

ARE PREFERENCE AND RESISTANCE TO CHANGE CONVERGENT EXPRESSIONS OF
STIMULUS VALUE?

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Behavioral momentum theory asserts that preference and relative resistance to disruption depend on reinforcement rates and provide converging expressions of the conditioned value of discriminative stimuli. However, preference and resistance to disruption diverge when assessing preference during brief extinction probes. We expanded upon this opposing relation by arranging target stimuli signaling equal variable-interval schedules across components of a multiple schedule. We paired one target stimulus with a richer reinforced alternative and the other with a leaner alternative. Furthermore, we varied reinforcement rates for the paired alternatives to assess the effects of manipulating relative conditioned value on preference and resistance to disruption by pre-session feeding, intercomponent food, and extinction. We replicated the opposing relation between preference and resistance to disruption but varying reinforcement rates for the paired alternatives did not systematically affect preference or resistance to disruption beyond levels observed in our initial condition. Importantly, we found that only preference between the target stimuli was related to relative baseline response rates in the presence of those stimuli. These findings suggest that preference during extinction probes might reveal more about baseline response rates between concurrently available alternatives than relative conditioned value. Resistance to disruption, conversely, appears to better reflect conditioned value because it is less confounded with baseline response rates and is a function of all sources of reinforcement obtained in the presence of a stimulus context.

Key words: behavioral momentum theory, resistance to change, preference, stimulus value, concurrent schedules, keypeck, pigeon

Basic research examining how reinforcement conditions influence the persistence of operant behavior has received attention for its relevance to the integrity and maintenance of behavioral interventions (e.g., Nevin & Wacker, 2013). Behavioral momentum theory provides a framework within which to understand behavioral persistence, defined as the resistance to change of behavior during conditions of disruption (e.g., extinction, satiation) relative to stable pre-disruption responding (see Nevin & Shahan, 2011). A general finding is that stimulus contexts arranging higher rates or greater magnitudes of reinforcement produce greater resistance to disruption of responding, even when some of

those reinforcers are presented independent of responding or contingent on an alternative response (Nevin, Tota, Torquato, & Shull, 1990). These findings suggest that operant response-reinforcer relations govern response rates, but the Pavlovian relation between a discriminative-stimulus context and reinforcement determines resistance to disruption (i.e., stimulus-reinforcer relation; see Podlesnik & Shahan, 2008, for a discussion of exceptions). Moreover, relative resistance to disruption between stimulus contexts purportedly reflects a fundamental determinant of behavior, which is the conditioned value of discriminative stimuli (see Nevin & Grace, 2000b).

To examine the role of Pavlovian stimulus-reinforcer relations in resistance to disruption, Nevin et al. (1990) arranged different overall rates of food reinforcement across components of a multiple schedule with pigeons. In two components signaled by different key colors, they arranged 15 reinforcers per hr according to variable-interval (VI) schedules on a right (target) key. In one of those components, a left key also arranged 45 reinforcers per hr for responses to a concurrently available alternative (60 reinforcers per hr total). The concurrently

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available reinforcers degraded the operant relation between target responding and reinforcement, thereby decreasing response rates in that component. However, the additional concurrently available reinforcers also enhanced the Pavlovian stimulus-reinforcer relation in that component. As a result, resistance to satiation and extinction of target responding was greater in the component with added reinforcement. Moreover, resistance to disruption of target responding with concurrently available reinforcement was similar to that in another component arranging 60 reinforcers per hr on the target key alone. These findings suggest that all sources of reinforcement arranged in the presence of a stimulus context increase resistance to disruption of the target response, even when those added reinforcers decrease response rates. These findings are consistent with the assertions of behavioral momentum theory and have been replicated across a range of species and in experimental and applied situations (see Nevin, 2009, for a review).

If greater resistance to disruption in a given stimulus context reflects enhanced conditioned value, other measures of conditioned value assessed by different methods also should be greater for stimulus contexts arranging overall higher reinforcement rates. Grace and Nevin (1997, 2000) assessed preference between stimulus contexts by arranging separate VI schedules of food reinforcement in the presence of red and green keylights with pigeons. Pigeons chose between two concurrently available white keys that provided access to the red and green keylights (i.e., concurrent-chains schedules). Preference was greater for the white keylight leading to the currently richer of the red and green keylights. Furthermore, relative resistance to disruption of responding was positively related to relative reinforcement rates arranged in the presence of the red and green keylights. Therefore, preference and relative resistance to disruption were positively related and varied as a function of the relative rates of reinforcement arranged between stimulus contexts (see Grace, Bedell, & Nevin, 2002, for a summary of similar findings; see Podlesnik, Jimenez-Gomez, Thrailkill, & Shahan, 2011, for limits to this relation). This relation suggests that preference and relative resistance to disruption (1) are a function of the Pavlovian relation between discriminative-stimulus contexts and the prevailing conditions of reinforce-

ment, and (2) are measures providing converging expressions of the relative conditioned value of discriminative-stimulus contexts (Nevin & Grace, 2000b).

Bell and Williams (2002) explored the generality of the relation between relative resistance to disruption and preference by assessing preference differently than Grace and Nevin (1997, 2000). They arranged a two-component multiple schedule with two concurrently available responses in both components with pigeons. In a component that arranged a richer overall reinforcement rate, they presented a VI 20-s schedule with a VI 40-s schedule. In the leaner component, they presented a VI 80-s schedule with a VI 40-s schedule. Next, Bell and Williams disrupted responding with pre-session feeding, intercomponent free-food presentations, and extinction. When comparing relative resistance to disruption of responding between the two VI 40-s stimuli, responding to the VI 40-s stimulus paired with the richer VI 20-s schedule was more resistant to disruption. When assessing preference during brief probes that paired the two VI 40-s schedule stimuli in extinction, however, pigeons responded more to the VI 40-s stimulus paired with the leaner VI 80-s stimulus (see also Belke, 1992; Gibbon, 1995). Thus, relative resistance to disruption was positively related to rate of reinforcement in the stimulus context but preference was negatively related. These findings prompted Bell and Williams to question the generality of the relation between preference and resistance to disruption. Moreover, such findings question the convergence of preference and resistance to disruption as expressions of the conditioned value of discriminative stimuli, as asserted by behavioral momentum theory.

Bell and Williams (2002) suggest that their findings reveal a limitation to the generality of the relation between preference and resistance to disruption. Bell and Williams, however, assessed preference with brief extinction probes, a different procedure from that used by Nevin and colleagues. Different processes might influence preference assessed during brief extinction probes compared to assessing preference during steady-state behavior using concurrent chains. Indeed, some evidence suggests that preference obtained during extinction probes provides little information about the relative conditioned value of stimuli trained in choice situations (Belke, 1992; see also

Gibbon, 1995; Misak & Cleaveland, 2011). Instead, Belke's findings suggest that preference for the VI 40-s stimulus paired with the leaner alternative (i.e., VI 80-s stimulus) during extinction probes primarily reflects baseline response rates between the VI 40-s stimuli and the corresponding concurrently available reinforced alternative. Given that Bell and Williams question the fundamental determinants of how conditioned value influences behavior, we wanted to give additional consideration to, and expand upon, their assertion about the purportedly opposing relation between preference and relative resistance to change.

In the present study, we also examined how the concurrently available sources of reinforcement influenced both relative resistance to disruption and preference for stimuli signaling two independent VI 40-s schedules. Because Bell and Williams (2002) arranged only a single set of reinforcement conditions, we arranged a wider range of reinforcement rates for the concurrently available schedules paired with the VI 40-s schedules. Manipulating these reinforcement rates allowed us potentially to influence the variables responsible for the opposing relation observed by Bell and Williams—baseline response rates versus the conditioned value of the stimuli signaling the VI 40-s schedules. If changing reinforcement rates for these concurrently available schedules affects the degree of preference between the VI 40-s schedules, these findings would suggest that relative conditioned value governs preference during extinction probes. If preference between the VI 40-s schedules more closely reflects baseline response rates, preference during extinction probes likely does not reflect conditioned value.

Methods

Subjects

Four homing pigeons maintained at approximately 80% of their free-feeding weights (± 15 g) by postsession supplemental feeding (as necessary) were used. The pigeons had prior experience with procedures similar to those arranged in the present experiment. When not in the experimental sessions, the pigeons were housed in individual cages in a temperature-controlled colony with a 12:12 hr light/dark cycle (lights on at 7:00 a.m.) and had free access to water.

Apparatus

The experiment was conducted in four Lehigh Valley Electronics pigeon chambers measuring 35 cm long, 35 cm high, and 30 cm wide. Three response keys were centered on the front panel 83 mm apart (center to center) and were 24 cm above the floor. The keys measured 25 mm in diameter, required about 0.1 N to operate, and could be transilluminated amber, blue, red, or green. Only the two side keys were used. Each response to an active key produced a 0.01-s flash of the houselight that served as response feedback. Primary reinforcers consisted of 2-s presentations of pigeon chow from a hopper. The hopper was accessible, when raised, through a 50-mm wide by 55-mm tall aperture located on the midline of the work panel with its center 100 mm from the floor. A 28-V DC clear bulb illuminated the aperture when the hopper was raised and all other lights were extinguished when the hopper was operated. General illumination was provided by a shielded 28-V DC clear bulb mounted 45 mm above the center key. A ventilation fan and white noise masked extraneous sounds. Control of experimental events and data recording were conducted with Med Associates® programming and interfacing.

Procedure

Baseline. The left columns of Table 1 show that responding was maintained on a two-component multiple schedule with a two-key concurrent VI VI schedule arranged in each component. In Condition 1, we arranged a concurrent VI 20-s VI 40-s schedule in the Rich component to alternate strictly with a concurrent VI 40-s VI 80-s schedule in the Lean component. For Pigeons 7561 and 38 in the Rich component, blue keys signaled the richer VI 20-s schedule (hereafter, VI Rich) and red keys signaled the VI 40-s schedule (i.e., VI 40 [Rich]). In the Lean component, green keys signaled the richer VI 40-s schedule (i.e., VI 40 [Lean]) and amber keys signaled the VI 80-s schedule (hereafter, VI Lean). For Pigeons 228 and 227, amber keys signaled the VI Rich alternative and green keys signaled the VI 40 (Rich) alternative; red keys signaled the VI 40 (Lean) alternative and blue keys signaled the VI Lean alternative.

During Condition 2, we changed the schedules to VI 10 s VI 40 s in the Rich component and to VI 40 s VI 160 s in the Lean component.

Table 1
Scheduled VI values for both alternatives within the Rich and Lean components across conditions.

