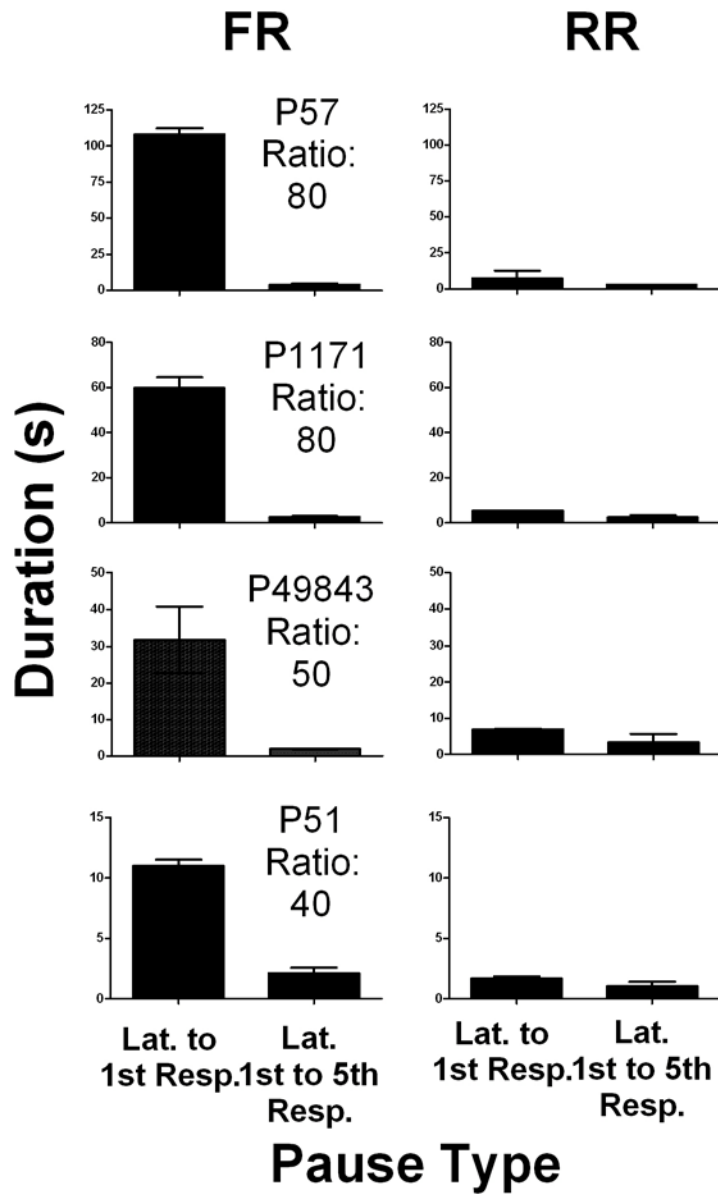


Figure 5. Latency (s) to the emission of the first response or until the latency to the emission of the first to the fifth response at rich-lean transitions across *mult* FR FR (left column) and *mult* RR RR (right column) conditions.

Figure 6 shows median pause durations (i.e., latency to the fifth response) at each transition type across an entire condition. The median was based on pauses collected from a

block of three consecutive sessions. In both of the *mult* FR FR and *mult* RR RR conditions, pausing was longer at rich-lean transitions compared to other transitions; pauses at rich-lean transitions were shorter than during the *mult* RR RR conditions. These results reproduced Perone and Courtney's (1992) results of extended pausing at rich-lean transitions.

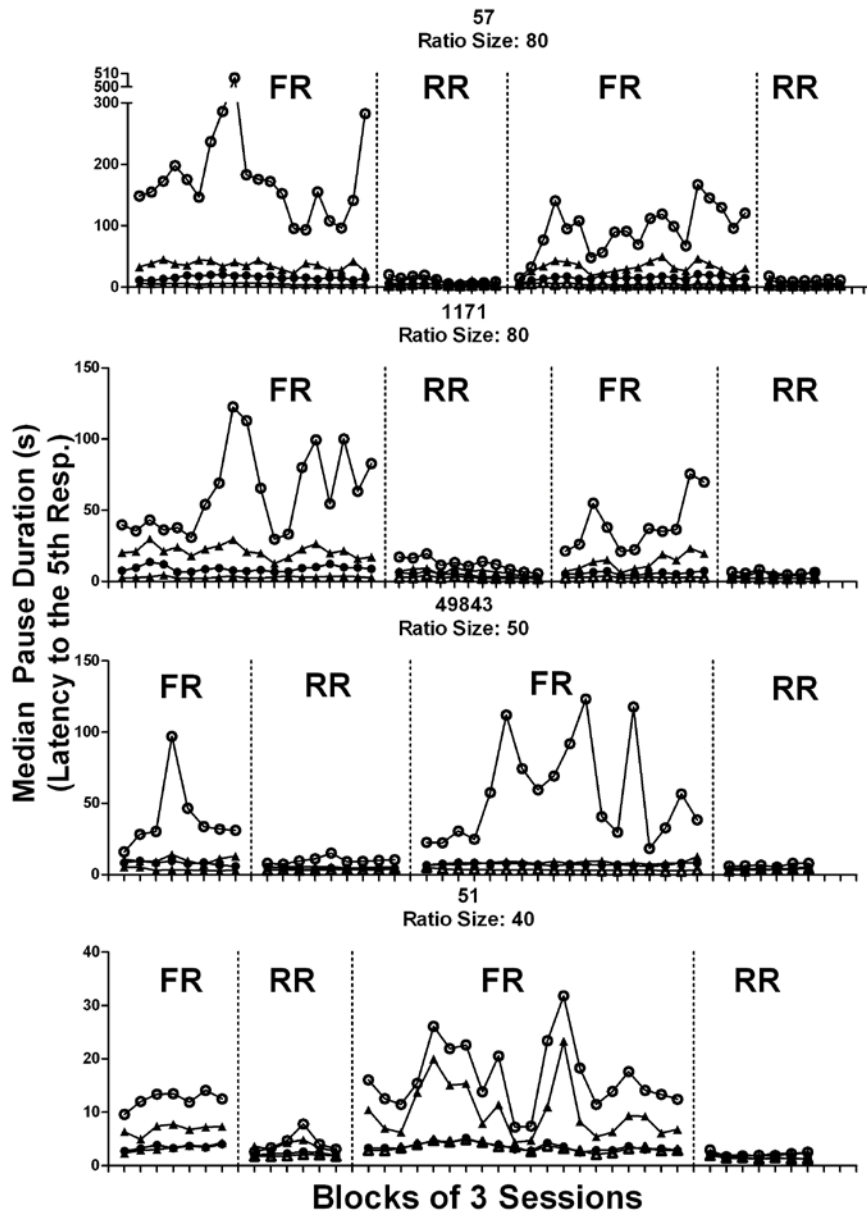


Figure 6. Median pause durations (latency to the fifth response) at rich-rich (closed circles), rich-lean (open circles), lean-lean (closed triangles), and lean-rich (open triangles) transitions across *mult* FR FR and *mult* RR RR conditions. Each data point represents the median pause duration based on pauses collected across a block of three sessions.

Figure 7 shows the percent difference in the median pause durations from each *mult* RR RR condition relative to its corresponding *mult* FR FR baseline (see Table 4 for absolute values). Data from the last six sessions of the same condition were averaged together. The percent difference score was calculated by subtracting the median pause duration of the *mult* FR FR condition from the median pause duration of the *mult* RR RR condition and dividing the result by the median pause duration from the *mult* FR FR condition. Relative to the *mult* FR FR condition, pauses at rich-lean transitions were substantially reduced for all pigeons (e.g., a decrease ranging from 74.04% for P49843 to 92% for P57).

Pigeon	Condition	Median Pause at Rich-Lean Transitions
P57	FR	145.20 (68.56, 328.50)
	RR	8.10 (5.68, 12.62)
	FR	114.30 (48.41, 209)
	RR	11.90 (9.14, 14.77)
P1171	FR	65.05 (30.01, 310.90)
	RR	5.87 (3.98, 7.52)
	FR	71.59 (36.22, 154.70)
	RR	5.44 (3.34, 9.28)
P49843	FR	31.01 (21.94, 81.22)
	RR	9.99 (8.15, 13.19)
	FR	39.98 (23.08, 399.90)
	RR	7.88 (6.50, 10.18)
P51	FR	12.83 (9.62, 17.73)
	RR	3.44 (2.66, 4.20)
	FR	13.28 (11.03, 15.76)
	RR	2.42 (2.06, 2.86)

Table 4. Absolute values for median pause durations (with 25th and 75th interquartile ranges) across *mult* FR FR and *mult* RR RR conditions.

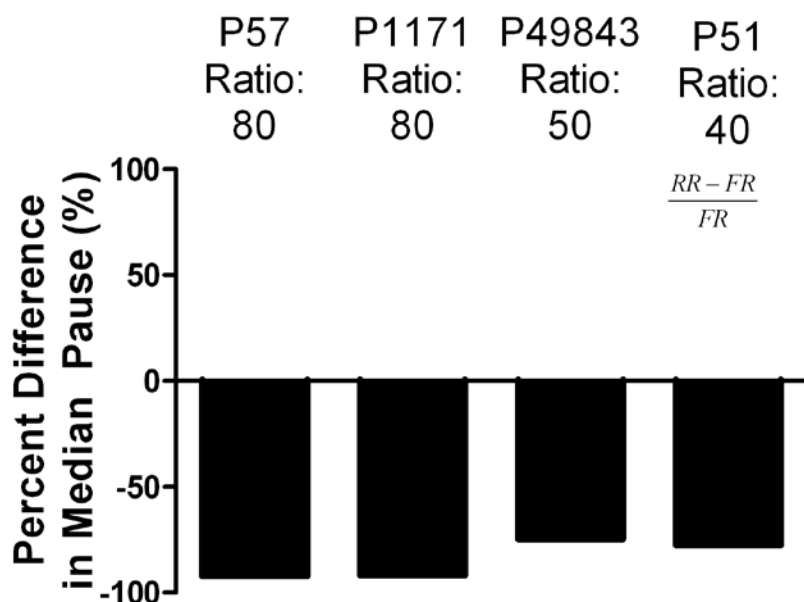


Figure 7. Percent difference (%) in median pause durations at rich-lean transitions from the *mult* RR RR condition compared to the *mult* FR FR condition. The percent difference score was calculated by subtracting the median pause duration of the *mult* FR FR condition from the median pause duration of the *mult* RR RR condition and dividing that result by the median pause duration from the *mult* FR FR condition.

Figure 8 compares the percent difference median pause durations at rich-lean transitions between the *mult* RR RR and *mult* VR VR with and without the FR 1 conditions compared to the *mult* FR FR condition. For all pigeons, the *mult* RR RR schedule produced a greater reduction in pausing at rich-lean transitions than the *mult* VR VR with the FR 1 condition. The *mult* RR RR schedule produced larger reductions in pauses at rich-lean transitions than the *mult* VR VR without the FR 1 schedule for pigeons 57 and 1171, whereas for pigeons 49843 and 51, both schedules were equally effective. These results suggest that there was not a large difference in reductions of pausing at rich-lean transitions using a four-valued VR schedule with and without

FR or a RR schedule. Equal reductions may be attributable to the way pausing was defined (the latency to the fifth response rather than the latency to the first response).

