Preference for 50% reinforcement over 75% reinforcement by pigeons

CASSANDRA D. GIPSON

University of Kentucky, Lexington, Kentucky

JÉRÔME J. D. ALESSANDRI

Université de Lille III, Lille, France

AND

HOLLY C. MILLER AND THOMAS R. ZENTALL

University of Kentucky, Lexington, Kentucky

When pigeons are given a choice between an initial-link alternative that results in either a terminal-link stimulus correlated with 100% reinforcement or a stimulus correlated with 0% reinforcement (overall 50% reinforcement) and another initial-link alternative that always results in a terminal-link stimulus correlated with 100% reinforcement, some pigeons show a preference for the initial-link alternative correlated with 50% reinforcement. Using this procedure, in Experiment 1, we found a relatively modest preference for 100% over 50% reinforcement. In Experiment 2, we decreased the reinforcement density for the second initial-link alternative to 75% and found a significant preference for the 50% reinforcement initial-link alternative. It may be that this “maladaptive” behavior results from a positive contrast between the expectation of reinforcement correlated with the 50% reinforcement initial-link alternative and the terminal-link stimulus correlated with 100% reinforcement. But apparently, the complementary negative contrast does not develop between the expectation of reinforcement correlated with the 50% reinforcement initial-link alternative and the terminal-link stimulus correlated with 0% reinforcement that often follow. Such paradoxical choice may account for certain human appetitive risk-taking behavior (e.g., gambling) as well.

When animals appear to behave maladaptively, it may inform us about the processes underlying their behavior. Hungry animals generally prefer alternatives that provide more reinforcement or a higher probability of reinforcement. Thus, when Kendall (1974) reported that pigeons preferred an alternative that provided food 50% of the time over one that provided food 100% of the time, the result was surprising. In Kendall's procedure, choice of one alternative led to a white-lit key and reinforcement 100% of the time, whereas choice of the other alternative led to reinforcement 50% of the time—100% of the time when a green light appeared, 0% of the time when a red light appeared. Kendall found that all four of his pigeons preferred the 50% reinforcement alternative.

Fantino, Dunn, and Meck (1979) noted an unusual aspect of Kendall's (1974) procedure that may have been responsible for the pigeons' surprising preference. By using dark keys in the initial link and by illuminating only the key that was chosen, the unchosen key remained dark, as it was during the initial link. Thus, when the pigeon chose the 50% reinforcement alternative and received the stimulus associated with 100% reinforcement, it continued to peck that key, but when it received the stimulus associated

with 0% reinforcement, it switched to the dark (inoperative) key because of its similarity to the dark initial-link key. This meant that the effective rate of reinforcement on the nominal 50% reinforcement side was actually closer to 100%, because the pigeons would switch to the other side when nonreinforcement was predicted. On the other hand, the effective rate of reinforcement on the nominal 100% side was actually less, because although it was 100% on the trials when the pigeons chose the 100% reinforcement side, it was 0% when the pigeon chose the 50% reinforcement side and the 0% reinforcement stimulus appeared, because the pigeon would tend to switch to the other (now inoperative) side key. Fantino et al. found, in fact, that when the stimulus on the chosen key was correlated with nonreinforcement, the pigeons began pecking the inoperative dark key.

Fantino et al. (1979) also showed that when the two keys in the initial link were lit (white) and the unchosen key turned dark, the pigeons more adaptively preferred the high-density reinforcement alternative over the low-density reinforcement alternative (about 62% of the time). When they attempted to replicate Kendall's (1974) procedure, although they did not find an overall preference for

T. R. Zentall, zentall@uky.edu

the low density of reinforcement alternative, they did find a decrease in the preference for the high density of reinforcement alternative. Finally, when they made the unchosen key in the terminal link different from the initial link by lighting it white, these same pigeons showed a modest preference for the high density of reinforcement alternative. Although Fantino et al. showed that when the experimental procedures were less ambiguous, the pigeons did not prefer the low density of reinforcement alternative, the preference for the high density of reinforcement alternative was a relatively modest 62% when it was unambiguous from the start and 57.5% when the pigeons were transferred from the ambiguous procedure to the unambiguous procedure. These values are rather surprising, given that the probability of reinforcement associated with the initial links (1.0 vs. .5) was so different.