Condition	Rich component		Lean component		Reinforcer ratios		Value			
	VI Rich	VI 40 (Rich)	VI 40 (Lean)	VI Lean	Rich	Lean	Predicted Value		Obtained Value	
							Relative	Total	Preference	Resistance
1	VI 20 s	VI 40 s	VI 40 s	VI 80 s	2.20 <i>0.34</i>	2.33 <i>0.21</i>	0.20 <i>0.06</i>	2.14 <i>0.17</i>	0.42 <i>0.26</i>	1.66 <i>0.68</i>
2	VI 10 s	VI 40 s	VI 40 s	VI 160 s	4.22 <i>0.44</i>	4.97 <i>0.23</i>	0.05 <i>0.01</i>	4.27 <i>0.39</i>	0.26 <i>0.30</i>	1.76 <i>0.70</i>
3	VI 20 s	VI 40 s	VI 40 s	VI 80 s	2.24 <i>0.31</i>	2.29 <i>0.13</i>	0.20 <i>0.04</i>	2.08 <i>0.07</i>	0.27 <i>0.27</i>	1.35 <i>0.24</i>
4	VI 20 s	VI 40 s	VI 40 s	VI 160 s	2.29 <i>0.37</i>	4.84 <i>0.72</i>	0.10 <i>0.03</i>	2.31 <i>0.22</i>	0.25 <i>0.18</i>	1.49 <i>0.61</i>
5	VI 20 s	VI 40 s	VI 40 s	VI 360 s	2.36 <i>0.26</i>	9.47 <i>1.81</i>	0.05 <i>0.01</i>	2.55 <i>0.06</i>	0.41 <i>0.43</i>	1.51 <i>0.62</i>

Under Reinforcer Ratios, obtained mean baseline reinforcer ratios (i.e., rich alternative / lean alternative) within the Rich and Lean components. Under Value, predicted and estimated values for the VI 40-s stimuli are shown (see also Procedures). Values greater than 1 indicate greater value for the VI 40(Rich) stimulus than the VI 40(Lean) stimulus. Under Relative, predicted value is expressed as the reinforcement rate obtained in the presence of the VI 40-s stimuli relative to the extreme alternative within the Rich and Lean components: (VI 40[Rich] / VI Rich) / (VI 40[Lean] / VI Lean). Relative value is predicted to be greater for the VI 40(Lean) stimulus across all conditions. Under Total, predicted value is expressed as the ratio of total obtained reinforcement rates within the Rich and Lean components: Rich component / Lean component. Total value is predicted to be greater for the VI 40(Rich) stimulus across all conditions. Under Preference, estimated value is expressed as the ratio of responding to the VI 40-s stimuli during extinction probes: (VI 40[Rich] / VI 40[Lean]). Under Resistance, estimated value is expressed as the ratio of mean log proportion of baseline response rates averaged across pre-session feeding, ICI food, and extinction in the presence of the VI 40-s stimuli: (VI 40[Rich]_{Disruption} / VI 40 [Rich]_{Baseline}) / VI 40[Lean]_{Disruption} / VI 40[Lean]_{Baseline}). SEM is shown in italics.

Condition 3 replicated Condition 1. During Condition 4, schedules were maintained at VI 20 s VI 40 s in the Rich component and changed to VI 40 s VI 160 s in the Lean component. Finally, in Condition 5, schedules were maintained at VI 20 s VI 40 s in the Rich component and changed to VI 40 s VI 360 s in the Lean component. Hereafter, the VI Lean and VI Rich schedules that were paired with the VI 40-s schedules often will be referred to as the “extreme alternatives.”

The middle columns of Table 1 show the obtained rich-to-lean reinforcer ratios between the concurrently available alternatives within the Rich and Lean components. These within-component reinforcer ratios approximated but consistently were greater than the arranged ratios. The more extreme obtained reinforcer ratios resulted from arranging independent VI schedules between alternatives (see Davison & McCarthy, 1988, Chapter 1, for a discussion).

The right columns of Table 1 show the predicted relative conditioned value for the VI 40-s stimuli calculated either relative to the reinforcement rates obtained from the concur-

rently available alternative within a component (Relative column), or as a function of total rates of reinforcement obtained between components (Total column). If conditioned value is determined by relative reinforcer rates within the components, then relative conditioned value for the VI 40-s stimuli should change with the ratio: (VI 40[Rich] / VI Rich) / (VI 40 [Lean] / VI Lean). Based on the obtained reinforcement ratios, the predicted relative conditioned value across conditions (C) would be: C1 = C3 > C4 > C5 = C2, and consistently greater for the VI 40(Lean) stimulus (i.e., less than 1.0). However, if conditioned value is determined by the ratio of total reinforcer rates obtained between the components (see Total column), then relative conditioned value for the VI 40-s stimuli should change with the ratio: total reinforcers obtained in the Rich component / total reinforcers obtained in the Lean component. Based on the obtained reinforcement ratios, the predicted relative conditioned value across conditions would be: C3 < C1 < C4 < C5 < C2, and consistently greater for the VI 40 (Rich) stimulus (i.e., greater than 1.0). In the

Results and Discussion sections, we compare these predicted values with our estimates of conditioned value, expressed as preference and relative resistance to disruption.

Sessions began with the first component being selected randomly, illumination of the houselight and corresponding key lights, and timing of the appropriate VI timers. In both components, the keylight colors and corresponding schedules alternated randomly between the left and right keys with each component presentation. Variable intervals were scheduled using a 9-interval list without replacement (Fleshler & Hoffman, 1962). If a VI timer lapsed, the next response on that key produced the food hopper. Hopper time was excluded from all response- and reinforcer-rate calculations. Reinforcers set up but not delivered during a component were held until the first response during the next presentation of that component. A 3-s changeover delay (COD) was arranged between the last response on one key and the first response on the other (see Shahan & Lattal, 1998). Components lasted 60 s and were separated by 30-s intercomponent intervals (ICIs), during which all lights were turned off and timing of all reinforcement schedules was suspended. Components alternated strictly throughout and sessions terminated after 45 components.

Disrupters. Three types of disrupters were used—presession feeding, response-independent food presentations during the ICIs, and extinction (see also Bell & Williams, 2002). The order of the three disrupters was counterbalanced across pigeons and at least six sessions of baseline separated the different disrupters. Presession feeding occurred 30 min prior to the start of the experimental session in the homecage and was assessed across five consecutive sessions, delivering 40 g prior to the first two sessions and 60 g prior to the last three sessions of disruption. Response-independent food was delivered during the ICI according to a variable-time 5-s schedule for five consecutive sessions. Extinction was assessed across 10 consecutive sessions, during which no food was presented but all other stimuli remained as in baseline.

Preference probes. After disruption tests, four probe sessions were arranged, with at least two baseline sessions following disruption and in between each probe session (see also Bell & Williams, 2002). In addition, we arranged probe

sessions only when response rates returned to levels observed throughout baseline conditions. During probe sessions, five additional 60-s components presented only the keylights associated with the two VI 40-s schedules in extinction. Probe components were arranged only after at least two presentations of the standard components. We arranged all condition changes following the fourth preference probe for all conditions.

Dependent measures. Baseline response-rate and reinforcement-rate measures were calculated as means of five consecutive sessions prior to disruption. All relative baseline response rates were calculated as the log ratio of baseline response rates in the presence of the richer alternative relative to the leaner alternative – Rich component: $\log(\text{VI Rich} / \text{VI 40[Rich]})$; Lean component: $\log(\text{VI 40[Lean]} / \text{VI Lean})$; Preference during extinction probes: $\log(\text{VI 40 [Rich]} / \text{VI 40[Lean]})$. Across conditions, we present means of the four preference probes conducted within a condition. Resistance to disruption was calculated as the log of the mean proportion of baseline response rates calculated across all sessions within a disruption test: $\log(\text{Disruption} / \text{Baseline})$. All measures of *relative* resistance to disruption were calculated as the Rich-to-Lean difference between log mean proportions of baseline response rates: $\log(\text{Rich}_{\text{Disruption}} / \text{Rich}_{\text{Baseline}}) - \log(\text{Lean}_{\text{Disruption}} / \text{Lean}_{\text{Baseline}})$ (see Nevin & Grace, 2000a, for a detailed rationale for using a difference measure). Total response rates (or total reinforcement rates) were calculated by summing the number of responses (or reinforcers) across both alternatives within a component and dividing by component time. The Appendix shows baseline and disruption response rates and baseline reinforcement rates across all conditions for individual pigeons. All linear-regression analyses were conducted with alpha set at .05.

Results

Baseline Responding

We assessed whether changing relative reinforcer rates within both components affected relative baseline response rates in a manner consistent with the generalized matching law (Baum, 1974). Figure 1 shows baseline relative response rates within the Rich and Lean components as a function of the obtained

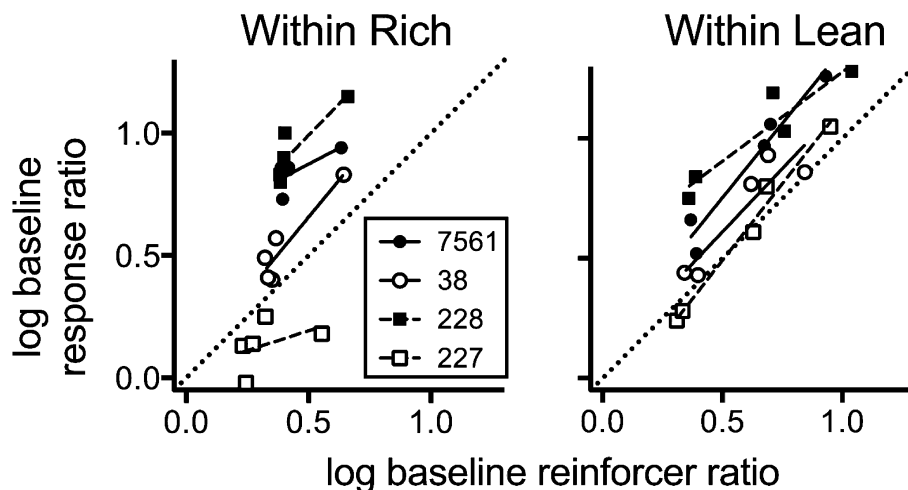


Fig. 1. Relative baseline response rates were calculated as the log ratio of baseline response rates in the presence of the richer alternative relative to the leaner alternative in the Rich component, $\log(\text{VI Rich} / \text{VI 40[Rich]})$, and Lean component, $\log(\text{VI 40[Lean]} / \text{VI Lean})$, as a function of relative baseline reinforcement rates from those alternatives. The dotted diagonal line indicates a slope of 1.0. Equations for least-squares linear-regression lines are shown in Table 2.

relative reinforcement rates within those components. All data points but one were above 0.0 on the y-axis, indicating greater responding on the richer alternative in both components (see Rich component for Pigeon 227 for the exception). Slopes of the linear-regression lines fit to individual data were positive in all instances, suggesting that changing log reinforcer ratios affected log response ratios. All slopes were greater than zero in the Rich and Lean components, and y-intercepts were positive in all cases, except for Pigeon 227 in the Lean component. Table 2 shows the linear-regression equations for individual pigeons. The combination of positive slopes and data points being above 0.0 on the y-axes suggest that baseline responding was under control of relative reinforcement rates arranged within the Rich and Lean components.