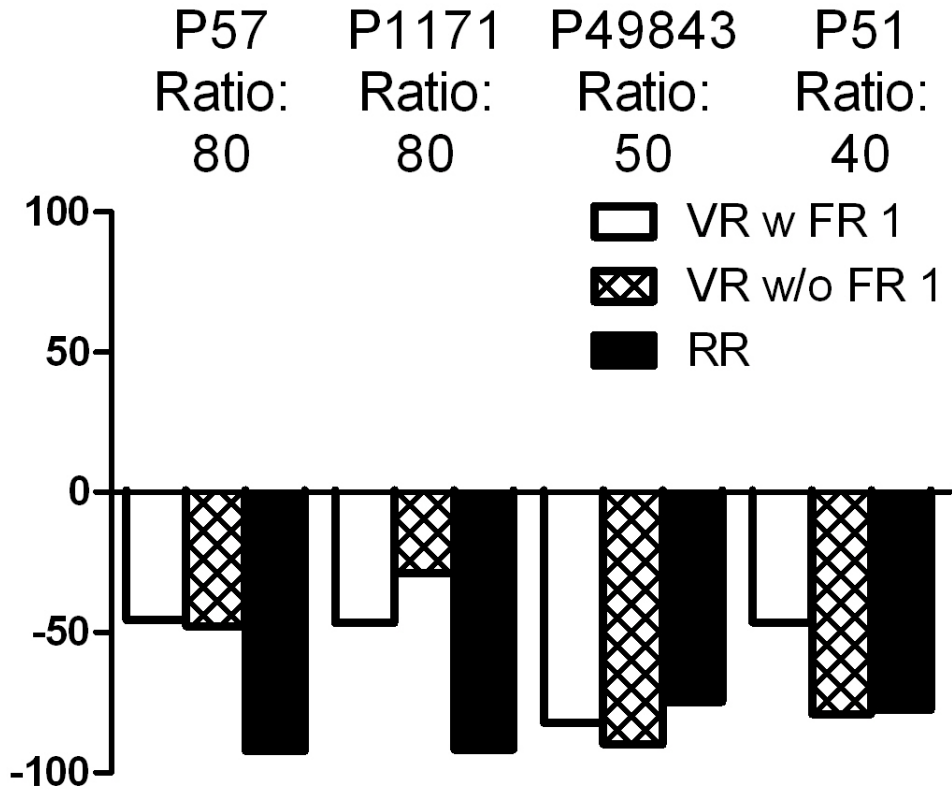


Figure 8. Percent difference (%) in median pause durations at rich-lean transitions from either the *mult* VR VR with the FR 1, *mult* VR VR without the FR 1, or the *mult* RR RR condition compared to the *mult* FR FR condition. The percent difference score was calculated by subtracting the median pause duration of the *mult* FR FR condition from the median pause duration of either the *mult* VR VR or *mult* RR RR condition and dividing that result by the median pause duration from the *mult* FR FR condition.

Experiment 1B showed that arranging a *mult* RR RR schedule did not relocate the pause to after the first response. In general, similar reductions in pausing at rich-lean transitions (relative the *mult* FR FR schedule) occurred on the *mult* RR RR schedule compared to the four-

valued VR schedule with and without the FR 1. Crossman et al. (1987) results showed that pausing on a simple VR 80 schedule (using Fleshler & Hoffman's [1962] distribution) was relatively longer than on a simple RR 80 schedule. However, this effect was small and occurred in two out of four pigeons, which is similar to the results of Experiment 1B.

General Discussion

Summary of Major Findings

In Experiment 1A, a four-valued, *mult* VR VR with a FR 1 schedule reduced pausing at rich-lean transitions relative to an equivalent-sized *mult* FR FR schedule, when the pause was defined as the latency to the first response. However, due to the discriminability of the FR 1 in the four-valued, *mult* VR VR schedule, the pause was relocated to between the first and fifth response. To make equal comparisons of pausing across conditions, the pause was redefined as the latency to the fifth response. Both *mult* VR VR schedule configurations, with and without a FR 1, reduced pausing at rich-lean transitions relative to the *mult* FR FR schedule.

Experiment 1A also sought to determine whether a four-valued, *mult* VR VR schedule configured with a FR 1 as the smallest ratio would more effectively reduce pausing at rich-lean transitions compared to an equivalent-sized *mult* VR VR schedule without a FR 1. Configuring a FR 1 into the VR schedule did not more effectively reduce pausing at rich-lean transitions compared to a VR schedule without a FR 1. Both four-valued, *mult* VR VR schedule configurations were equally effective at reducing pausing at rich-lean transitions.

Experiment 1B attempted to use a *mult* RR RR schedule to reduce pausing at rich-lean transitions (relative to a *mult* FR FR schedule) without relocating the pause after the first response. The *mult* RR RR schedule effectively reduced pausing at rich-lean transitions without relocating the pause after the first response. The RR, VR with the FR 1, and the VR without the

FR 1 schedules were, in general, equally effective at reducing pausing at rich-lean transitions relative to a FR schedules.

Why Did Shorter Pauses Occur on VR and RR Schedules?

The simple-schedule literature may inform why pauses on the *mult* VR VR and *mult* RR RR schedules were shorter than on the *mult* FR FR schedules. Schlinger et al. (2008) suggested that shorter pauses occur on simple VR schedules (compared to FR schedules) because the ratio size of the upcoming ratio is unpredictable and sometimes rather small (e.g., FR 1), which weakens the stimulus control of the postreinforcement period from reliably signaling a period of nonreinforcement (see also, Ferster & Skinner, 1957). Thus, the type of rich-lean transition from reinforcement to nonreinforcement on simple schedules may be relatively less aversive on VR and RR schedules than on FR schedules. Applying this account to the multiple-schedule, the *mult* VR VR and *mult* RR RR schedules may have reduced the aversiveness of the simple-schedule transition from reinforcement to nonreinforcement, but left the disparity in reinforcer magnitude unaffected.

The role of the disparity in reinforcer magnitude on pausing at rich-lean transitions may have been modulated by the ratio size on VR and RR schedules. Mazur (1986) showed that animals subjectively value a large VR schedule (e.g., VR 60) as equivalent to a smaller FR schedule (FR 30). Pausing at rich-lean transitions has been shown to be a function of the ratio size (Perone, 2003). If the ratios sizes of 80, 50, and 40 on the *mult* VR VR and *mult* RR RR schedules used in the current study were subjectively valued as a smaller FR schedule, then shorter pauses at rich-lean transitions would be expected—despite the disparity in reinforcer magnitude.

Pausing as an Index of Aversiveness

If pausing is an index of the aversiveness of the rich-lean transition (e.g., Perone, 2003), then shorter pauses on *mult* VR VR and *mult* RR RR schedules compared to *mult* FR schedules suggest that the stimuli signaling rich-lean transitions are relatively less aversive on VR and RR schedules. To the best of my knowledge, the simple schedule literature does not provide any studies in which animals were given an explicit opportunity to escape on simple VR or RR schedules. Instead, evidence that suggests that a VR schedule is less aversive than an equivalent-sized FR schedule shows that attack is less frequent toward a conspecific on a simple VR schedule than on a FR schedule (Webbe et al., 1974). For direct confirmation that rich-lean transition using *mult* VR VR or *mult* RR RR schedules are less aversive than *mult* FR FR schedules, future researchers may wish to provide animals an explicit opportunity to either escape or to aggress towards a conspecific.

Comparing the Four-Valued, VR Schedule to a More Traditional VR Schedule

Using the four-valued, *mult* VR VR schedule and randomly selecting each individual ratio was done to increase the overall and local probability of encountering a FR 1. Increasing the discriminability of the FR 1 was intended to make the *mult* VR VR schedule more effective at reducing pausing at rich-lean transitions (e.g., Field et al., 1996; Schlinger et al., 1990). An unintended consequence of increasing the discriminability of the FR 1 in the *mult* VR VR schedule was that the pause was relocated to after the first response.

The generality of the effects of the four-valued, *mult* VR VR schedules to more traditional VR schedules was limited. The four-valued, VR schedule used in the current study was based on Field et al.'s (1996) distribution of individual ratios (see also Ahearn et al., 1992; Andrezejewski et al., 2001). A unique feature of Field et al.'s distribution is that the difference between successive individual ratios is large. As a result, there is an extended period of

nonreinforcement after each individual ratio, which may account for why the FR 1 in the *mult* VR VR schedule relocated the pause to after the first response. Typical VR schedules tend to use a distribution of individual ratios that minimize the discriminability of each ratio. For example, the Fleshler and Hoffman (1962) distribution minimizes the discriminability of an individual ratio by keeping the difference between successive individual ratios small. The Fleshler and Hoffman distribution also keeps the probability of reinforcement as a function of time (or responses) since reinforcement constant. Fleshler and Hoffman never stated how many individual ratios should be used to prevent the discriminability of each individual ratio, but using a large number of individual values allows for a closer approximation to a constant-probability of reinforcement schedule.

Another feature of the current study's atypical VR schedule that limits its generality to traditional VR schedules was the random selection of an individual ratio at the beginning of each multiple-schedule component. This arrangement increased the local probability of encountering the same ratio in a row, which may have enhanced the discriminability of the FR 1 in the *mult* VR VR schedule. Traditional VR schedules cycle through the entire distribution of individual ratios before presenting the same individual ratio again.

Priming

The atypical *mult* VR VR schedule may more closely resemble the scheduling features and response patterns of a mixed-ratio (MR) schedule. Mixed-ratio schedules are typically configured with around two or three individual ratios (Catania, 2006), which is close to the four used in the atypical *mult* VR VR schedule. Also, MR schedules tend to arrange two extreme ratio sizes that are highly discriminable. For example, a MR 50 schedule is often configured with a FR 1 and FR 99. This arrangement is similar to the distribution of individual ratios in the atypical

mult VR VR schedule. For example, a VR 80 schedule was configured with a FR 1, FR 40, FR 120, and FR 160; the two extreme values were FR 1 and FR 160. In terms of response patterning, MR schedules tend to produce short pauses and long IRTs (e.g., Fantino, 1967). These long IRTs on MR schedules may be conceived as relocated pauses. Ferster and Skinner (1957) characterized this response pattern as “priming.” Priming is said to occur when a few responses are emitted before pausing occurs within the ratio (instead of before the first response) at approximately the same number of responses it would take to complete the smallest discriminable ratio.

Suggestive evidence that relocated pauses in the current study were the result of aversive stimulation (analogous to when the pause occurs before the first response) is supported by Thompson’s (1964) study that provided pigeons with an explicit escape opportunity on a MR 125 schedule with values of FR 25 and FR 225. Escape was more likely to occur on the larger ratio at around 25 responses (the end of the smaller ratio). The results suggest that a period of aversive stimulation was displaced until after the smallest ratio, which may be comparable to when pausing was relocated until after the first response at rich-lean transitions in the *mult* VR VR with FR 1 schedule conditions.

Priming may be attributable to the discriminability of the smallest ratio configured, which may be accounted for by the fact that the first response is reinforced, not depending on whether the active ratio is the smaller ratio or the larger ratio. The discriminability of the smallest ratio may become accentuated where there is a large disparity between the size of the smallest ratio and the next largest ratio. To eliminate this problem, *mult* RR RR schedules (a constant-probability schedule) were programmed. On the *mult* RR RR schedule, the pause was located between the end of the reinforcer and before the first response; IRTs were uniformly brief. This

“smoother” response pattern on the *mult* RR RR schedule was attributed to each response having an equal probability of being reinforced.

Limitations

Related to the limited generality of the atypical *mult* VR VR schedule, a potential limitation of the current study was the decision not to pursue determining the optimal configuration of a VR schedule that would prevent relocation of the pause and still reduce pausing at rich-lean transition. Future researchers interested in pursuing this endeavor might alter the probability of obtaining a FR 1 by increasing the number of individual ratios configured until smooth patterns of responding emerge. This manipulation was bypassed in favor of using RR schedules because the literature (e.g., Mazur, 1983) suggested that it was the most effective way to reduce pausing without relocating the pause. Also, this tactic was more consistent with translational goals of the research program, as opposed to potentially pursuing countless parametric permutations to find the optimal way to arrange a VR schedule.