According to the generalized matching law, slopes and y-intercepts of the functions relating log response ratios to log reinforcer ratios estimate sensitivity and bias, respectively (Baum, 1974). In previous studies, sensitivity typically has been estimated from 0.8–1.0 with bias being approximately 0.0 (see Baum, 1979, for a review). Most studies obtained accurate sensitivity and bias estimates by manipulating log reinforcer ratios from approximately -1 to $+1$ log units. Due to the question of interest in the present study, the arranged log reinforcer ratios only ranged from 0.30 log units in the

Rich component and from 0.65 log units in the Lean component. Therefore, the specific parameter estimates should be taken with caution.

Preference

We assessed whether preference changed as a function of relative reinforcement rates arranged within the components or as a function of total reinforcement rates obtained in the Rich component relative to the Lean component. Figure 2 shows preference between the VI 40-s stimuli, $\log(\text{VI 40[Rich]} / \text{VI 40[Lean]})$, as a function of relative reinforcer rates for the extreme alternatives, $\log(\text{VI Rich} / \text{VI Lean})$, and as a function of relative total reinforcer rates summed across the two alternatives within both components, $\log(\text{VI Rich} + \text{VI 40[Rich]} / \text{VI 40[Lean]} + \text{VI Lean})$. Plotting preference in these ways allows us to assess whether preference changed as a function of within- or between-component changes in relative reinforcement rates. All data points were below 0.0, indicating systematically greater preference for the VI 40(Lean) stimulus. Further, preference in the present study approximated preference obtained in previous studies (Belke, 1992; Bell & Williams, 2002; Gibbon, 1995). To be consistent with these previous studies, we express preference differently here, as a proportion of response rates to the VI 40 (Lean) stimulus relative to response rates to the VI 40(Rich) stimulus. Mean preference in the

Table 2

Least-squares linear-regression fits to data in figures (relevant figure indicated in parentheses). F-values for slopes significantly different from zero are indicated with an asterisk.

Dependent measure	Pigeon	Within Rich		Within Lean	
		equation	F-value	equation	F-value
Baseline response ratios (Figure 1)	7561	$y = 0.52x + 0.61, r^2 = .51$	3.18	$y = 1.24x + 0.13, r^2 = .95$	55.22*
	38	$y = 1.22x + 0.50, r^2 = .87$	20.31*	$y = 1.06x + 0.08, r^2 = .84$	15.55*
	228	$y = 1.04x + 0.33, r^2 = .77$	9.77	$y = 0.74x + 0.53, r^2 = .88$	21.45*
	227	$y = 0.33x + 0.03, r^2 = .19$	0.70	$y = 1.28x - 0.15, r^2 = .98$	177.60*
PF - Within components (Figure 6)	7561	$y = -0.36x + 0.07, r^2 = .49$	2.86	$y = 0.01x - 0.08, r^2 = .00$	0.01
	38	$y = 0.00x + 0.07, r^2 = .00$	0.00	$y = -0.16x - 0.01, r^2 = .28$	1.15
	228	$y = 0.38x - 0.12, r^2 = .03$	0.09	$y = 0.37x - 0.21, r^2 = .23$	0.92
	227	$y = -0.26x + 0.05, r^2 = .22$	0.83	$y = -0.37x + 0.14, r^2 = .34$	1.52
ICI - Within components	7561	$y = -0.20x + 0.25, r^2 = .02$	0.05	$y = -0.30x + 0.07, r^2 = .20$	0.73
	38	$y = -0.53x + 0.10, r^2 = .21$	0.81	$y = -1.03x + 0.36, r^2 = .98$	139.60*
	228	$y = -0.23x + 0.13, r^2 = .06$	0.20	$y = -0.37x + 0.17, r^2 = .70$	7.08
	227	$y = 0.25x + 0.04, r^2 = .04$	0.12	$y = -0.27x - 0.17, r^2 = .13$	0.44
EXT - Within components	7561	$y = 1.00x - 0.25, r^2 = .53$	3.39	$y = 0.08x - 0.15, r^2 = .01$	0.04
	38	$y = -0.22x + 0.20, r^2 = .09$	0.30	$y = -0.33x + 0.05, r^2 = .16$	0.57
	228	$y = -0.10x + 0.10, r^2 = .02$	0.05	$y = -0.22x - 0.03, r^2 = .44$	2.38
	227	$y = -0.61x + 0.36, r^2 = .19$	0.70	$y = -0.12x + 0.04, r^2 = .02$	0.07
		Extreme alternatives		Total reinforcers	
		equation	F-value	equation	F-value
Preference (Figure 2)	7561	$y = -0.46x - 0.40, r^2 = .17$	0.61	$y = -0.49x - 0.65, r^2 = .04$	0.12
	38	$y = -0.37x - 0.03, r^2 = .29$	1.23	$y = -0.96x + 0.01, r^2 = .48$	2.75
	228	$y = -0.56x - 0.82, r^2 = .57$	4.03	$y = -0.91x - 1.01, r^2 = .27$	1.10
	227	$y = 0.31x - 0.49, r^2 = .33$	1.49	$y = 0.61x - 0.45, r^2 = .20$	0.74
PF - VI 40s (Figure 3)	7561	$y = 0.20x - 0.00, r^2 = .21$	0.80	$y = 0.95x - 0.20, r^2 = .84$	16.07*
	38	$y = 0.22x - 0.16, r^2 = .91$	31.41*	$y = 0.43x - 0.12, r^2 = .68$	6.24
	228	$y = -0.47x + 0.59, r^2 = .30$	1.30	$y = -0.41x + 0.30, r^2 = .05$	0.16
	227	$y = 0.08x - 0.01, r^2 = .53$	3.36	$y = 0.15x + 0.01, r^2 = .30$	1.29
ICI - VI 40s	7561	$y = -0.00x + 0.12, r^2 = .00$	0.00	$y = 0.38x - 0.04, r^2 = .25$	1.02
	38	$y = 0.32x + 0.04, r^2 = .25$	0.99	$y = 0.71x + 0.05, r^2 = .30$	1.28
	228	$y = 0.52x - 0.24, r^2 = .83$	15.01*	$y = 0.66x + 0.02, r^2 = .22$	0.84
	227	$y = 0.18x + 0.03, r^2 = .21$	0.80	$y = -0.00x + 0.20, r^2 = .00$	0.00
EXT - VI 40s	7561	$y = -0.37x + 0.46, r^2 = .54$	3.49	$y = -0.66x + 0.38, r^2 = .35$	1.62
	38	$y = 0.02x + 0.05, r^2 = .00$	0.01	$y = 0.34x - 0.06, r^2 = .20$	0.74
	228	$y = -0.12x + 0.36, r^2 = .14$	0.48	$y = 0.09x + 0.19, r^2 = .01$	0.03
	227	$y = 0.25x - 0.13, r^2 = .53$	3.44	$y = 0.59x - 0.13, r^2 = .45$	2.43
PF - Total (Figure 5)	7561	—	—	$y = 0.16x + 0.11, r^2 = .03$	0.08
	38	—	—	$y = 0.18x + 0.07, r^2 = .05$	0.17
	228	—	—	$y = -0.03x + 0.20, r^2 = .00$	0.01
	227	—	—	$y = -0.29x + 0.23, r^2 = .03$	0.10
ICI - Total	7561	—	—	$y = 0.09x + 0.27, r^2 = .00$	0.01
	38	—	—	$y = 0.21x + 0.11, r^2 = .33$	1.48
	228	—	—	$y = 0.52x + 0.07, r^2 = .67$	6.03
	227	—	—	$y = 0.81x - 0.12, r^2 = .44$	2.37
EXT - Total	7561	—	—	$y = 0.17x + 0.10, r^2 = .12$	0.41
	38	—	—	$y = 0.12x + 0.15, r^2 = .03$	0.10
	228	—	—	$y = 0.23x + 0.13, r^2 = .07$	0.22
	227	—	—	$y = 0.28x + 0.08, r^2 = .08$	0.27

present study was .77. Belke (1992) reported a mean preference from 4 pigeons of .79. Bell and Williams (2002) reported a mean preference from 8 pigeons of .70. Gibbon (1995) reported preference from 6 pigeons that did not differ significantly from .80 (mean of approximately

.79, as estimated from his Figure 3). Therefore, overall levels of preference in the present experiment were consistent with previous findings.

When assessing the effects of changing relative reinforcement rates on preference,

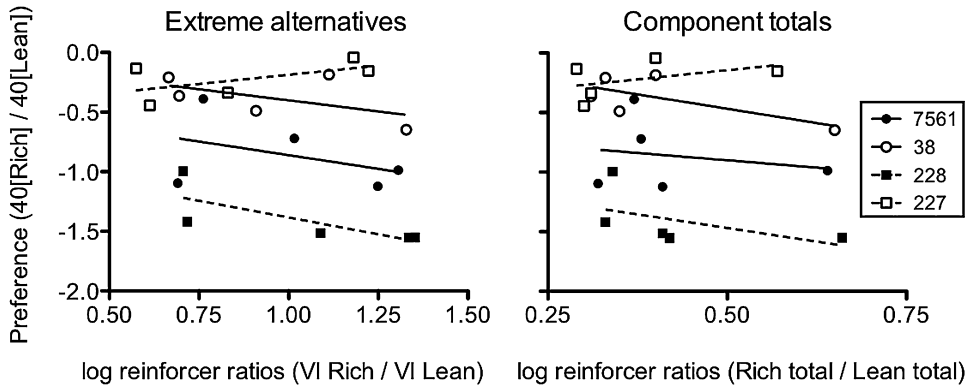


Fig. 2. Preference for the VI 40(Rich) stimulus relative to the VI 40(Lean) stimulus, $\log(\text{VI } 40[\text{Rich}] / \text{VI } 40[\text{Lean}])$, as a function of relative baseline reinforcement rates for the extreme alternatives on the left, $\log(\text{VI Rich} / \text{VI Lean})$, or total reinforcement rates on the right, $\log(\text{VI Rich} + \text{VI } 40[\text{Rich}] / \text{VI } 40[\text{Lean}] + \text{VI Lean})$. Equations for least-squares linear-regression lines are shown in Table 2.

however, no linear-regression lines from either panel of Figure 2 differed significantly from zero (see Table 2). These findings suggest that changes in relative reinforcement rate did not reliably affect preference. Furthermore, the Preference column of Table 1 shows our estimates of conditioned value given as the ratio of responding, VI 40[Rich] / VI 40[Lean]. Preference more closely corresponded with predicted value expressed relative to the ex-

treme alternatives paired with the VI 40-s stimuli (see Relative column of Table 1) than with the ratio of total reinforcement obtained within the components (see Total column). This is because both preference and predicted value were less than 1.0, i.e., preference for the VI 40(Lean) stimulus. Nevertheless, preference did not consistently change across conditions with changes in Relative or Total predicted values.