Applied Implications

The major applied implication of the current study was that rich-lean transitions between VR and RR schedules were less aversive than between FR schedules. In an applied setting, the rich-lean transition between a VR and RR schedule should occasion or elicit relatively less aberrant behavior. As a result, this should reduce physical harm to the individual and others, which should, in turn, allow the therapist or teacher more time to spend on teaching and devote less time to managing aberrant behavior. Applied researchers have used VR schedules to deliver performance pay in business settings (beaver trapping: Latham & Dossett, 1978; planting tree seedlings: Yukl & Latham, 1975; for a review see, Bucklin & Dickinson, 2001), to reinforce compliance with requests in a classroom (Neef, Shafer, Egel, Catalado, & Parrish, 1983), to

reinforce correct responding on early literacy rhyming tasks (Broussard, Van-DerHeyden, Fabre, Stanley & Ordoynne, 2006), to arrange choices between food or sedentary activities in obese and nonobese women (Saelens & Epstein, 1996), to increase exercise in obese and nonobese boys (De Luca & Holborn, 1992), and to increase the quality of children's handwriting (Veena, Romate, & Bhogle, 2002). However, VR schedules have not been directly applied to reduce transition-related CAB. The benefit of using a VR or a RR schedule over a FR is that a variable schedule should occasion less transition-related aberrant behavior without having to retard progress by reducing the overall number of responses required for reinforcement.

Developing a RR schedule into an applied treatment for CAB at rich-lean transitions should also be considered. Using a RR schedule might require a therapist to randomly deliver a reinforcer (e.g., praise) by rolling a gaming die after each discrete response (e.g., an answer to a math problem) when interspersing preferred activities (e.g., spelling questions) with less-preferred activities (e.g., math questions). To increase the social validity of this treatment, perhaps, the client could roll the die (under the supervision of the therapist) to turn the classroom into a more game-like environment. However, a potential problem arises if a task does not easily lend itself to identifying and reinforcing discrete responses. Efforts to develop the RR schedule into an applied treatment for aberrant behavior at rich-lean transitions are being planned using a table-top procedure. This procedure requires the client to separate different colored mealtime utensils according to Perone and Courtney's (1992) multiple-schedule procedure (Sherman et al., 2010).

Applied researchers may benefit from the finding that not all VR schedule configurations engender the same response patterning. If IRTs were ignored, then the atypical VR schedule with the FR 1 would have appeared highly effective at reducing pausing at rich-lean transitions.

However, configuring a FR 1 resulted in relocating the pause to after the first response. From an applied perspective, simply displacing the aversive stimulation to another period would still be a problem because the aversive stimulation had not been reduced or removed.

Conclusion

In sum, a four-valued, *mult* VR VR schedule (with and without a FR 1 as the smallest ratio) and a *mult* RR RR schedule were equally effective at considerably reducing pausing at rich-lean transitions compared to a *mult* FR FR schedule. When a FR 1 was the smallest ratio configured in the four-valued, *mult* VR VR schedule, pausing was relocated to within the ratio rather than before the emission of the first response. A *mult* RR RR schedule did not relocate the pause. The important applied implication of this study is that using VR or RR schedules may reduce the aversiveness of preferred- to less-preferred activity transitions, which should reduce the motivation to engage in aberrant behavior.

Experiment 2A: The Effects of Timeouts on Pausing at Rich-Lean Transitions

By conceptualizing the aversiveness of the stimuli signaling a rich-lean transition as an interaction between rich- and lean- schedule components, this may allow information from other literatures that address other types of behavioral interactions (e.g., multiple-treatment interference: McGonigle, Rojahn, Dixon, & Strain, 1987; simultaneous negative contrast: Haggblom, 1979) to inform how to reduce the aversiveness of stimuli signaling a rich-lean schedule transition. A way to reduce behavioral interactions in the applied (e.g., McGonigle et al., Rojahn, Dixon, & Strain, 1987) and basic research (e.g., Baron, Mikorski, & Schlund, 1992; Ferster & Skinner, 1957; Haggblom, 1979; Mazur & Hyslop, 1982; Perone, Perone, & Baron, 1987) is to impose a noncontingent, timeout period between multiple-schedule components (an intercomponent interval) or between discrete trials (an intertrial interval). Arranging a timeout

period typically involves changing the stimulus conditions from those prevailing during reinforcement to a set of neutral conditions.

In an applied research setting, McGonigle et al. (1987) investigated the effects of a timeout by lengthening the intercomponent interval (i.e., the time between the end of one multiple-schedule component and before the start of the next schedule component) on multiple-treatment interference. McGonigle et al. compared the effects of several different treatments on mouthing objects and fingers exhibited by a boy with severe intellectual and developmental disabilities (IDD) using an alternating-treatments design. When a 1-min timeout was imposed between each treatment, different treatments all had the same effect on mouthing, suggesting that these treatments influenced one another. Imposing a 2-hr timeout between treatments resulted in separate treatments having different effects on mouthing, suggesting the multiple-treatment interference was reduced.

In a basic research setting, Haggbloom (1979) used a 2 x 2 factorial design to investigate the effects of timeout by lengthening the intertrial interval (i.e., the time between the end of a trial and before the start of the next trial) on simultaneous negative contrast in a discrete-trial runway procedure. Haggbloom exposed a control group of rats to two different runways both ending in small amount of food (e.g., 1 food pellet), and an experimental control group of rats exposed to both a large amount of food (e.g., 12 food pellets) in one runway and a small amount of food in a different runway. These groups were divided into groups that received exposure to either a 3-min, 4-min, or 24-hr timeout. Distinct runway colors were used to signal the amount of food in the goal box (e.g., black runway = large amount of food; white runway = small amount of food). At the 3- or 4-min timeout, simultaneous negative contrast occurred when the experimental group showed a significant increase in latencies to leave the startbox compared to

the control group. At the 24-hr timeout, simultaneous negative contrast did not occur, suggesting that the effect of the past trial was eliminated with long timeout durations.

The effects of imposing a timeout period on pausing during simple ratio schedules have been investigated (e.g., Baron et al., 1992; Perone et al., 1987; Mazur & Hyslop, 1982). For example, Baron et al. (1992) examined the effects of different timeout durations (0-, 5-, 10-, 20-, and 30-s) on pause durations in rats using progressive-ratio (PR) schedules. The PR schedule was arranged by the increasing size of the ratio after each reinforcer in steps of 5. Responding was maintained with different milk concentrations (i.e., 30%, 50%, and 70%). Both the timeout duration and the reinforcer magnitude varied between conditions. Pausing increased as a function of the current ratio in the PR schedule. Longer timeouts and larger reinforcer magnitudes tended to decrease pauses at given ratio sizes. These results attest to the effectiveness of a timeout to reduce pausing on simple PR schedules.

In the context of a simple FR schedule, Mazur and Hyslop (1982) examined the effects of a 30-s postreinforcement timeout on pausing in pigeons using FR 50, FR 100, and FR 150 schedules. The postreinforcement timeout was imposed after each reinforcer and before the start of the next ratio for half of the FR trials. During the timeout, the key was darkened and the FR schedule was suspended, but the houselight remained on. Compared to pauses following no timeout, a 30-s timeout reduced the median pause duration for one pigeon at FR 100, one at FR 150, and another across FR 50, FR 100, and FR 150. Responses during the timeout were infrequent, suggesting that these short pauses were not attributable to a poor discrimination (i.e., pecking the key throughout the timeout). However, it is important to note that for approximately 38% of sessions, the pause durations from the timeout trials were relatively longer than on the

no-timeout trials. Thus, timeouts, in general, were effective at decreasing pausing on simple FR schedules.

Perone et al. (1987) reported that a 30-s postreinforcement timeout on a simple FR 30 schedule did not affect the median or mean pause duration. However, timeouts did change the distribution of pause durations by increasing the proportion of relatively short pauses. Perone et al. (1987) interpreted their timeout results supported Harzem and Harzem's (1981) account of pausing. Their account argues that, on simple FR schedules, pausing is controlled by the unconditioned inhibitory effects of the past reinforcer. According to this account, the pause following large reinforcers should decrease because of the passage of time imposed by the timeout.

Applying the account above to Perone and Courtney's (1992) multiple-schedule procedure, extended pausing following the rich-reinforcer magnitude should decrease because of the passage of time imposed by the timeout. Another possibility is that a timeout may function as extinction (a third schedule component), which would make the timeout leaner than the lean schedule component. Thus, all transitions after the timeout would become lean-rich transitions, which should shorten the pause durations. In both of these cases, if a timeout reduces the negative schedule interaction at a rich-lean transition, then the stimuli signaling this transition may be rendered less aversive.

The effects of timeouts on pausing at rich-lean transitions have been studied in the human operant laboratory (Sherman et al., 2010). Timeouts were imposed between the end of the reinforcer delivery and before the start of the next schedule component for each of the four transition types (e.g., rich-timeout-rich, rich-timeout-lean, lean-timeout-lean, and lean-timeout-rich). These timeouts increased the ICI (i.e., the time between multiple-schedule components)

and occurred between every transition. During the timeout, the schedule-correlated background colors on the computer screen were changed to a neutral background color (i.e., a blank screen). Timeout durations were yoked to each individual's mean pause durations at rich-lean transitions from a previous condition with no timeout. Relative to the no-timeout conditions, timeouts produced considerable reductions in mean pause durations at rich-lean transitions for each participant with IDD. In addition, the timeout produced pauses at rich-lean transitions that were equally short as pauses at lean-lean transitions, suggesting that the rich-lean schedule interaction was eliminated. These unpublished results show that, under laboratory conditions, a timeout effectively reduced pausing at rich-lean transitions and removed the rich-lean schedule interaction in the clinical population of interest.

The effects of a timeout on rates of chronic aberrant behavior (CAB) at rich-lean transitions were assessed in a classroom-analog setting using participants with IDD (Sherman et al., 2010). Participants were provided access to a set of activities for 5 min. each. During a no-timeout baseline, at the end of each activity, participants were immediately transitioned to the next activity and were asked to engage in that activity by a research assistant. During the timeout condition, before transitioning to the next activity, participants were moved to a different location, a timer was set to 30 s, and the participant waited with the assistant for the timer to elapse. In two out of three participants, rates of CAB at rich-lean transitions were reduced by a 30-s timeout; CAB increased in all transitions for the third participant. No CAB occurred during the timeout period, suggesting that the timeout period was neutral. These unpublished results, in general, attest to effectiveness of a 30-s timeout to reduce socially important CAB at rich-lean transitions in a clinically relevant population.

Unpublished results from a different laboratory reported contradictory findings with animals. Metzger and Perone (1990) exposed pigeons to timeouts imposed between each transition type for half of the multiple-schedule components. Within session, the timeout duration for a particular transition was yoked to the pause duration for that same transition when a timeout was not present. Although reductions in pausing at rich-lean transitions occurred following a timeout, pause durations at rich-lean transitions were longer than pause durations at lean-lean transitions, indicating a continued interaction of the past and current reinforcer—contrary to the considerable reductions in pausing at rich-lean transitions and the undifferentiated pause durations at rich-lean transitions and lean-lean transitions reported in the human laboratory (Sherman et al., 2010). That is, the Metzger and Perone study did not reduce the pause at rich-lean transitions to the same extent as in Sherman et al.’s human study.

The current study sought to reproduce the considerable pause reductions at rich-lean transitions and the undifferentiated pauses between rich-lean transitions and lean-lean transitions observed in humans by modifying Metzger and Perone’s (1990) animal procedures to approximate the human procedure (e.g., Sherman et al., 2010) as closely as possible. Metzger and Perone imposed a timeout after half of the multiple-schedule components, which may have weakened the effectiveness of the timeout on pausing at rich-lean transitions. To maximize the effectiveness of the timeout, Sherman et al. imposed a timeout after every multiple-schedule component. Metzger and Perone varied the timeout duration across transition types, which may have allowed the longest timeout to signal a rich-lean transition. Sherman et al. prevented such a discrimination by imposing a standardized timeout duration across transition types. Thus, the current study compared the effects of a standardized-timeout duration imposed after every multiple-schedule component on pausing at rich-lean transitions.

Method

The pigeons, apparatus, procedures, and stability criteria were the same as in Experiment 1, unless otherwise noted. Pigeons were exposed to a *mult* FR FR schedule involving four different transitions (e.g., rich-rich, rich-lean, lean-lean, and lean-rich) with no timeout (0 s). In the next condition, a noncontingent timeout was imposed between the end of the reinforcer and before the start of the next schedule component (e.g., rich-timeout-rich, rich-timeout-lean, lean-timeout-lean, and lean-timeout-rich). During the timeout, the houselight remained on, but the response key remained dark until the timeout elapsed. If a response occurred within the last 5 s of the timeout, then the onset of the schedule-correlated stimuli (i.e., the next component) was postponed by an additional 5 s. Sessions ended after 180 min or until 41 reinforcers were obtained.

Experimental Conditions. Initially, the timeout duration in the experimental condition was yoked to an individual pigeon's median pause duration at rich-lean transitions from the previous baseline *mult* FR FR condition (0-s timeout). This was done to systematically replicate the procedures from the human operant timeout study (Sherman et al., 2010). Pigeons 49843 and 51 stopped responding within session. Pigeon 49843 completed as few as five transitions per session during the timeout condition when the timeout duration for each transition was yoked to the median pause at the rich-lean transition from the no timeout condition. Subsequently, a standard 50-s timeout was imposed after each transition for all pigeons. Thereafter, the timeout duration was reduced to 20 s in order to increase the overall rate of reinforcement. Table 5 lists the sequence of experimental conditions for each pigeon, the number of sessions in each condition, and the number of transitions completed during the final six sessions of each condition.

Pigeon	Timeout	Sessions	Rich-Rich	Rich-Lean	Lean-Lean	Lean-Rich
P57	0 s	60	60	60	60	60
	50 s	60	42	33	36	34
	20 s	60	60	60	60	60
P1171	0 s	40	60	60	60	60
	50 s	60	23	23	30	21
	20 s	60	43	46	42	47
P49843	0 s	60	60	60	60	60
	50 s	60	45	40	40	39
	20 s	60	49	44	48	48
P51	0 s	20	60	60	60	60
	50 s	60	40	38	40	38
	20 s	46	60	60	60	60

Table 5. Shown are the sequence of experimental conditions (timeout durations) and the number of sessions in each condition. Also shown is the number of transitions from the last six sessions for each transition type.

Results and Discussion

For pigeons 57, 49843, and 51, responses did not occur during the timeout. Pigeon 1171 averaged one response per transition. None of the pigeons contacted the protective contingency in the final six sessions of the timeout conditions.

Initially, the duration of the timeout was yoked to the median pause duration at the rich-lean transition from the previous no-timeout condition. The yoking procedure yielded huge differences in timeout durations across pigeons. For example, pigeon 51 had very short median pauses (7.27 s) in the no-timeout condition. To maximize the chances of observing an effect of the timeout for pigeon 51, the first timeout duration (19.63 s) was based on the largest mean pauses from the no-timeout condition. Pigeon 49843 had relatively long pauses with a median of 339.08 s; he spent most of the session in timeout. Across several sessions for pigeon 49843, the total number of transitions completed declined to less than 5 (out of 40) per session, which made

data analysis increasingly difficult. To increase the number of transitions completed, the timeout duration was standardized to 50 s. Only data from the 50- and 20-s timeout conditions procedures will be presented.

The median pause duration results from 50-s timeout condition (shown in Figure 9) should be interpreted with caution because conditions had to be terminated after 60 sessions, and the overall number of transitions completed decreased considerably (ranging from approximately a 32% to 60% decrease) relative to the 0-s no-timeout condition (see Table 5 for the absolute number of transitions completed). Out of 60 possible rich-lean transitions, pigeon 57 completed 33 transitions, pigeon 1171 completed 23 transitions, pigeon 49843 completed 40 transitions, and pigeon 51 completed 38 transitions. During the last six sessions of the 50-s timeout condition, pigeon 57 tended to stop at the rich-lean transitions and pigeons 1171, 49843, and 51 were equally likely to stop at either the rich-lean transition or the lean-lean transition. In some cases, at least one response was emitted after presenting the schedule-correlated key color. Pauses were included in the data analysis if at least one response was emitted. This may have introduced variability and chance factors in the data analysis, which is a reason to use extreme caution when interpreting the data from the 50-s timeout data. Another reason to use caution when interpreting the timeout summary data is that the data sets between the no-timeout and timeout conditions were very different due to the lack of data in the timeout conditions. The results of the timeout condition may be due to an artifact introduced by a lack of data.

Figure 9 shows median pause durations (with 25th and 75th interquartile ranges) from the rich-lean and lean-lean transitions from the final six sessions in the no-timeout and timeout conditions. In the 0-s no-timeout condition, pauses were relatively longer at rich-lean transitions (57: 176.37 s; 1171: 42.59 s; 49843: 339.08 s; 51: 6.07 s) compared to lean-lean transitions (57:

18.41 s; 1171: 12.98 s; 49843: 8.6 s), which reproduced Perone and Courtney's (1992) results. Median pauses at rich-lean transitions were reduced in the 50-s timeout condition for pigeons 1171 (9 s) and 49843 (51.57 s); however, long pauses in pigeon 49843, indicated by the 75th interquartile, were not reduced. No effect was observed for pigeon 57. Pause durations at both rich-lean and lean-lean transitions increased to similar levels and were undifferentiated for pigeon 51 (lean-lean: 20.79 s; rich-lean: 23.37 s). Undifferentiated pauses between rich-lean and lean-lean transitions suggested that the rich-lean schedule interaction was disrupted for pigeon 51. That is, the passage of time imposed by the timeout may have disrupted the rich-lean schedule interaction by weakening the effects of the past reinforcer. Overall, the 50-s timeout produced mixed results across subjects: pigeons 1171 and 49843 showed a decrease in pausing at rich-lean transitions, no effect was shown for pigeon 57, and pauses at rich-lean transitions and lean-lean transitions were undifferentiated for pigeon 51. Again, the timeout results should be interpreted with extreme caution because of a potential artifact related to not completing a large percentage of transitions.

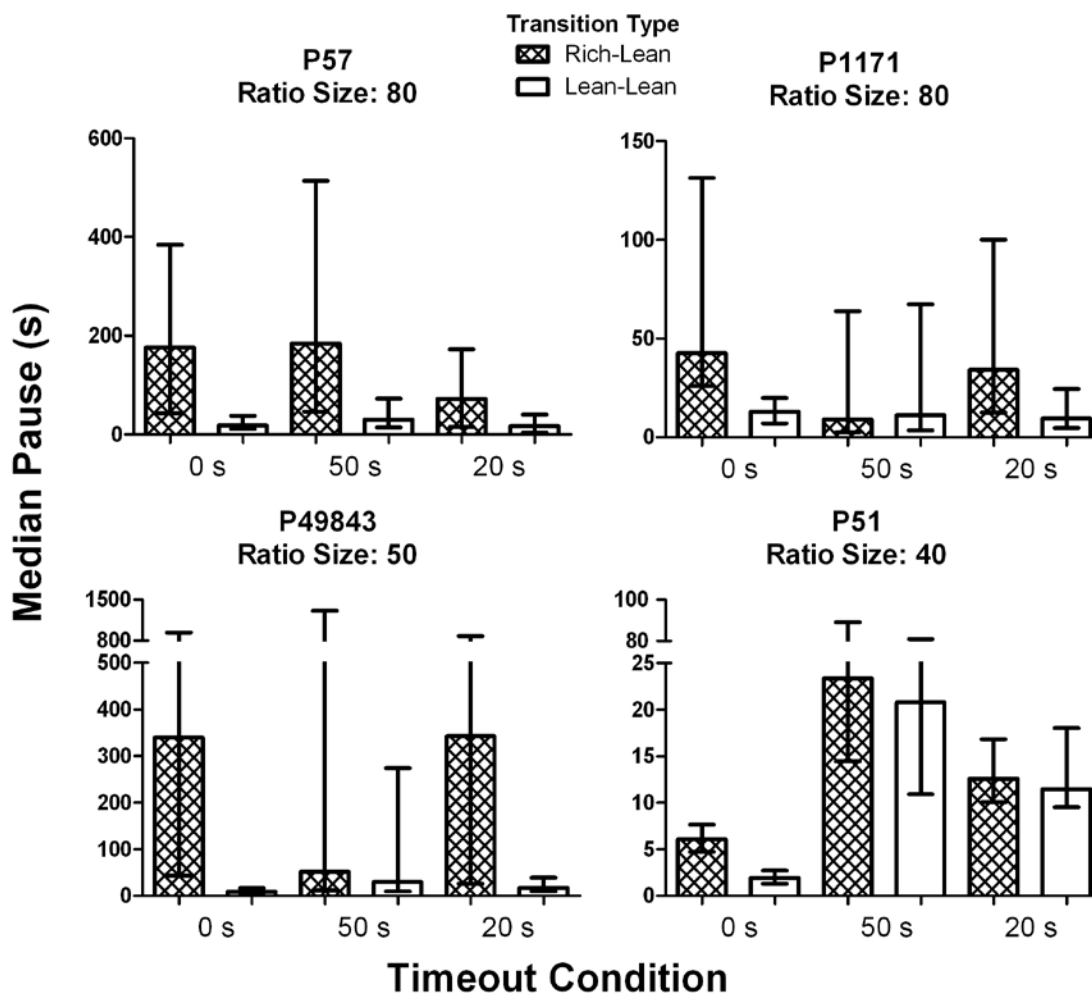


Figure 9. Median pause durations (error bars represent the 25th and 75th interquartile ranges) collapsed from the last six sessions in the 0-s no-timeout condition and timeout conditions (50- and 20-s) are shown on the y-axis. The filled bars represent pauses at rich-lean transitions and the unfilled bars represent pauses at lean-lean transitions.

Inspection of the tapes revealed that pigeons were “pacing” in front of response key and food receptacle. The timeout may have increased the overall response effort (as suggested by the pacing), which may have strained FR performance. Another notion was that the decrease in the number of transitions completed was affected by a decrease in the overall rate of reinforcement

imposed by the timeout. Both of these notions predicted that decreasing the timeout duration should increase the number of transitions completed. Increasing the number of transitions completed would remove a potential artifact from the timeout results.

The timeout duration was decreased from 50- to 20-s. For each pigeon, the percentage of transitions completed increased (P57: 61.52%; P1171: 83.51%; P49843: 15.24%; P51: 53.85%) in the 20-s timeout condition relative to the 50-s timeout condition (see Table 5 for the absolute number of transitions completed). However, pigeons 1171 and 49843 still did not complete all transitions; they completed 74.17% and 78.75% of the total possible transitions, respectively. In addition, only pigeon 51 met the stability criteria. Figure 9 shows that relative to the 0-s no-timeout condition, the 20-s timeout condition reduced the median pause duration at the rich-lean transition for pigeon 57. Both pauses at rich-lean and lean-lean transitions increased relative to the no-timeout condition for pigeon 51, which was similar to the effect in the 50-s timeout condition, albeit smaller. No effect occurred for pigeons 1171 and 49843, which suggested that this timeout length did not disrupt the rich-lean schedule interaction because pause patterns resembled those in the no-timeout condition. The results from the 20-s timeout condition should be cautiously interpreted because only pigeon 51's pause durations met the stability criteria, and pigeons 1171 and 49843 did not complete all the transitions.

In an effort to facilitate an equal comparison between the pause durations from the no-timeout condition to the timeout conditions, relative pause frequencies were sorted into different bin sizes (see Figure 10). This molecular analysis permits a visual inspection of the relative distribution of pauses from the last six session of each condition. In the 0-s no-timeout condition, the relative pause distribution at rich-lean transitions had a negative skew toward longer pauses for pigeons 57 and 1171, pigeon 49843 showed a bimodal distribution with one mode of

relatively short pauses (see the 33.89-s bin) and another mode of relatively long pauses (see the 678-s + bin), and pigeon 51 showed a normal distribution of pause durations. Given these different distributions, it is important to provide a more molecular analysis of the pause data, rather than simply providing the median as a single summary statistic. Timeouts tended to affect the shortest and/or longest bins. Thus, the change in median pause durations during the timeout conditions were attributable to either: a) an increase in the relative frequency of the shortest pauses and a decrease in the longest pauses (50 s: P1171; 20 s: P57), b) an increase in only the shortest pauses (50 s: P49843), or c) an increase in only the longest pauses (50- and 20-s: P51).