Why was preference not systematically related to our manipulations of the relative reinforcement rates or conditioned value? One possibility is that we did not manipulate the reinforcement conditions enough to impact preference reliably. The arranged log reinforcer ratios in the presence of the extreme alternatives paired with the VI 40-s stimuli covered a 0.65-log unit range, which is the same as the reinforcer ratios arranged within the Lean component. The arranged log reinforcer ratios in the presence of the Rich relative to the Lean component covered a 0.30-log unit range, which is the same as that arranged within the Rich component. If neither of these manipulations to the reinforcer ratios were sufficiently large, then perhaps we cannot expect to observe systematic changes in preference.

We also should not expect preference to be related to any aspect of the baseline conditions if the range of reinforcer ratios tested was not large enough. Instead, we found that preference during extinction probes was related to relative baseline response rates in the presence of the VI 40-s stimuli. Figure 3 plots preference as a function of the log ratio of baseline response

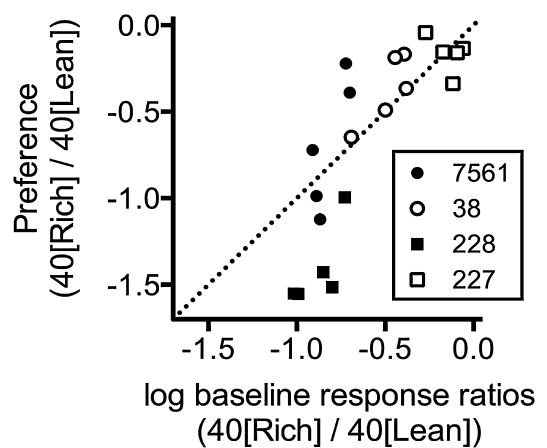


Fig. 3. Preference for the VI 40(Rich) stimulus relative to the VI 40(Lean) stimulus, $\log(\text{VI } 40[\text{Rich}] / \text{VI } 40[\text{Lean}])$, as a function of relative baseline response rates to the VI 40(Rich) stimulus relative to the VI 40(Lean) stimulus, $\log(\text{VI } 40[\text{Rich}] / \text{VI } 40[\text{Lean}])$. The dotted diagonal line indicates perfect correlation between responding during preference probes and baseline log response ratios.

rates to the two VI 40-s stimuli. Preference for the VI 40(Lean) stimulus was less extreme if baseline response rates to the VI 40-s stimuli were less differentiated across pigeons. Data points from 3 of the 4 birds distributed around the dotted diagonal line, indicating a strong relation between baseline log response ratios and probe preference. For Pigeon 228, preference was more extreme than baseline log response ratios (see also Belke, 1992, Herrnstein & Loveland, 1976). Therefore, preference appeared to be strongly controlled by the

relative baseline response rates in the presence of the VI 40-s stimuli.

Resistance to Disruption

We assessed whether resistance to disruption changed as a function of relative reinforcement rates arranged within the components or as a function of total reinforcement rates obtained in the Rich component relative to the Lean component. Figure 4 shows relative resistance to disruption between the VI 40-s stimuli, $\log(\text{VI } 40[\text{Rich}]_{\text{Disruption}} / \text{VI } 40[\text{Lean}]_{\text{Disruption}})$

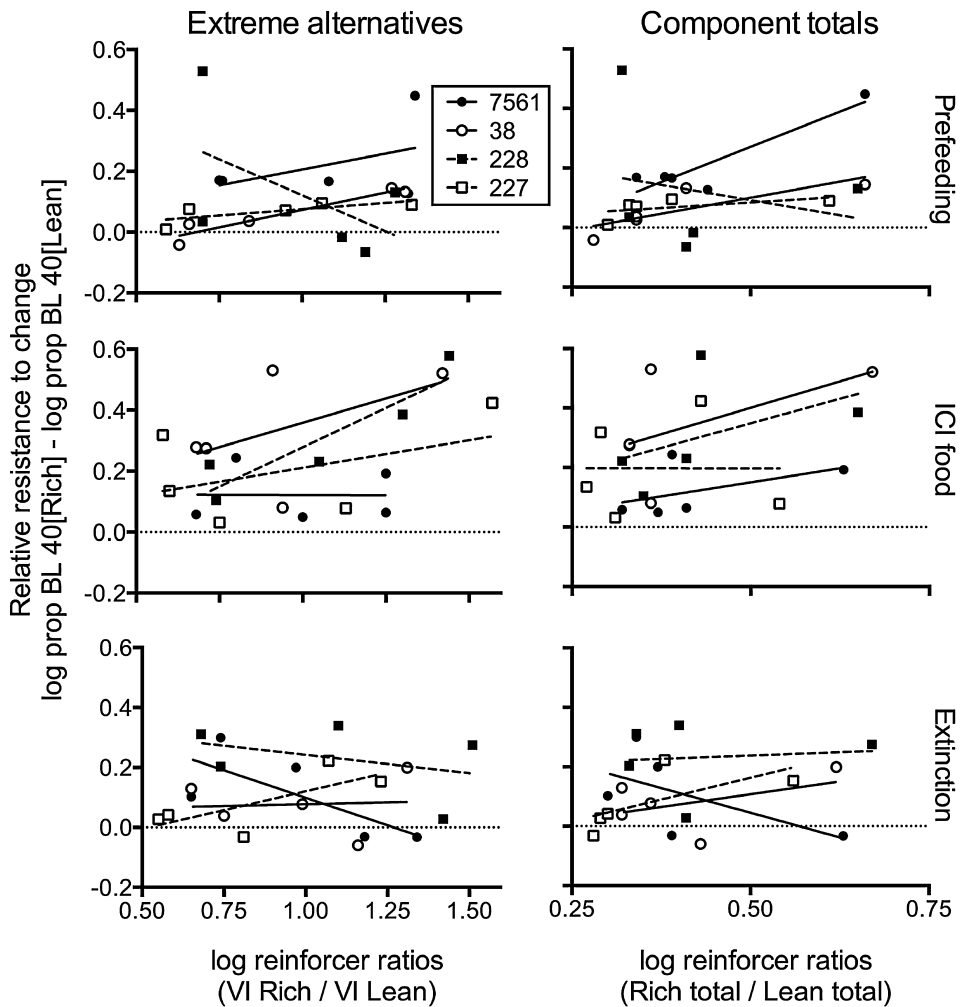


Fig. 4. Relative resistance to precession feeding (top row), ICI food (middle row), and extinction (bottom row) for the VI 40(Rich) stimulus relative to the VI 40(Lean) stimulus, $\log(\text{VI } 40[\text{Rich}]_{\text{Disruption}} / \text{VI } 40[\text{Rich}]_{\text{Baseline}}) - \log(\text{VI } 40[\text{Lean}]_{\text{Disruption}} / \text{VI } 40[\text{Lean}]_{\text{Baseline}})$, as a function of relative baseline reinforcement rates for the extreme alternatives on the left, $\log(\text{VI Rich} / \text{VI Lean})$, or total reinforcement rates on the right, $\log(\text{VI Rich} + \text{VI } 40[\text{Rich}] / \text{VI } 40[\text{Lean}] + \text{VI Lean})$. Equations for least-squares linear-regression lines are shown in Table 2.

$[\text{Rich}]_{\text{Baseline}}) - \log(\text{VI } 40[\text{Lean}]_{\text{Disruption}} / \text{VI } 40[\text{Lean}]_{\text{Baseline}})$ as a function of relative reinforcer rates for the extreme alternatives, $\log(\text{VI Rich} / \text{VI Lean})$, and as a function of relative total reinforcer rates summed across the two alternatives within both components, $\log(\text{VI Rich} + \text{VI } 40[\text{Rich}] / \text{VI } 40[\text{Lean}] + \text{VI Lean})$. As with preference, plotting relative resistance to disruption in these ways allows us to assess whether resistance to disruption changed as a function of within- or between-component changes in relative reinforcement rates. Most data points were above 0.0 on the y-axis, indicating that responding to the VI 40(Rich) stimulus had greater resistance to pre-session feeding (17 out of 20), ICI food (20 out of 20), and extinction (16 out of 20) than did responding to the VI 40(Lean).

However, Figure 4 also reveals that relative resistance to pre-session feeding, ICI food, and extinction did not change systematically as a function of changes in relative reinforcer rates presented as extreme alternatives or component totals. Table 2 shows that the slope of the regression lines differed statistically from zero only in 3 of 18 instances (see pre-session feeding for Pigeons 7561 and 38, ICI food for Pigeon 228). Therefore, the concurrently available sources of reinforcement generally enhanced relative resistance to disruption of responding to the VI 40(Rich) stimulus, but relative resistance to disruption between the VI 40-s stimuli was largely insensitive to changes in reinforcement rates for the extreme alternatives. As described above with preference, the absence of systematic changes in relative resistance to disruption between the two VI-40-s stimuli across conditions might have been due the relatively limited range across which reinforcement rates were manipulated. This point is addressed further in the Discussion.

We also examined whether our estimates of conditioned value, when expressed as relative resistance to disruption, changed as a function of changes in predicted value. Table 1 shows our estimates of conditioned value as relative resistance to disruption (Resistance column). We calculated estimated value as the ratio of the mean log proportion of baseline response rates averaged across pre-session feeding, ICI food, and extinction in the presence of the VI 40-s stimuli: $(\text{VI } 40[\text{Rich}]_{\text{Disruption}} / \text{VI } 40[\text{Rich}]_{\text{Baseline}}) / (\text{VI } 40[\text{Lean}]_{\text{Disruption}} / \text{VI } 40[\text{Lean}]_{\text{Baseline}})$. Relative resistance to disruption

more closely corresponded with predicted value expressed as total reinforcement obtained within components (see Total column) than when value was expressed relative to the extreme alternatives paired with the VI 40-s stimuli (see Relative column). This is because both relative resistance to disruption and predicted value were greater than 1.0, i.e., greater resistance to disruption in the presence of the VI 40(Rich) stimulus. Nevertheless, relative resistance to disruption did not consistently change across conditions with changes in Relative or Total predicted values.