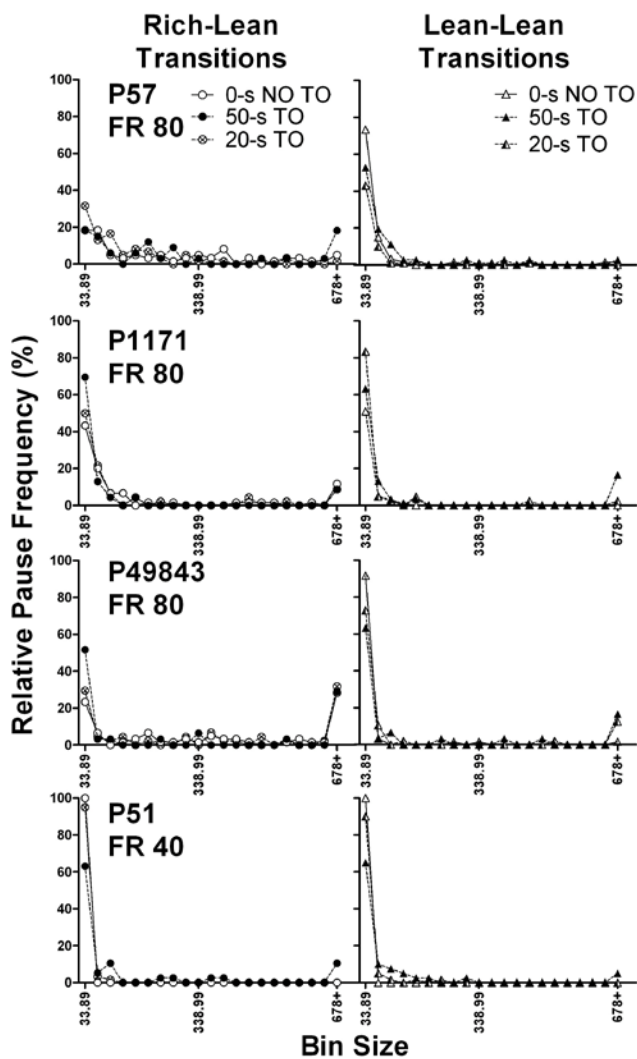


Figure 10. Relative frequency of pause durations at rich-lean (left column) and lean-lean transitions (right column) from the no-timeout and 50- and 20-s timeout conditions sorted into bins. Transitions from the no-timeout condition are represented with an open symbol (0-s NO TO: rich-lean: open circle; lean-lean: open triangle). Transitions separated by a 50-s timeout are represented with a closed symbol (50-s TO: rich-lean: closed circle, lean-lean: closed triangle). Transitions separated by a 20-s timeout are represented with a partially filled symbol (20-s TO: rich-lean: a circle with an “x” inside, lean-lean: a triangle with the left half closed).

Suggestive evidence of reductions in pause durations at rich-lean transitions in the 50-s timeout condition is consistent with the human timeout results (Sherman et al., 2010). Undifferentiated pausing at rich-lean and lean-lean transitions and stopping at rich-lean and lean-lean transitions is also suggestive that the rich-lean schedule interaction was disrupted. Due to the passage of time imposed by the timeout, the effects of the past reinforcer may have been weakened, which would essentially separate the multiple schedule into simple FR schedules ending in rich and lean reinforcer magnitudes. Thus, there may have been a main effect of the upcoming rich or lean reinforcer magnitude on pausing and stopping. The results from the 50-s timeout condition should be interpreted with extreme caution for at least three reasons. First, the pause data never became quantitatively and qualitatively stable for any of the pigeons (i.e., conditions were terminated after the 60-session limit). Second, pigeons completed only 40 to 69% of all possible transitions, which may have introduced an artifact into the timeout results. Third, it is unclear if using a pause from an incomplete ratio (provided that at least a single response occurred) contributed to the variability of the data set.

To explore whether the 50-s timeout affected the number of transitions completed by either increasing the response effort or decreasing the overall rate of reinforcement, the timeout was reduced to 20 s. For all pigeons, the number of transitions completed increased, which provided support for these notions. However, the 20-s timeout did not disrupt the rich-lean transition, except for one pigeon.

Experiment 2B: The Effects of the Rich and Lean Reinforcer Magnitudes on Pausing in a Simple FR Schedule

Another hypothesis was that the lean reinforcer magnitude was not capable of maintaining behavior at the given FR value alone. That is, the multiple schedule had some

potentially important interactions that may have supported responding in the lean schedule. These important interactions may also have impacted the number of transitions completed, such that when the interaction of the two schedules was removed, the lean reinforcer magnitude could no longer maintain behavior. One of these interactions is the requirement that the lean-schedule component must be completed to obtain a rich component (with .5 probability). Thus, the multiple schedule may have “chain-like” features such that lean-rich transitions might be important in maintaining responding on the lean component.

The long 50-s timeout may have removed these interactive relations and removed the support of the rich schedule. Conversely, the 20-s timeout may have been short enough to maintain these supportive interactions, which a) increased the number of transitions completed, and b) allowed the rich-lean effect as well. A 20-s timeout may have been enough time to disrupt the rich-lean transition for pigeon 51 because his pause durations at rich-lean transitions were less than 20 s. Thus, we proposed to eliminate all schedule interactions by running simple FR schedules with either the rich or the lean reinforcer magnitude. Based on the results of the 50-s timeout condition, pauses should be longer on the simple FR schedule with the lean reinforcer magnitude than on the rich reinforcer magnitude (see Ferster and Skinner’s, 1957 description of FR performance with insufficient reinforcer magnitude), and fewer ratios should be completed resembling performance on the 50-s timeout condition.

Method

The pigeons, apparatus, procedures, stability criteria were the same as in Experiment 2A, unless otherwise noted.

Experimental conditions. Pigeons were randomly assigned to either a simple FR schedule that ended in the rich (7 pellets) or lean (1 pellet) reinforcer magnitude. The order of exposure to

these two conditions was counterbalanced across pigeons (see Table 6). A postreinforcement timeout was not imposed. Sessions ended after the completion of 21 ratios or 180 min had elapsed, whichever came first. The same key color assignments that were used in Experiment 2A to signal rich and lean reinforcer magnitudes were used in the simple FR schedules.

Pigeon	Reinforcer Magnitude	Sessions	Ratios Completed
P57	Lean	60	35
	Rich	37	126
P1171	Rich	42	126
	Lean	60	39
P49843	Lean	22	17
	Rich	27	126
P51	Rich	26	126
	Lean	60	126

Table 6. Shown is the sequence of simple FR conditions ending in either the rich reinforcer magnitude (7 food pellets) or the lean reinforcer magnitude (1 food pellet), the number of sessions at each condition, and the number of completed ratios across the last six sessions ($n=126$).

Stability criteria. The following was added to stability criteria: if three consecutive sessions occurred without a single response on the key, then the condition was terminated.

Results and Discussion

Figure 11 shows the median pause durations in the simple FR schedule with the rich and lean reinforcer magnitudes (shown in order of exposure) across the final six individual sessions. Each pigeon reliably completed all the ratios ($n=126$) in the simple FR schedule ending in the rich reinforcer magnitude (7 food pellets). As predicted, pauses on the simple FR schedule with the rich reinforcer magnitude were considerably shorter than pauses in the simple FR schedule

ending in the lean reinforcer magnitude (1 food pellet). This pattern of results suggested that the pausing was controlled by the upcoming reinforcer (see the excitatory account of pausing: Shull, 1979), which is the same pattern of results that should occur if the timeout weakened the effects of the past reinforcer, and pausing came under the primary control of the upcoming reinforcer in the timeout conditions.

In the simple FR schedule with the lean reinforcer magnitude, pigeons 57, 1171, and 49843 did not complete a large percentage of the lean ratios (the percentage of lean ratios completed: P57: 27.78%; P1171: 30.95%; P49843: 13.49%) —similar to what occurred in the timeout conditions (see Table 4 for the absolute number of transitions completed). An extreme case was pigeon 49843: this condition eventually had to be terminated due to the pigeon's failure to emit a single response after three consecutive sessions. These results suggest that the lean reinforcer magnitude was insufficient to maintain responding on its own, except for pigeon 51. Insufficient reinforcement may have contributed to the failure to complete all the transitions within a session (Ferster & Skinner, 1957).

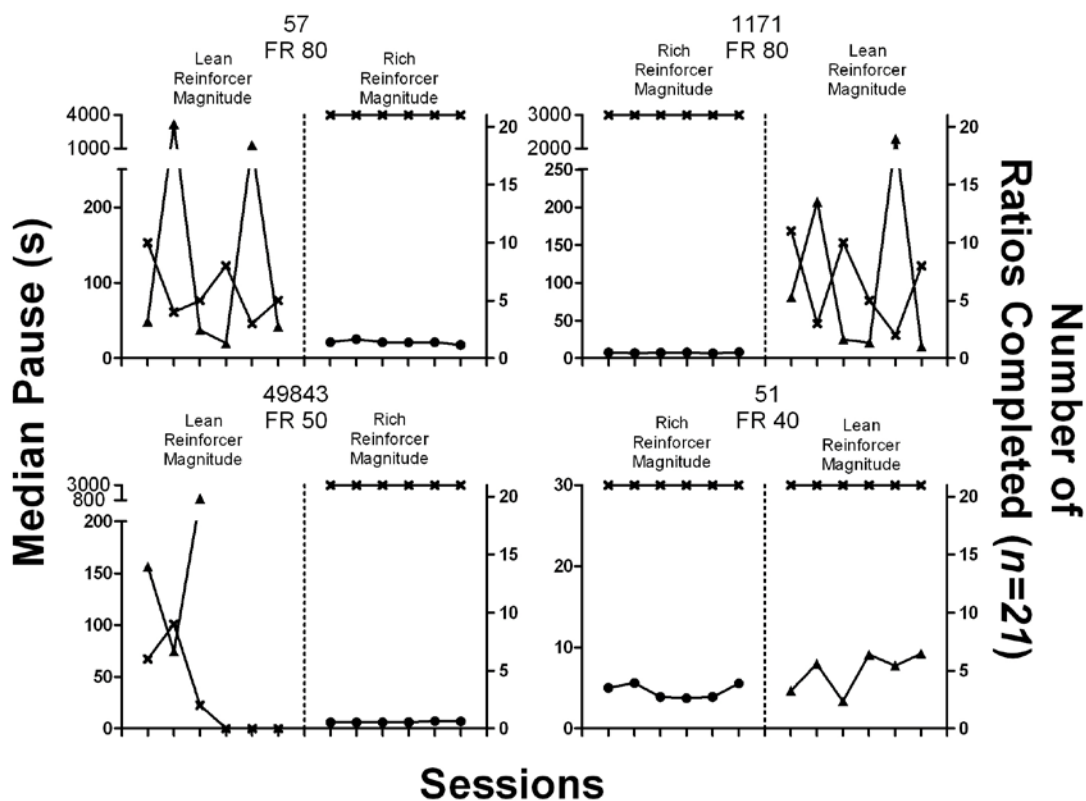


Figure 11. On the left y-axis, median pause durations (s) from the last six sessions on the simple FR schedules ending in the rich reinforcer magnitude for seven food pellets (closed circles) or the lean reinforcer magnitude for one food pellet (closed triangles). On the right y-axis, the number of ratios (“x”) completed ($n=21$) for each session in the simple-schedule conditions is shown on the right y-axis.

The results of Experiment 2B suggested that the 50-s timeout from Experiment 2A separated the multiple schedule into simple FR schedules. In addition, the lean reinforcer magnitude was an insufficient amount to maintain behavior in the lean component. This issue went undetected because during training, pigeons’ performances were maintained by an intermediate reinforcer magnitude amount (four pellets) instead of a single pellet.

The 50-s timeout may have decreased the number of transitions completed because the supportive interactions of the rich-rich and lean-rich transitions were disrupted, which maintained responding in the lean component. Quantitatively and qualitatively unstable data and a large decrease in the number of transitions completed made the timeout results difficult to interpret. Imposing a fewer number of timeouts per transition (e.g., 5) might allow the pigeons to complete all the transitions because more supportive interactions would be available, which would make the data more interpretable by removing a potential artifact. Fewer timeouts should also produce similar effects on pausing compared to the 50-s timeout condition.

Experiment 2C: The Effects of Timeout Probes on Pausing at Rich-Lean Transitions

Metzger and Perone (1990) imposed fewer timeout trials than the amount used in the current study. It is important to note that the current experiment was not designed to replicate Metzger and Perone's procedure. Instead, the current experiment was intended to systematically replicate the human operant procedure (Sherman et al., 2010), which imposed a timeout after all multiple-schedule components. Metzger and Perone imposed timeouts after half of the multiple-schedule components and still failed to remove the rich-lean schedule interaction. A different aspect of the Metzger and Perone procedure, as opposed to imposing fewer timeouts, may have contributed to a failure to remove the rich-lean schedule interaction. Metzger and Perone used different timeout durations across the four transition types. Because Metzger and Perone's timeout durations were yoked to transitions without a timeout, the length of the timeout used for the rich-lean transition was longer than at the other transition types. A long passage of time imposed by a long timeout after a rich reinforcer could signal that a rich-lean transition was upcoming, which may have occasioned/elicited pausing during the timeout. The timeout may not have removed the rich-lean schedule interaction because pausing continued after the timeout

elapsed. Perhaps it may have taken some time for the rich-lean transition to become discriminable. This potential discrimination was prevented in Experiment 2A by imposing a standardized timeout duration between all four transitions that occurred after every schedule component. The length of the timeout used in the current study was not predictive of particular transition, nor was the location of the timeout within the session predictive of any transition type. Thus, the failure to remove the rich-lean schedule interaction in the Metzger and Perone may have been the result of arranging different timeout durations for each transition type, rather than imposing fewer number of timeout trials. Therefore, imposing a fewer number of timeouts should not obscure a potential timeout effect on pausing at rich-lean transitions.

The goal of this study was to test whether randomly imposing a standardized 50-s timeout between each of the four transitions for half of the multiple-schedule components would ensure the completion of all transitions and produce similar effects to the 50-s timeout condition in Experiment 2A (which were difficult to interpret). Pause durations at transitions with and without a timeout were compared within session.

Method

The pigeons, apparatus, and procedures were the same as in 50-s timeout condition from Experiment 2A, except the location and the number of the timeouts were different.

Experimental Conditions. To reestablish extended pausing at rich-lean transitions after the simple FR schedule conditions, pigeons were briefly exposed to a series of no-timeout sessions. In the 50-s timeout-probe condition, timeouts were randomly imposed between half of every type of transition (e.g., 5 rich-lean transitions with timeout; 5 rich-lean transitions without a timeout; 5 lean-lean w/ timeout, 5 lean-lean w/o timeout, etc.).

Initially, the timeout-probe duration was 50-s for all pigeons and the ratio size on the *mult*

FR FR schedule was the same as in Experiment 2A and 2B. Pigeon 57 was never exposed to the 50-s timeout-probe condition using his original ratio size of FR 80. Responding could not be maintained in a brief series of no-timeout sessions that were designed to reestablish extended pausing at rich-lean transitions after the simple FR schedule conditions. Pigeon 1171 did not complete all the transitions in the 50-s timeout-probe condition. Subsequently, the ratio size was reduced to FR 40 for all pigeons in order to ensure that all of the transitions would be completed. In addition, the timeout-probe duration was changed from 50- to 9.55-s for pigeon 51 because his pause durations were considerably shorter than 50-s. Table 7 shows the sequence of experimental conditions (the timeout duration), ratio size, and the number of sessions at each condition, and the number of transitions completed across different transitions types with and without a timeout.

Pigeon	Timeout Duration	Ratio Size	Sessions	Rich-Rich (TO)	Rich-Lean (TO)	Lean-Lean (TO)	Lean-Rich (TO)
P57	50 s	40	16	30 (30)	30 (30)	30 (30)	30 (30)
P1171	50 s	80	14	27 (25)	24 (24)	20 (21)	23 (22)
	50 s	40	31	30 (30)	30 (30)	30 (30)	30 (30)
P49843	50 s	50	21	30 (30)	30 (30)	30 (30)	30 (30)
	50 s	40	31	30 (30)	30 (30)	30 (30)	30 (30)
P51	50 s	40	26	30 (30)	30 (30)	30 (30)	30 (30)
	9.55 s	40	32	30 (30)	30 (30)	30 (30)	30 (30)

Table 7. Shown is the sequence of the timeout conditions, the size of the ratio, the number of sessions at each condition, and the number of transitions completed for each transition type with and without a timeout. The number of transitions completed with a timeout imposed is shown in parenthesis. Pigeon 57 was never exposed to the 50-s timeout-probe condition with a ratio size of FR 80.

Results and Discussion

Table 5 shows that pigeons 49843 and 51 completed all transitions, but pigeon 1171 completed 77.5% of his transitions (see Table 7 for the absolute number of transitions completed). The results of pigeon 1171's data (shown in Figure 12) should be interpreted with caution because he did not complete all transitions. Pigeon 57 was never exposed to the 50-s timeout-probe condition; responding was not maintained in no-timeout sessions prior to the 50-s timeout-probe condition. Pigeons' 1171 and 51 ratio sizes were the largest in the study at FR 80.

Figure 12 shows median pause durations from the rich-lean and lean-lean transitions collapsed across the final six sessions in 50-s timeout-probe condition. For the transitions without a timeout, pauses were relatively longer at rich-lean transitions than at lean-lean transitions for pigeons 1171 and 49843. However, for pigeon 51, no differentiation between median pauses at rich-lean and lean-lean transitions occurred. During the rich-lean transitions with a timeout, Pigeon 49843 had shorter pauses compared to rich-lean transitions without timeout. For pigeon 1171, no effect was found; his data should be interpreted with caution because he did not complete all the transitions. For pigeon 51, pauses at rich-lean transitions with a timeout were longer than at lean-lean transitions without a timeout, and pauses at rich-lean transitions with a timeout were longer than without a timeout.

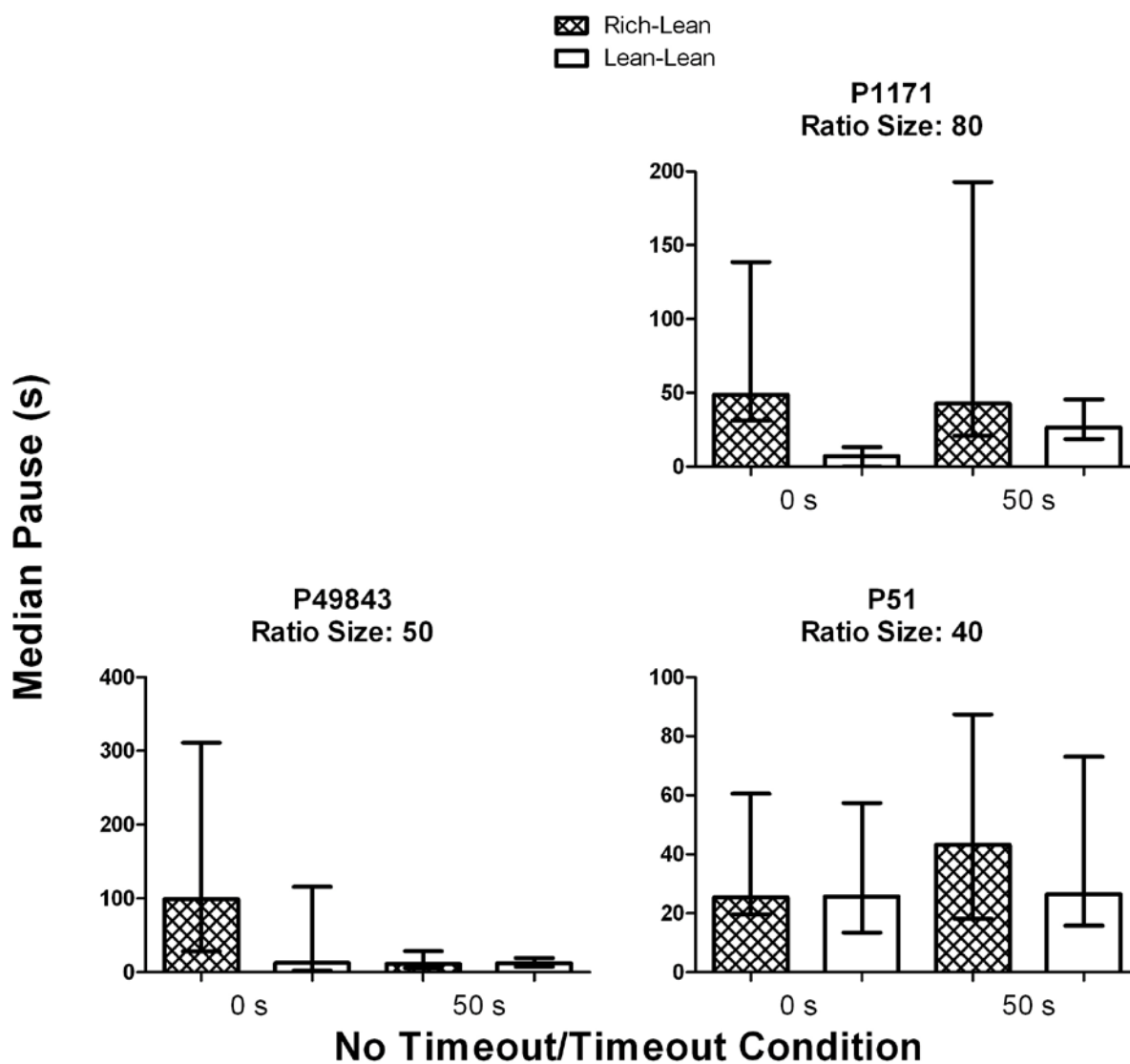


Figure 12. Median pause durations (error bars represent the 25th and 75th interquartile ranges) from the 50-s timeout-probe condition (collapsed across the last six sessions) are shown on the y-axis. The filled bars (“x”) represent pauses at rich-lean transitions and the unfilled bars represent pauses at lean-lean transitions. Note that pigeon 57 was not exposed to this condition.

Figure 13 shows the relative pause frequencies at rich-lean and lean-lean transitions with and without a 50-s timeout probe. For pigeon 49843, timeouts increased the frequency of the shortest pauses and decreased the frequency of the longest pauses at rich-lean transitions. For pigeon 1171, timeouts had no effect on relative pause frequencies at rich-lean transitions. For pigeon 51, timeouts increased the frequency of the longest pauses at rich-lean transitions.