We assessed the relation between relative resistance to disruption and relative baseline response rates to the two VI 40-s stimuli in a manner analogous to the assessment with preference shown in Figure 3. We found no systematic relation between relative resistance to disruption and relative baseline response rates for any of the disrupter types across pigeons (data not shown).

Preference and Resistance to Disruption

Figure 5 shows no systematic relation between relative resistance to the three disrupter types and preference for responding to the VI 40-s stimuli. As might be expected from the unsystematic preference (Figure 2) and resistance to disruption (Figure 4) as a function of reinforcement rate, the Pearson's r correlation between these measures across all pigeons was not statistically significant for pre-session feeding, $r(18) = -.07$, ICI food, $r(18) = -.21$, or extinction, $r(18) = -.30$. At the level of individual pigeons, the correlation between preference and relative resistance to disruption was statistically greater than zero only for Pigeon 228 during pre-session feeding, $r(18) = .93$.

Total Resistance to Disruption

Figure 6 shows relative resistance to disruption of total response rates summed across the two alternatives within the Rich and Lean components as a function of relative reinforcer rates. Most data points were above 0.0 on the y-axis, indicating that total responding in the Rich component was more resistant to pre-session feeding (19 out of 20), ICI food (20 out of 20), and extinction (20 out of 20). Nonetheless, in no case did the slope of the regression lines differ statistically from zero (see Table 2), suggesting that manipulating reinforcement rates for the extreme alternatives did not

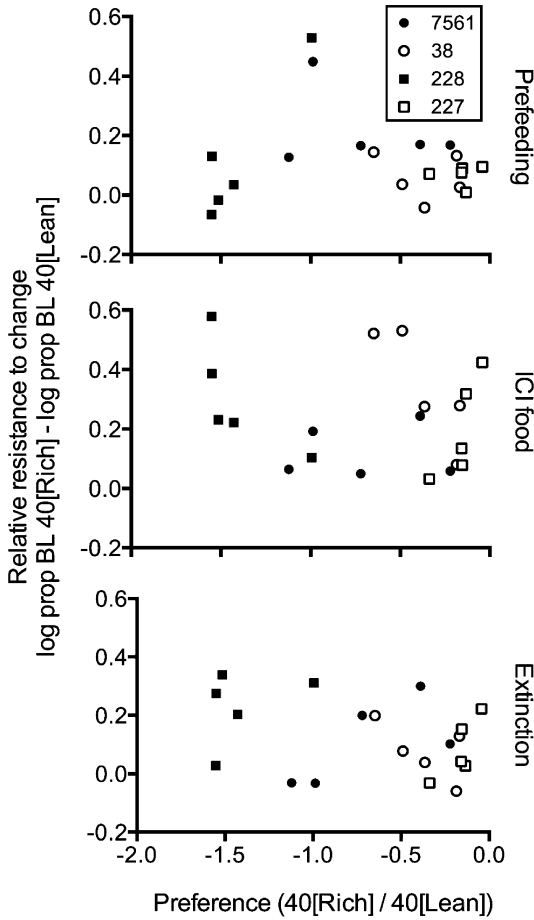


Fig. 5. Relative resistance to pre-session feeding (top row), ICI food (middle row), and extinction (bottom row) for the VI 40(Rich) stimulus relative to the VI 40(Lean) stimulus, $\log(\text{VI } 40[\text{Rich}]_{\text{Disruption}} / \text{VI } 40[\text{Rich}]_{\text{Baseline}}) - \log(\text{VI } 40[\text{Lean}]_{\text{Disruption}} / \text{VI } 40[\text{Lean}]_{\text{Baseline}})$, as a function of preference for the VI 40(Rich) stimulus relative to the VI 40(Lean) stimulus, $\log(\text{VI } 40[\text{Rich}] / \text{VI } 40[\text{Lean}])$.

systematically impact relative resistance to disruption of total responding between components.

Within-component Resistance to Disruption

Given the general trend that increasing relative reinforcement rates increased relative baseline response rates within components (see Figure 1), we also assessed relative resistance to disruption between the concurrently available responses within the Rich and Lean components. Figure 7 shows relative resistance to disruption of responding between the two

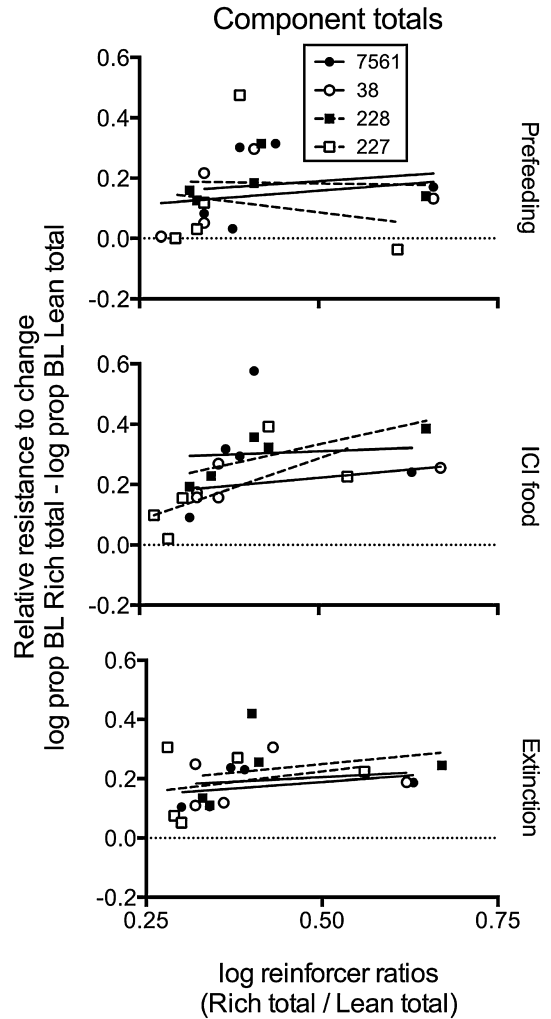


Fig. 6. Relative resistance to pre-session feeding (top row), ICI food (middle row), and extinction (bottom row) for total responding in the Rich component relative to total responding in the Lean component, $\log(\text{VI Rich} + \text{VI } 40[\text{Rich}]) - \log(\text{VI } 40[\text{Lean}] + \text{VI Lean})$, as a function of relative total baseline reinforcement rates within each component, $\log(\text{VI Rich} + \text{VI } 40[\text{Rich}] / \text{VI } 40[\text{Lean}] + \text{VI Lean})$. Equations for least-squares linear-regression lines are shown in Table 2.

alternatives within the Rich component (left column) and Lean component (right column) as a function of relative reinforcer rates between those alternatives. In the Rich component, relative resistance to disruption is calculated as log proportion of baseline response rates for the VI Rich alternative minus log proportion of baseline response

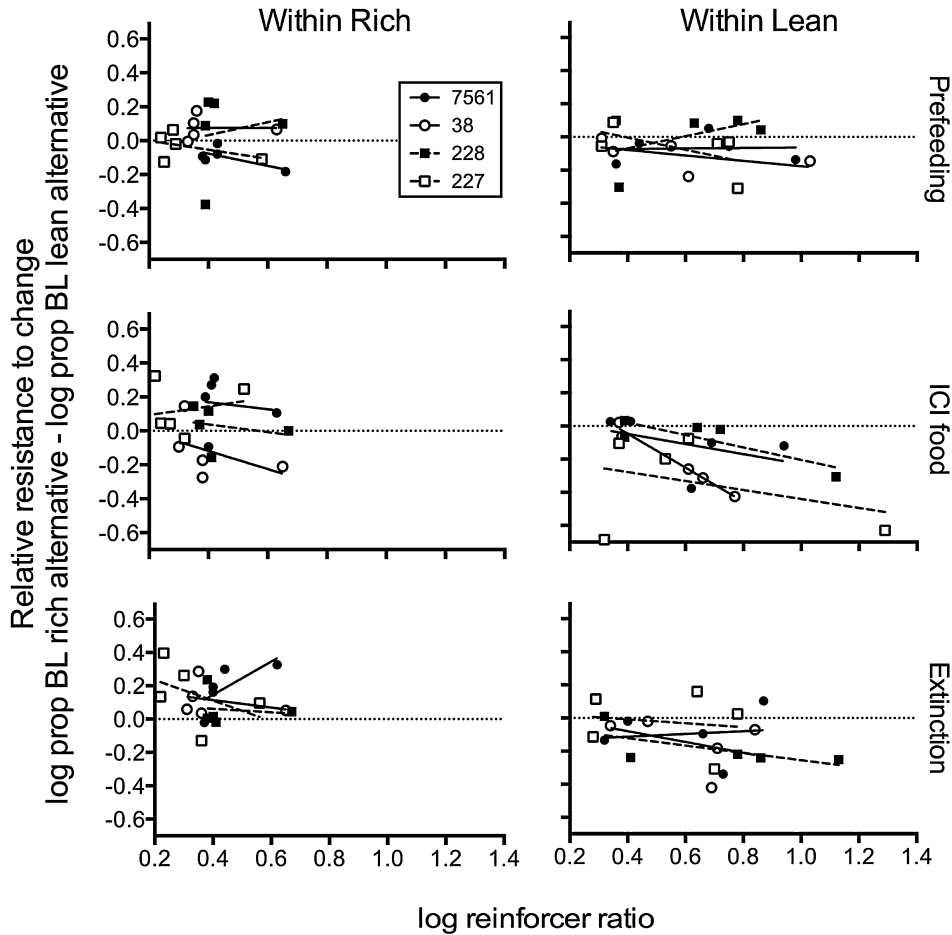


Fig. 7. Relative resistance to presession feeding (top row), ICI food (middle row), and extinction (bottom row) between the richer and leaner alternatives within the Rich component, $\log(\text{VI Rich}) - \log(\text{VI 40 Rich})$, and Lean component, $\log(\text{VI 40 Lean}) - \log(\text{VI Lean})$, as a function of relative baseline reinforcement rates in those components. Equations for least-squares linear-regression lines are shown in Table 2.

rates for the VI 40(Rich) alternative. In the Lean component, relative resistance to disruption is calculated as log proportion of baseline response rates for the VI 40(Lean) alternative minus log proportion of baseline response rates for the VI Lean alternative. Relative resistance to presession feeding, ICI food, and extinction did not change systematically with changes in relative reinforcement rates. Table 2 shows that slope of the regression line differed statistically from zero in only one instance (ICI food within the Lean component for Pigeon 38). Within both the Rich and Lean components, however, there are some systematic effects. In the Rich component,

relative resistance to extinction (bottom left panel) was greater for the richer alternative, falling above 0.0 on the y-axis in 17 out of 20 instances. Such differences were absent for presession feeding (10 out of 20 instances) and ICI food (13 out of 20 instances). Conversely, relative resistance to disruption, if anything, tended to be greater for the leaner alternative in the Lean component. Data points were below 0.0 on the y-axis with presession feeding in 14 out of 20 instances, ICI food in 16 out of 20 instances, and extinction in 15 out of 16 instances (see Nevin *et al.*, 1990, Figure 10, for similar findings). Thus, these data suggest that

relative resistance to disruption between concurrently available alternatives is not consistently related to differences in reinforcement rates between those alternatives.

Discussion

The present study arranged a choice between response alternatives in two separate stimulus contexts. While controlling reinforcement rates for one alternative in both components (i.e., VI 40-s schedules), we manipulated reinforcement rates for the more extreme alternatives (i.e., VI Rich and VI Lean) across conditions. Overall, the present findings replicated those of Bell and Williams (2002), showing greater resistance to disruption in the presence of the VI 40-s stimulus trained in the same stimulus context as the richer VI schedule. Preference during extinction probes showed the opposite pattern—we found greater preference for the VI 40-s stimulus trained with the leaner VI schedule, also consistent with the findings of Bell and Williams (2002; see also Belke, 1992, Gibbon, 1995). Neither preference nor relative resistance to disruption of responding to the VI 40-s stimuli changed systematically with our changes in relative reinforcement rates or changes in predicted values (see Table 1). However, we found preference to be a function of baseline response rates in the presence of the VI 40-s stimuli, causing us to question the use of extinction probes for assessing relative conditioned value of discriminative stimuli (see also Belke, 1992).

The overall greater resistance to disruption of responding to the VI 40-s stimulus trained in the Rich component is consistent with assertions of behavioral momentum theory. Overall higher rates of reinforcement obtained from any and all alternatives within a context enhance the conditioned value of all stimuli within that context (Nevin & Grace, 2000b). To further support these assertions, we also found greater resistance to disruption in the Rich component when summing total responding across the two alternatives in both components (see also Bell & Williams, 2002). These findings might be surprising given that different stimuli signaled the concurrently available alternatives in both components in these studies. These findings suggest that the total rate of reinforcement obtained from both alternatives enhanced the conditioned value of the broader stimulus

context that included the individual stimuli associated with both alternatives.

Another primary assertion of behavioral momentum theory is that preference and relative resistance to disruption both provide an expression of the relative conditioned value of stimulus contexts (Grace & Nevin, 1997). Inconsistent with this assertion, however, the present findings replicated others showing greater preference for the VI 40-s stimulus from the Lean component (e.g., Belke, 1992; Bell & Williams, 2002; Gibbon, 1995). Unlike resistance to disruption, preference did not support the assertion that all sources of reinforcement enhance the conditioned value of all concurrently available stimuli within a broader context. If preference probes are an adequate expression of stimulus value as suggested by Bell and Williams (2002; see also McDevitt & Williams, 2003), these findings question the generality of preference and relative resistance to disruption providing converging expressions of conditioned value.

There is good reason to presume, however, that preference during extinction probes is not determined by the overall rate of reinforcement in the presence of a stimulus context. The present study attempted to expand on the opposing relation between preference and relative resistance to disruption observed by Bell and Williams (2002) by varying reinforcement rates for the extreme alternatives (i.e., VI Rich and VI Lean). Variations in those reinforcement rates did not systematically affect preference or relative resistance to disruption beyond the levels observed in the conditions that replicated the training conditions arranged by other researchers (e.g., Belke, 1992; Bell & Williams, 2002; Gibbon, 1995). Instead, we found that preference was closely related to relative baseline response rates in the presence of the VI 40-s stimuli. Therefore, our findings join Belke's in suggesting that preference obtained during extinction probes might reveal more about baseline relative response rates in choice situations—preference does not directly reflect relative conditioned value of stimuli that results from training with the baseline conditions of reinforcement.

From the perspective of behavioral momentum theory, these findings imply that preference during extinction probes reveal little about conditioned value as a function of Pavlovian stimulus-reinforcer relations, which is typically

thought to govern preference and relative resistance to disruption (Nevin & Grace, 2000b). Instead, we propose that the influence of relative baseline response rates in the presence of the VI 40-s stimuli on preference with extinction probes might better reflect operant response-reinforcer relations established between concurrently available alternatives during baseline conditions. Because preference so closely reflected baseline response rates, preference might only be indirectly related to reinforcement conditions. Given that absolute response rates can vary considerably among individuals in the presence of the same reinforcement conditions (e.g., Catania & Reynolds, 1968), we cannot expect preference to follow reliably any predictions that directly link preference with reinforcement (e.g., Gibbon, 1995; Herrnstein & Loveland, 1976; Williams & Royalty, 1989).

The conditioned value of a stimulus can only be determined indirectly through behavioral measurement. There is no behavioral method for assessing stimulus value directly – it is a hypothetical construct. As we have shown in the present study, preference during extinction probes appears to be primarily determined by baseline response rates. Moreover, preference, when assessed with extinction probes, does not reveal the possibility that concurrently available sources of reinforcement might enhance conditioned value. If anything, findings with preference probes suggest that concurrently available sources of reinforcement compete for conditioned value (e.g., Belke, 1992). Behavioral momentum theory, conversely, proposes that conditioned value is determined by all sources of reinforcement in the presence of a given stimulus (Nevin & Grace, 2000b). The most commonly used expressions of stimulus value, resistance to disruption and preference in concurrent chains (see Grace *et al.*, 2002, for a review), are used for the purpose of minimizing the influence of baseline response rates. Given that these measures are less confounded with baseline response rates than are preference probes, we are inclined to conceive of conditioned value in ways consistent with behavioral momentum theory. Conditioned value is a property of stimulus contexts that is determined by all sources of reinforcement obtained within that context.

To remove the influence of relative baseline response rates on preference following baseline

conditions arranged in the present experiment, a better test of preference between the VI 40-s stimuli would be to arrange what Grace and Savastano (2000) called response-strength probes. After training with baseline conditions identical to those arranged in the present experiment, brief extinction probes would arrange a choice between two concurrently available alternatives during the initial links of concurrent chains. Responding to one alternative provides access according only to the VI 40 (Rich) stimulus as a terminal link. Responding to the other alternative provides access only to the VI 40 (Lean) stimulus as a terminal link. More responding to the initial link providing access to the VI 40 (Rich) stimulus would suggest that the overall rate of reinforcement obtained in the presence of that stimulus context influenced preference between the VI 40-s stimuli, consistent with the assertions of behavioral momentum theory.

With regard to the unsystematic effects of variations of reinforcement rates on relative resistance to change, it should be noted that varying reinforcement rates affected baseline choice performance (see Figure 1). These findings suggest that the pigeons discriminated the different relative reinforcement rates obtained within both components. However, it is possible that relative reinforcement rates did not vary enough between components to influence relative resistance to disruption within this range of reinforcement rates. Table 1 shows that the greatest between-component change in relative total reinforcer rates was only a two-fold change between the first two conditions, from 2.14 per hr to 4.28 per hr. Estimates of sensitivity relating relative resistance to disruption to changes in between-component reinforcement rates have approximated 0.5 (Nevin, 2002). With this sensitivity combined with some variation in the measure, it might be no surprise that relative resistance to change did not differ with these limited variations in reinforcement rates. Nevertheless, we observed greater resistance to disruption in the Rich component across all ratios of between-component reinforcement rates.

We also found no reliable effect of within-component changes in relative reinforcement rates on relative resistance to disruption between the two alternatives arranged within the Rich and Lean components (see Figure 7). This lack of effect within components might be

surprising given that the within-component changes in reinforcement rates (1) systematically affected relative response rates within both components, and (2) were greater than the relative reinforcement rates arranged between components, at least within the Lean component. A review of previous studies support the present findings suggesting that relative resistance to disruption between concurrently available alternatives is not systematically related to differences in relative reinforcement rates. Table 3 lists studies we have reviewed that arranged two-alternative concurrent VI schedules presenting a richer and leaner alternative. All studies were designed to assess decreases in response rates to the two alternatives through changes in running weight, extinction, ICI food, pre-session feeding/satiation, or from within-session changes. We obtained these data from tables or directly from authors¹. Table 3 also shows the species used, reinforcement schedules, type of disruption, and the log of the mean proportion of baseline averaged across all subjects for the richer and leaner alternative from each study. We calculated separate mean log proportion of baseline values within a study anytime the authors assessed either different reinforcement rates or different methods of disruption.

Figure 8 shows the mean log proportion of baseline response rates from the richer alternative on the y-axis and the mean log proportion of baseline response rates from the leaner alternative on the x-axis. Data points above the dashed diagonal line indicate greater resistance to disruption for the richer alternative and points falling below indicate greater resistance to disruption for the leaner alternative. The more negative values indicate greater disruption relative to baseline response rates. Because data points cluster along the dashed diagonal line, Figure 8 reveals no systematic relation of relative resistance to disruption between concurrently available alternatives arranging different reinforcement rates².

The absence of a systematic effect of relative reinforcement rates when assessing relative

resistance to disruption between concurrently available alternatives differs starkly from the reliable and general patterns observed when assessed between separate stimulus contexts (e.g., multiple schedules; see Nevin & Grace, 2000b, for a review). Nevertheless, the lack of systematic effect with concurrently available alternatives is entirely consistent with the assertions of behavioral momentum theory. As originally suggested by Nevin et al. (1990), concurrently available sources of reinforcement decrease the rate of a reinforced response by weakening the operant response-reinforcer relation. Nonetheless, the concurrently available reinforcement also increases resistance to disruption of all responses in the presence of a stimulus context by enhancing the Pavlovian stimulus-reinforcer relation. Thus, any reinforcement obtained from either alternative of the concurrent schedule enhances the conditioned value of the discriminative-stimulus context in which those response alternatives reside. As such, we question the reliability of any differences in relative resistance to disruption obtained between concurrently available alternatives until these effects can be brought under direct experimental control through systematic manipulations.