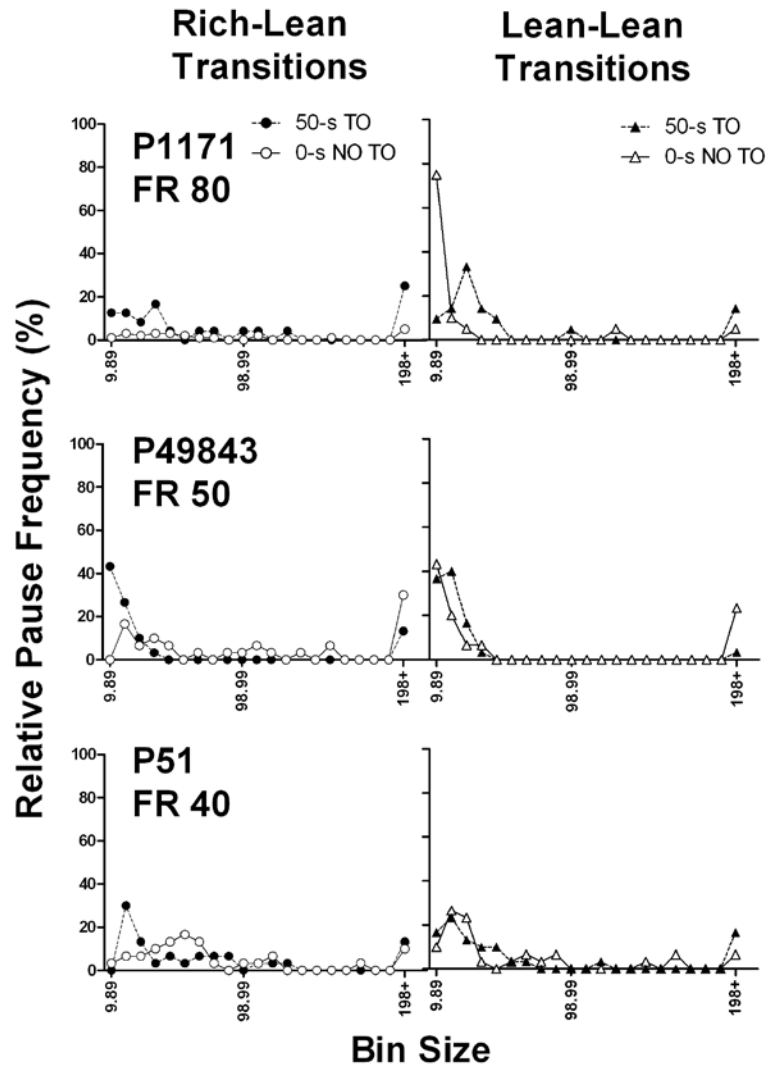


Figure 13. Relative frequency of pause durations at rich-lean (right column) and lean-lean transitions (left column) from the 50-s timeout-probe conditions sorted into bins. Transitions from the no-timeout condition are represented with an open symbol (0-s NO TO: rich-lean: open circle; lean-lean: open triangle). Transitions separated by a 50-s timeout are represented with a closed symbol (50-s TO: rich-lean: closed circle, lean-lean: closed triangle).

Subsequently, all pigeons were exposed to a standardized ratio size of FR 40 due to pigeons 57 and 1171 stopping responding at FR 80. The timeout duration remained at 50 s for each pigeon, except for pigeon 51. His pauses were much shorter than the other birds' pauses. Thus, the timeout duration for pigeon 51 was set to 9.55 s, which was based on his median pause duration at rich-lean transitions from a set of no-timeout sessions.

Each pigeon completed all the programmed transitions (see Table 5) in the 50- and 9.55-s timeout probe with a standard FR 40 condition. Thus, the results in Figure 14 are not affected by issues of variability and chance factors introduced when the pigeons stopped responding in the 50- and 20-s timeout conditions from Experiment 2A. For the transitions without a timeout, pauses were relatively longer at rich-lean transitions than at lean-lean transitions in all pigeons, except for pigeon 51. Overall, the timeout had mixed effects on pausing at rich-lean transitions across subjects: two pigeons showed a decrease in the median pause durations (57 and 49843), whereas two pigeons (1171 and 51) showed no change in pause durations. For one of the pigeons that showed a decrease in the median at rich-lean transitions (49843), longer pauses indicated by the 75th quartile were not reduced.

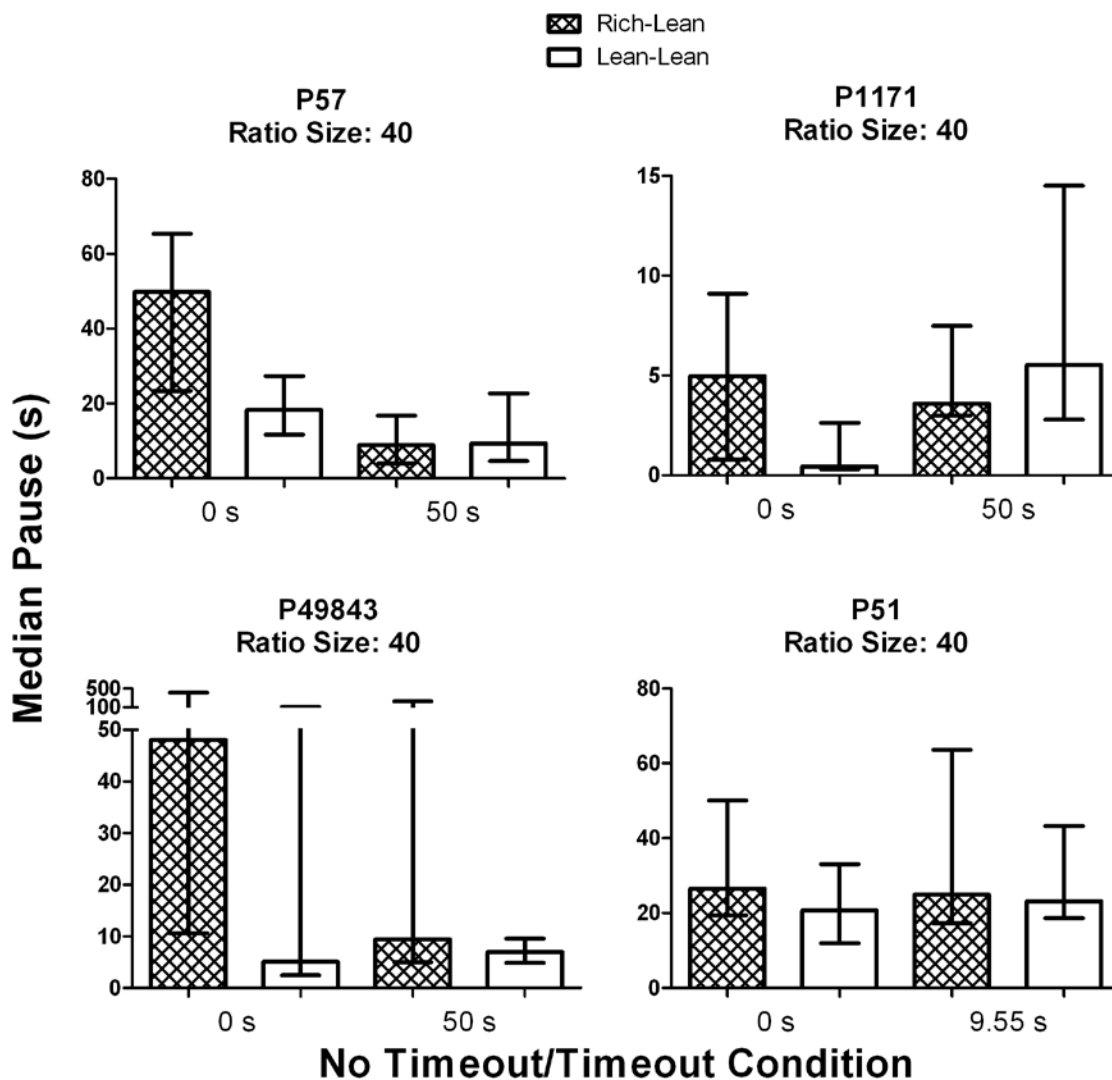


Figure 14. Median pause durations (error bars represent the 25th and 75th interquartile ranges) from the 50-s timeout-probe condition (collapsed across the last six sessions) are shown on the y-axis. The filled bars represent pauses at rich-lean transitions and the unfilled bars represent pauses at lean-lean transitions. Note that the ratio size was FR 40 for all pigeons.

Figure 15 shows the relative pause frequencies at rich-lean and lean-lean transitions from the 50-s timeout probe with a standard FR 40 condition. For pigeon 57, timeouts at rich-lean

transitions increased the relative frequency of the shortest pauses. For pigeon 49843, a timeout between the rich-lean transitions increased the frequency of pauses in the shortest bin and decreased the frequency in the longest bin. For pigeons 1171 and 51, relative pause frequencies at rich-lean transitions were unaffected by the timeout. Thus, the results of this molecular analysis are in agreement with the median pause measure: the timeout produced mixed effects.

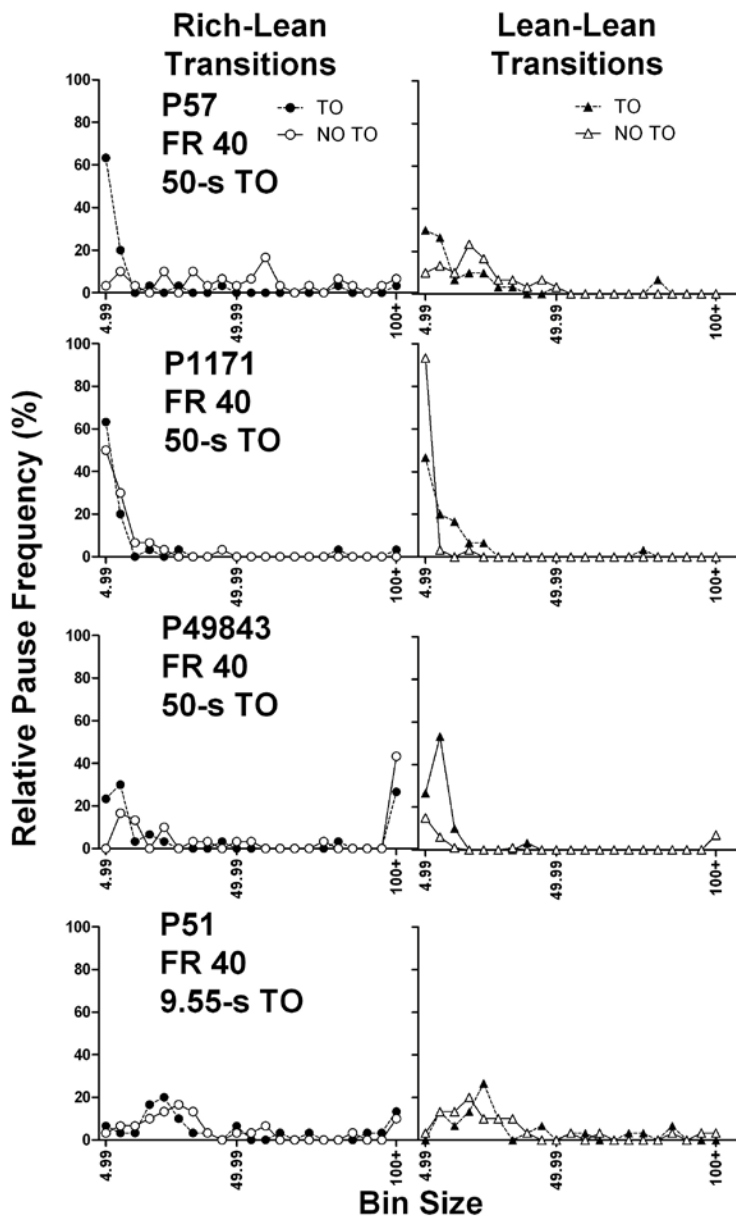


Figure 15. Relative frequency of pause durations at rich-lean (right column) and lean-lean transitions (left column) from the 50-s timeout probe at FR 40 condition sorted into bins. Transitions from the no-timeout condition are represented with an open symbol (0-s No TO: rich-lean: open circle; lean-lean: open triangle). Transitions separated by a 50-s timeout are represented with a closed symbol (50-s TO: rich-lean: closed circle, lean-lean: closed triangle).

General Discussion

Summary of Major Findings

In general, imposing a timeout between each of the four transition types failed to produce consistent effects within and between subjects. In the first condition, a 50-s timeout was always imposed between transitions. Two pigeons showed a decrease in median pausing at rich-lean transitions, one pigeon showed no effect, and the other showed an increase in pausing. For one of the pigeons that showed a decrease in pausing, the 75th interquartile and a molecular analysis showed that the relative frequency of long pauses was not reduced. Thus, the effect of 50-s timeout was inconsistent across pigeons and was small.

At a 20-s timeout, only one pigeon showed a reduction in median pauses at rich-lean transitions, two pigeons showed no effect, and one showed an increase in pausing. The results for the 20-s timeout condition were generally inconsistent with the results from 50-s timeout condition, except for the one pigeon that showed an increase in pausing in both timeout conditions.

Next, pigeons were exposed to a simple FR schedule condition. Pigeons reliably completed all programmed ratios for the rich reinforcer magnitude (7 food pellets). However, the lean reinforcer magnitude (1 food pellet) was insufficient to maintain reliable responding in three out of four pigeons.