Understanding that all sources of reinforcement enhance the persistence of all responses within a stimulus context, however, likely provides little consolation to applied researchers and practitioners. Techniques to decrease problem behavior frequently involve arranging concurrently available reinforcement for desirable behavior to compete with and replace problem behavior (see Petscher, Rey, & Bailey, 2009, for a review). Ideally, techniques to decrease problem behavior also would result in a desirable behavior that is more persistent than problem behavior (see Mace, McComas, Mauro et al., 2010; Podlesnik, Bai, & Elliffe, 2012). Unfortunately, the findings shown in Figure 8 suggest that relative resistance to disruption between concurrently available alternatives is not a simple function of relative reinforcement rates. Clearly, the factors determining the relative persistence of concurrently available alternatives remain to be understood.

In summary, the present findings support those of Bell and Williams (2002) that two potential measures of conditioned value of discriminative stimulus contexts, relative

¹ The authors thank Tony Nevin, Matt Bell, Stephanie da Silva, and Fran McSweeney for providing their data.

² We also observed no systematic effect overall or within any study when relative resistance to disruption was plotted as a function of either relative or overall reinforcement rate (data not shown).

Table 3
Studies included in review arranging conditions to decrease response rates in concurrent schedules (see Figure 8).

Study	Subjects	Concurrent schedules	Disrupter	Log prop BL Rich	Log prop BL Lean
Bell & Williams (2002)	Pigeons	VI 20 VI 40	PF	-0.14	-0.22
			ICI food	-0.05	-0.05
			EXT	-0.21	-0.28
		VI 40 VI 80	PF	-0.24	-0.28
			ICI food	-0.19	-0.21
da Silva, Maxwell, & Lattal (2008)	Pigeons	VI 60 VI 360	EXT	-0.34	-0.25
			EXT + VI 180 s	-1.55	-1.30
McLean & Blampied (1995, Part 3)	Pigeons	VI 40 VI 80	ICI food	-0.04	0.04
McLean, Campbell-Tie, & Nevin (1996)	Pigeons	VI 80 VI 360		-0.11	-0.12
		VI 40 VI 80	ICI food	-0.32	0.12
McSweeney (1975)	Pigeons	VI 40 VI 120		-0.22	-0.13
		VI 30 VI 120	%FFW	-0.17	-0.22
		VI 60 VI 240		-0.07	-0.34
McSweeney, Weatherly, & Swindell (1996)	Rats	VI 11.25 VI 22.5	Within-session changes	-0.07	-0.13
		VI 22.5 VI 45		0.13	0.17
		VI 45 VI 90		-0.24	-0.39
		VI 90 VI 180		0.01	-0.06
		VI 180 VI 360		-0.08	0.04
		VI 360 VI 720		-0.01	-0.24
	Pigeons	VI 11.25 VI 22.5	Within-session changes	0.05	0.16
		VI 22.5 VI 45		-0.14	-0.06
		VI 45 VI 90		-0.58	-0.79
		VI 90 VI 180		0.08	-0.06
		VI 180 VI 360		-0.46	-0.37
		VI 360 VI 720		-0.27	-0.17
Myerson & Hale (1988)	Pigeons	VI 90 VI 180	EXT	-0.30	-0.35
Nevin, Tota, Torquato, & Shull (1990, Expt 3)	Pigeons	VI 80 VI 240	EXT	-0.35	-0.22
Podlesnik, Bai, & Elliffe (2012)	Pigeons	VI 37.5 VI 150	PF	-0.54	-0.32
			Satiation	-0.38	-0.31
			EXT	-0.59	-0.54
Rau, Pickering, & McLean (1996)	Pigeons	VI 60 (6.5) VI 60 (2.5)	ICI food	-0.14	-0.11
Present study	Pigeons	VI 10 VI 40	EXT	-0.98	-0.97
			PF	-0.28	-0.25
			ICI food	-0.14	-0.15
		VI 20 VI 40	EXT	-0.24	-0.19
			PF	-0.35	-0.33
			ICI food	-0.24	-0.10
		VI 40 VI 80	EXT	-0.24	-0.28
			PF	-0.27	-0.32
			ICI food	-0.55	-0.45
		VI 40 VI 160	EXT	-0.57	-0.38
			PF	-0.49	-0.15
			ICI food	-0.18	-0.31
		VI 40 VI 360	EXT	-0.29	-0.42
			PF	-0.49	-0.43
			ICI food	-0.51	-0.30
			EXT	-0.62	-0.57

All VI schedule values are in seconds, with numbers in parentheses for Rau et al. (1996) indicating reinforcer durations. Resistance to change is shown for Rich and Lean alternatives as log proportion of baseline response rates average across all subjects for a given disrupter type (e.g., ICI food) and then averaged across all amounts tested with that disrupter type. Note that da Silva et al. (2008) extinguished concurrent-schedule responding while simultaneously reinforcing a different response according to a VI 180-s schedule. McSweeney (1975) manipulated the percentage of free-feeding body weight (% FFW) from 80% to 110%. We used data from the 80% conditions as baseline from which to calculate the log proportion of baseline response rates. McSweeney et al. (1996) assessed within-session changes in 5-min bins across 60-min sessions. We averaged response rates from the first 15 min as baseline and averaged the log proportion of baseline response rates across the following three 15-min bins.

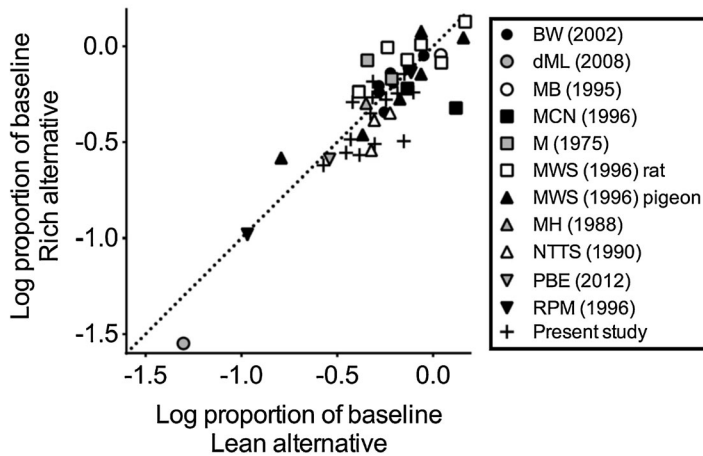


Fig. 8. Review of existing literature assessing resistance to disruption between concurrently available alternatives (see Table 3 for details on individual studies). Mean log proportion of baseline for the richer alternative is presented on the y-axis and the leaner alternative is presented on the x-axis (see text for more details). The dotted diagonal line indicates no difference in resistance to disruption between the richer and leaner alternatives. Legend shows studies in alphabetical order by author initials and as presented in Table 3.

resistance to disruption and preference during extinction probes, revealed opposite conclusions. Resistance to disruption of responding to a stimulus signaling VI 40-s schedules was greater in a context in which a concurrently available response arranged a higher reinforcement rate. These findings are consistent with the assertions of behavioral momentum theory suggesting that the conditioned value of discriminative-stimulus contexts are a function of the overall rate of reinforcement obtained in the presence of a stimulus context (Nevin & Grace, 2000b). Preference, conversely, was greater for the stimulus signaling the VI 40-s schedule in a context in which a concurrently available response arranged a lower reinforcement rate. However, we found that preference was a function of relative baseline response rates between the VI 40-s stimuli, a finding that questions the usefulness of preference probes for assessing relative conditioned value of stimuli (see also Belke, 1992; Gibbon, 1995). The lack of relation between preference in extinction probes and relative resistance to disruption clearly suggests that not all purported assessments of conditioned value are equivalent and likely reflect different aspects or determiners of behavior, such as stimulus-reinforcer versus response-reinforcer relations.

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Appendix
Responses per min during baseline (BL), precession feeding (PF), intercomponent food (ICI), and extinction (EXT). Reinforcers per min during baseline for both response alternatives in the Rich and Lean components.

		Baseline and disruption response rates						Baseline reinforcement rates					
		Rich component			Lean component			Rich component			Lean component		
Pigeon	Condition	VI Rich	VI 40(R)	Log ratio	VI 40(L)	VI Lean	Log ratio	VI Rich	VI 40(R)	Log ratio	VI 40(L)	VI Lean	Log ratio
7561	1												
	BL	94.04	10.73	0.94	64.00	16.19	0.60	3.06	1.26	0.39	1.25	0.55	0.36
	PF	69.84	10.34	0.83	41.64	15.33	0.43						
	BL	89.64	14.22	0.80	57.93	21.25	0.44	3.07	1.21	0.40	1.25	0.49	0.41
	ICI	64.27	12.68	0.71	29.47	10.14	0.46						
	BL	96.16	13.67	0.85	71.26	21.11	0.53	3.01	1.27	0.37	1.39	0.55	0.40
	EXT	35.98	5.36	0.83	14.02	4.34	0.51						
	2												
	BL	90.11	10.10	0.95	79.80	12.48	0.81	6.25	1.38	0.66	1.37	0.29	0.68
	PF	50.60	8.64	0.77	24.32	3.37	0.86						
	BL	93.36	12.21	0.88	89.49	7.88	1.06	6.10	1.45	0.63	1.43	0.35	0.62
	ICI	76.03	7.81	0.99	36.73	7.68	0.68						
	BL	102.77	10.95	0.97	87.40	8.05	1.04	5.97	1.44	0.62	1.47	0.27	0.73
	EXT	59.31	2.98	1.30	25.67	5.17	0.70						
	3												
	BL	90.53	15.96	0.75	84.29	18.77	0.65	2.82	1.18	0.38	1.35	0.49	0.44
	PF	69.45	15.18	0.66	54.41	13.27	0.61						
	BL	81.48	15.27	0.73	84.48	17.98	0.67	2.97	1.17	0.41	1.37	0.62	0.34
	ICI	74.01	7.42	1.00	35.88	7.19	0.70						
	BL	89.81	17.82	0.70	89.05	19.49	0.66	3.03	1.21	0.40	1.44	0.68	0.32
	EXT	47.16	6.02	0.89	23.76	7.07	0.53						
	4												
	BL	88.36	9.68	0.96	96.40	9.16	1.02	3.03	1.13	0.43	1.43	0.25	0.75
	PF	84.74	11.13	0.88	75.55	8.16	0.97						
	BL	81.98	14.78	0.74	91.72	7.61	1.08	2.92	1.10	0.42	1.43	0.29	0.69
	ICI	65.97	5.80	1.06	32.08	3.36	0.98						
	BL	92.26	11.92	0.89	103.63	8.70	1.08	2.88	1.14	0.40	1.41	0.31	0.66
	EXT	42.54	3.78	1.05	20.76	2.17	0.98						
	5												
	BL	86.54	10.68	0.91	88.05	4.27	1.31	3.04	1.13	0.43	1.38	0.14	0.98
	PF	57.73	7.42	0.89	45.63	3.03	1.18						
	BL	85.06	12.18	0.84	89.97	4.44	1.31	2.89	1.18	0.39	1.42	0.16	0.94
	ICI	82.48	7.46	1.04	47.51	3.09	1.19						
	BL	88.86	14.45	0.79	94.94	6.39	1.17	3.03	1.11	0.44	1.48	0.20	0.87
	EXT	19.10	1.56	1.09	11.00	0.58	1.28						
	38												
	BL	58.03	25.83	0.35	57.73	20.86	0.44	2.68	1.19	0.35	1.39	0.62	0.35
	PF	30.80	10.81	0.45	26.65	11.79	0.35						
	BL	68.99	23.00	0.48	65.71	26.01	0.40	2.79	1.18	0.38	1.31	0.55	0.38
	ICI	20.20	10.04	0.30	15.23	6.98	0.34						

(Continued)

Appendix. (Continued)

Pigeon		Baseline and disruption response rates						Baseline reinforcement rates					
		Rich component			Lean component			Rich component			Lean component		
		VI Rich	VI 40(R)	Log ratio	VI 40(L)	VI Lean	Log ratio	VI Rich	VI 40(R)	Log ratio	VI 40(L)	VI Lean	Log ratio
2	BL	69.06	29.90	0.36	65.06	23.77	0.44	2.77	1.30	0.33	1.44	0.49	0.47
	EXT	33.79	10.67	0.50	21.24	8.13	0.42						
	BL	84.59	13.03	0.81	65.02	6.49	1.00	5.71	1.35	0.63	1.26	0.31	0.61
	PF		2.41	0.88	8.62	1.49	0.76						
	BL	93.95	13.00	0.86	57.22	8.75	0.82	5.64	1.25	0.65	1.25	0.21	0.77
	ICI	50.67	11.40	0.65	15.11	6.15	0.39						
	BL	72.94	11.04	0.82	59.44	6.53	0.96	5.47	1.22	0.65	1.33	0.27	0.69
	EXT	47.56	6.39	0.87	21.76	6.29	0.54						
	BL	75.78	22.53	0.53	56.51	18.74	0.48	2.83	1.26	0.35	1.26	0.62	0.31
	PF	26.13	7.18	0.56	16.94	5.71	0.47						
3	BL	60.82	21.46	0.45	48.23	20.47	0.37	2.63	1.32	0.30	1.29	0.55	0.37
	ICI	26.43	11.58	0.36	13.71	5.54	0.39						
	BL	72.73	22.73	0.51	60.50	20.47	0.47	2.72	1.32	0.31	1.33	0.60	0.34
	EXT	54.43	14.86	0.56	29.40	11.07	0.42						
	BL	59.66	24.32	0.39	54.75	10.24	0.73	2.61	1.15	0.36	1.34	0.38	0.55
	PF	31.18	8.49	0.56	17.60	3.72	0.67						
	BL	65.97	13.14	0.70	52.61	8.34	0.80	2.67	1.11	0.38	1.32	0.33	0.61
	ICI	19.86	7.44	0.43	8.79	2.53	0.54						
	BL	69.03	16.83	0.61	58.92	7.56	0.89	2.65	1.15	0.36	1.39	0.27	0.71
	EXT	29.79	6.68	0.65	19.56	3.83	0.71						
5	BL	56.13	21.31	0.42	60.00	7.86	0.88	2.55	1.19	0.33	1.34	0.13	1.03
	PF	30.31	11.64	0.42	24.14	4.42	0.74						
	BL	47.12	23.00	0.31	52.62	9.52	0.74	2.53	1.20	0.32	1.33	0.29	0.66
	ICI	36.06	12.57	0.46	23.88	8.89	0.43						
	BL	60.29	18.85	0.51	62.64	6.89	0.96	2.61	1.17	0.35	1.23	0.18	0.84
	EXT	22.38	3.62	0.79	13.78	1.78	0.89						
	BL	100.28	10.44	0.98	75.75	9.69	0.89	2.93	1.18	0.39	1.37	0.59	0.37
	PF	62.25	15.41	0.61	33.08	8.49	0.59						
	BL	97.34	19.15	0.71	86.80	16.10	0.73	3.09	1.32	0.37	1.39	0.57	0.39
	ICI	31.35	5.67	0.74	20.19	3.47	0.77						
228	BL	99.66	15.88	0.80	74.04	17.95	0.62	2.98	1.23	0.38	1.30	0.62	0.32
	EXT	53.93	8.48	0.80	19.33	4.58	0.62						
	BL	112.84	7.40	1.18	83.44	4.41	1.28	6.20	1.40	0.65	1.37	0.33	0.63
	PF	89.82	4.68	1.28	39.13	1.71	1.36						
	BL	119.42	8.92	1.13	86.74	6.94	1.10	6.16	1.33	0.67	1.35	0.31	0.64
	ICI	63.53	4.74	1.13	18.95	1.55	1.09						
	BL	110.08	8.01	1.14	81.32	5.14	1.20	6.37	1.36	0.67	1.44	0.20	0.86

(Continued)

Appendix. (Continued)

Pigeon	Condition	Baseline and disruption response rates						Baseline reinforcement rates					
		Rich component			Lean component			Rich component			Lean component		
		VI Rich	VI 40(R)	Log ratio	VI 40(L)	VI Lean	Log ratio	VI Rich	VI 40(R)	Log ratio	VI 40(L)	VI Lean	Log ratio
227	3	EXT	59.24	3.88	1.18	20.94	2.31	0.96					
		BL	118.21	14.67	0.91	100.94	16.15	0.80	3.20	1.31	1.47	0.65	0.36
		PF	94.04	9.53	0.99	60.53	7.70	0.90					
		BL	99.56	15.74	0.80	90.95	16.09	0.75	3.07	1.21	1.45	0.59	0.39
		ICI	42.81	5.16	0.92	17.91	3.70	0.69					
4		BL	115.06	11.32	1.01	100.94	10.73	0.97	3.03	1.19	1.43	0.55	0.41
		EXT	65.48	6.21	1.02	34.70	6.39	0.73					
		BL	98.84	15.83	0.80	98.61	9.85	1.00	3.10	1.24	1.43	0.24	0.78
		PF	91.49	8.70	1.02	56.33	4.47	1.10					
		BL	98.69	16.40	0.78	102.59	8.59	1.08	3.05	1.36	1.43	0.27	0.72
5		ICI	76.39	9.08	0.93	33.39	2.93	1.06					
		BL	89.55	13.51	0.82	86.52	8.54	1.01	2.98	1.17	1.41	0.23	0.78
		EXT	40.03	6.30	0.80	18.49	3.03	0.79					
		BL	86.98	12.60	0.84	89.36	6.12	1.16	3.09	1.17	1.44	0.20	0.86
		PF	85.36	7.45	1.06	61.45	3.81	1.21					
227	1	BL	107.97	8.37	1.11	104.05	3.91	1.43	3.00	1.17	1.43	0.11	1.12
		ICI	59.14	6.56	0.96	21.53	1.64	1.12					
		BL	105.09	9.58	1.04	102.69	5.86	1.24	2.86	1.20	1.47	0.11	1.13
		EXT	64.57	3.42	1.28	34.34	3.50	0.99					
		BL	60.71	48.88	0.09	59.13	27.42	0.33	2.17	1.25	1.16	0.56	0.31
2		PF	53.76	41.56	0.11	49.21	25.95	0.28					
		BL	63.31	48.71	0.11	52.64	30.23	0.24	2.21	1.27	1.22	0.58	0.32
		ICI	25.10	17.44	0.16	9.05	25.16	-0.44					
		BL	59.47	39.96	0.17	45.96	31.94	0.16	2.08	1.26	1.14	0.58	0.29
		EXT	49.09	24.16	0.31	26.13	13.95	0.27					
3	2	BL	88.21	53.69	0.22	79.81	11.94	0.82	4.53	1.20	1.20	0.21	0.75
		PF	71.18	55.65	0.11	67.27	10.81	0.79					
		BL	87.22	62.51	0.14	86.15	14.84	0.76	4.40	1.33	1.32	0.32	0.61
		ICI	41.05	16.69	0.39	19.19	3.93	0.69					
		BL	92.89	59.50	0.19	95.44	14.25	0.83	4.59	1.25	1.35	0.27	0.70
227	3	EXT	84.63	43.47	0.29	49.05	14.87	0.52					
		BL	79.96	46.84	0.23	60.96	34.76	0.24	2.46	1.37	1.23	0.54	0.35
		PF	62.68	48.96	0.11	53.53	24.90	0.33					
		BL	66.10	53.98	0.09	62.80	33.53	0.27	2.27	1.23	1.33	0.57	0.37
		ICI	32.30	24.01	0.13	20.48	13.91	0.17					
227		BL	67.16	52.91	0.10	66.03	31.70	0.32	2.42	1.22	1.20	0.64	0.28
		EXT	41.19	17.78	0.36	20.17	12.57	0.21					

(Continued)

Appendix. (*Continued*)

Pigeon		Baseline and disruption response rates						Baseline reinforcement rates					
		Rich component			Lean component			Rich component			Lean component		
		VI Rich	VI 40(R)	Log ratio	VI 40(L)	VI Lean	Log ratio	VI Rich	VI 40(R)	Log ratio	VI 40(L)	VI Lean	Log ratio
4	BL	65.28	57.29	0.06	78.58	19.78	0.60	2.23	1.17	0.28	1.29	0.25	0.71
	PF	61.84	46.84	0.12	54.52	15.07	0.56						
	BL	46.42	58.16	-0.10	67.77	17.80	0.58	2.13	1.27	0.22	1.30	0.38	0.53
	ICI	31.04	18.46	0.23	20.00	8.28	0.38						
	BL	60.84	64.59	-0.03	90.40	20.25	0.65	2.12	1.25	0.23	1.43	0.33	0.64
5	EXT	57.92	24.72	0.37	37.21	5.76	0.81						
	BL	79.33	53.81	0.17	89.36	7.12	1.10	2.47	1.26	0.29	1.31	0.22	0.78
	PF	72.64	51.51	0.15	68.70	11.17	0.79						
	BL	75.71	42.99	0.25	81.88	6.21	1.12	2.65	1.28	0.32	1.39	0.07	1.29
	ICI	38.44	24.17	0.20	17.35	5.61	0.49						
	BL	82.39	38.81	0.33	79.94	9.54	0.92	2.54	1.10	0.36	1.31	0.22	0.78
	EXT	39.62	25.11	0.20	31.01	3.49	0.95						