In subsequent conditions, pigeons were re-exposed to the multiple-schedule procedure. The number of timeouts was reduced to increase the number of transitions completed. One pigeon was never exposed to the condition and another pigeon still did not complete all the transitions. Mixed results still occurred in the timeout-probe condition: one pigeon showed a

decrease in pausing at rich-lean transitions, one showed no effect, and the other pigeon showed an increase in pausing.

In the final condition, a standardized FR 40 schedule was used, and the timeout duration remained 50 s for all pigeons, except for one pigeon that was exposed to a 9.55 s timeout. Each pigeon completed all the programmed transitions because the ratio size was reduced from either FR 80 or FR 50. Mixed effects, again, were observed: two pigeons showed a decrease in pausing at rich-lean transitions (for one of these pigeons, the effect was relatively small), and two pigeons showed no effect. These results were inconsistent with the 50-s timeout condition that imposed a timeout after all multiple-schedule components.

Overall, the results from the 50- and 20-s timeout conditions may be largely irrelevant or uninterpretable due to the extreme variability and chance factors introduced when pigeons stopped responding. That is, the number of transitions completed in the timeout condition considerably decreased relative to the no-timeout condition. The data sets across the no-timeout and 50- and 20-s timeout conditions are very different because of the lack of data in the timeout condition, which could mean that timeout results may be an artifact of lack of data. More specifically, the timeout data could be confounded with the reduction in the number of observations per data point, which could greatly bias the results depending on how few observations were obtained. The lack of data issue is also compounded with the fact that pigeons had very different FR performances and ratio sizes. The 50- and 20-s timeout from Experiment 2A did affect responding so it was an important variable, but it is unclear how to interpret the effect.

The primary goal of the timeout-probe conditions was to ensure that pigeons completed all transitions. The timeout-probe condition was somewhat successful at ensuring that pigeons

completed all the transitions, but the ratio size also had to be reduced in order for the pigeons to complete all the transitions. A result of reducing the ratio size to FR 40 was that it produced much shorter pauses than at the previous ratio sizes (e.g., FR 80 and FR 50); for one pigeon, the extended pausing effect of the rich-lean transition was not observed. Thus, it is not clear whether these were ideal parameters, which also makes it difficult to compare these results to the previous studies that used a larger ratio size. In general, the timeout generally produced inconsistent results within and between subjects and tended to be ineffective at reducing pausing at rich-lean transitions.

Reconciling the Human and Animal Timeout Results

The current study was designed to reconcile the discrepant unpublished findings between Sherman et al.'s (2010) human and Metzger and Perone's (1990) animal timeout results by replicating the Sherman et al. procedure. Sherman et al. showed that timeouts arranged in the human operant laboratory considerably decreased pausing at rich-lean transitions to the extent that pauses at rich-lean transitions and lean-lean transitions were equally short—suggesting that the rich-lean schedule interaction was removed. Similar findings were reported in a classroom analog setting. The rates of CAB at rich-lean transitions decreased following a timeout in two out of three participants, except that CAB increased following a timeout for one participant. Metzger and Perone (1990) reported that a timeout reduced pausing at rich-lean transitions in pigeons, but failed to remove the schedule interaction between the rich- and lean-schedule components—contradictory to Sherman et al.'s results with humans. Due to the mixed results obtained in the current study, it is difficult to reconcile the human (Sherman et al.) and animal (Metzger & Perone) timeout results.

The Effects of Timeout on Pausing Are Complex

The mixed results from the current study are in agreement with Ferster and Skinner's (1957) descriptions of the effects of timeouts on pausing with simple FR schedules. Ferster and Skinner reported that one pigeon showed an increase in pausing on a FR 85 schedule after a 3-min timeout whereas a different pigeon on the same schedule showed a decrease in pausing. These results and others obtained by Ferster and Skinner suggest that the effect of a timeout on pausing is a complex interaction between the size of the ratio, the length of the timeout, and the length of the pause duration. In the current study, issues of an insufficient lean reinforcer magnitude and the rich-lean schedule interaction only further complicated studying the effects of timeouts on pausing. Because the effects of timeouts on pausing are more complicated than previously assumed, future researchers may wish to return to using simple FR schedules to begin to systematically investigate the complex interaction between the timeout duration, ratio size, and pause duration. This task may be accomplished by adjusting the ratio size until three patterns of pausing emerge (e.g., short, intermediate, and long) in each individual subject. In the timeout condition, subjects could be exposed to short, intermediate, and long timeout durations tailored to each individual subject's pause duration—as opposed to the current study, which tended to ignore individual differences in pausing by using a standard timeout duration. In addition, the pigeons in the current study were exposed to different ratio sizes (e.g., FR 80, FR 50, and FR 40), which might mean that a standardized timeout duration could affect different ratios differently. Also, recall that Mazur and Hyslop (1984) showed different between-subjects effects of a timeout on pausing using simple FR schedules, and Perone, Perone, and Baron (1987) could only detect an effect of the timeout on pausing by analyzing relative pause distributions. Once the effects of timeouts on simple FR schedules are better understood, then these results may be

used to better inform a future study investigating the effects of timeout on pausing at rich-lean transitions.

Not Completing All Transitions

A major effect of the timeout was that pigeons tended to stop responding during the session, which affected the number of transitions completed. This effect made data analysis difficult because the number of transitions completed varied across individual sessions. For example, the number of rich-lean transitions completed in one session would be two and in the next session there would be four completed transitions, which introduced a great deal of variability into the analysis. The current experiment evaluated several possibilities of why responding was not maintained in the timeout conditions. The first set of possibilities was that imposing a timeout between transitions decreased the overall rate of reinforcement or increased the response effort, which strained FR performance. These possibilities were evaluated by decreasing the timeout from 50 to 20 s. At the 20-s timeout condition, the number of transitions completed increased, which provides support for both of these possibilities. Understanding the role of these variables was not pursued in favor of investigating a different hypothesis.

Insufficient Reinforcement

A better account of why the pigeons did not complete all programmed transitions in the timeout conditions comes from the results of the simple FR conditions. In the simple FR schedule with the lean reinforcer magnitude (1 food pellet), three out of four pigeons (P57, P1171, and P49843) did not complete a large percentage of the programmed ratios. These results suggested that the lean reinforcer magnitude was insufficient to maintain behavior in the lean component. Ferster and Skinner (1957) described that on simple FR schedules, conditions of insufficient reinforcement can lengthen the pause durations. In the current study, if stopping for

the remainder of the session can be conceived as a considerably long pause, then an insufficient lean reinforcer magnitude may account for why the pigeons stopped responding.

“Chain-like” Features of the Multiple Schedule

A question raised in response to the finding that the lean reinforcer magnitude was insufficient to maintain responding was, why did the pigeons finish all the transitions in the no-timeout condition? A possible answer was that responding in the lean-schedule component was maintained due to the chain-like features of the multiple schedule. For instance, pauses at lean-lean transitions remained short because completing the lean-schedule component would sometimes (with a 50% probability) result in access to a rich-schedule component. Responding in the lean component may have also been maintained by access to favorable transitions that signal a relative improvement in reinforcement conditions such as the rich-rich and lean-rich transitions. The Premack principle (Premack, 1959, 1962, & 1971) supports the notion that responding in the lean component (a low-probability response) can be maintained by access to the rich component (a high-probability response). To test the possibility of chain-like features of the multiple schedule, the amount of timeouts during a session was decreased to minimize the disruption to these potential supportive interactions, but at least one pigeon did not finish all the transitions. Perhaps this particular pigeon would have benefited from receiving even fewer timeouts per session, but, due to time constraints on the experiment, the ratio size was set to FR 40 for all pigeons. Thus, the possibility that the multiple schedule has chain-like features was not fully explored. Future researchers may wish to systematically investigate the potential chain-like features of the multiple schedule by manipulating the sequence of schedule components such that the probability of an upcoming component being a rich component is either 25%, 50%, or 75%.

Temporally Extended Control of the Past Reinforcer

Although the data are extremely difficult to interpret, an interesting finding was that a 20-s timeout did not remove the rich-lean schedule interaction. A way that timeout might remove the rich-lean schedule interaction is by eliminating the effects of the past reinforcer. A finding in a delayed-matching-to-sample (DMTS) study (e.g., Blough, 1959) is that the percent of correct choices on the “to be remembered” sample stimulus decreases as a function of the delay interval (e.g., White, 1985, 2001). Delay intervals of around 15- to 20-s typically reduce percent choice correct responding to chance levels (e.g., White, 1985). Thus, the timeout durations used in the current study should have provided ample time for the control of the past reinforcer to be “forgotten.” A possibility why a 20-s timeout did not remove the rich-lean schedule interaction was this timeout duration was shorter than pause duration at rich-lean transitions.

In an unpublished study, Galuska (2003) used timeout durations longer than the ones used in the current study and failed to remove the rich-lean schedule interaction. He concluded that the effects of the past reinforcer are temporally extended. In support of the temporally-extended effects of the past reinforcer, Haggbloom (1979) reported that a 24-hr ITI was necessary to reduce simultaneous negative contrast, which is a type of contrast that bears a striking similarity to the extended pausing effect of the rich-lean transition (Perone & Courtney, 1992).

Stimulus Conditions During the Timeout

A possibility of why the timeout was not effective at eliminating the control of the past reinforcer was that the stimulus conditions during the timeout resembled those during the time-in period. During the timeout, the response key was darkened, but the houselight remained on during the entire session. By not turning off the houselight, the stimulus conditions during the timeout may have resembled those during time-in. Roberts and Grant (1979) showed in a DMTS

study that changing the stimulus conditions during the delay interval can reduce accuracy. For example, Roberts and Grant found that when the houselight was turned on during a typically dark delay interval, accuracy decreased considerably. Thus, turning off the houselight in the current study may have decreased control of the past reinforcer and eliminated the rich-lean schedule interaction. However, Mazur and Hyslop (1983) did not turn off their houselight during the timeout, nor did Perone, Perone, and Baron (1987) remove the response lever during the timeout. Both studies reported that a timeout affected pausing on simple FR schedule despite not changing all the stimulus conditions during the timeout. Thus, it is unlikely that not turning off the houselight in the current study affected the timeout results. Moreover, the timeout was discriminable because the birds responded during the timeout during their initial exposure to the timeout. However, after several sessions, responding during the timeout did not occur or was infrequent.

Applied Implications

Translating the timeout in the current study to applied interventions may involve noncontingently imposing a “sit and wait” period between a high-preferred activity (e.g., recess) to a low-preferred activity (e.g., math). Such an intervention may not be a desirable treatment option based on the results of the current study. If the pause duration as an index of aversiveness of the rich-lean transitions (e.g., Perone, 2003), then the aversiveness of the critical transition was reduced for only half of the pigeons. Moreover, for one pigeon, the timeout did not reduce the relative frequency of long pauses (also indicated by the 75th interquartile range). Using the pause duration as an analog of aberrant behavior (Sherman et al., 2010), long pauses may be more clinically relevant than short pauses because aberrant behavior may more likely to occur during long pauses. Thus, imposing a “sit and wait” period between a high- to low-preferred

activity may not render this transition less aversive, which might occasion/elicit emotional behaviors or noncompliance during the presentation of the low-preferred activity. Perhaps, giving participants a moderately preferred activity (e.g., a math-related game) between the high-low preferred activity transition may render the transition less aversive.

Conclusion

The effects of the timeout on pausing at rich-lean transitions were mixed: two pigeons showed a decrease in pausing whereas the other pigeons showed no effect. For one of the pigeons that showed a decrease in pausing, the timeout did not affect the relative frequency of clinically important long pauses, which suggests the timeout effect was small. These mixed results make it difficult to reconcile the differences in unpublished studies that showed timeout removed the rich-lean schedule interaction in humans (Sherman et al., 2010), but not in pigeons (Metzger & Perone, 1990). However, the current study was able to address why pigeons stopped responding in non-probe timeout conditions—because the lean reinforcer magnitude was insufficient to maintain behavior in the lean component. This finding raised an interesting new possibility that the Perone and Courtney (1992) multiple-schedule schedule has chain-like properties, which merits investigation in its own right.

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