Spetch, Belke, Barnett, Dunn, and Pierce (1990) further clarified the conditions under which pigeons would choose the low density of reinforcement alternative by manipulating the duration of the terminal link between 10 and 90 sec. When reinforcement on the low density of reinforcement alternative was signaled, they found that when the terminal link was short, most of the pigeons generally preferred the high density of reinforcement alternative, whereas when the terminal link was long, the results were mixed, but 3 of the 4 pigeons actually preferred the low probability of reinforcement alternative (see also Dunn & Spetch, 1990; Spetch, Mondloch, Belke, & Dunn, 1994). Thus, it appears that although Kendall's (1974) results were likely biased by the ambiguity in his procedure, under certain conditions, some pigeons do appear to prefer an alternative that provides 50% reinforcement over one that provides 100% reinforcement.

Similar results were reported by Mazur (1995) using a different measure of preference. In one of his conditions, the choice of one alternative produced 50% reinforcement (either a signal for 100% reinforcement or a signal for 0% reinforcement, each after a delay of 10 sec). Mazur (1995) asked what delay of reinforcement for a second alternative that reliably provided 100% reinforcement would produce indifferent choice. Mazur (1995) found that 3 of the 4 pigeons were indifferent when the delay to reinforcement for the reliable 100% reinforcement was less than 10 sec. Thus, one can infer that these pigeons preferred 50% reinforcement over 100% reinforcement when the delay to reinforcement was equal (10 sec).

Similarly, Mazur (1996) found that when the reinforcement and nonreinforcement for the 50% reinforcement alternative was signaled by a stimulus that was present for 20 sec, 3 of the 7 pigeons showed indifference only when a reliable 100% reinforcement alternative was delayed by less than 20 sec. However, under unsignaled conditions, the pigeons were indifferent between 50% reinforcement delayed by 20 sec and 100% reinforcement only when the 100% reinforcement option was delayed by over 30 sec. Once again, the implication is that when nonreinforcement was signaled and the delay to reinforcement was equal (20 sec), 50% reinforcement was preferred over 100% reinforcement.

The role of signaled reinforcement (in the context of nonreinforcement on other trials) was further demon-

strated by McDevitt, Spetch, and Dunn (1997), who found that although 2 of 4 pigeons preferred the 50% reinforcement alternative over the 100% reinforcement alternative when reinforcement and nonreinforcement were signaled, interpolating a 5-sec gap between choice of the 50% reinforcement alternative and the signal for reinforcement resulted in a strong preference for the 100% reinforcement alternative by all 4 pigeons.

Mazur's (1984) *hyperbolic decay model* can account for several related phenomena, including the preference for small immediate reinforcement over large delayed reinforcement and for the preference for a mixture of short and long delays over the average of the two delays. However, as Mazur (1984) acknowledged, this model has difficulty accounting for the preference for 50% reinforcement over 100% reinforcement.

The purpose of Experiment 1 was to ask whether we could replicate the mixed preference for high density of reinforcement over low density of reinforcement found by several investigators (e.g., Belke & Spetch, 1994; Fantino et al., 1979; Mazur, 1995) and to confirm that Kendall's (1974) procedure included an artifact that was responsible for the strong preference for 50% reinforcement over 100% reinforcement. The purpose of Experiment 2 was to determine whether there are conditions under which a statistically reliable preference might be found for a lower density of reinforcement over a higher density. We selected 75% reinforcement for the higher density alternative because it is midway between 100% and 50% reinforcement.

EXPERIMENT 1

Method

Subjects

The subjects were 16 White Carneaux pigeons of undetermined sex (5–8 years old), purchased as retired breeders from the Palmetto Pigeon Plant, Sumter, South Carolina. The pigeons were maintained at 85% of their free-feeding body weight and had free access to water and grit. They were housed in a colony room that was kept on a 12:12-h light:dark cycle and were cared for in accordance with University of Kentucky animal care guidelines. All of the pigeons had previously served in a matching-to-sample experiment with hue stimuli of the kind used in the present experiment.

Apparatus

Two standard (LVE/BRS, Laurel, MD) test chambers were used, both with inside measurements of 35 cm high, 30 cm long, and 35 cm across the response panel. The response panel in each chamber had a horizontal row of three response keys 25 cm above the floor. The rectangular keys (2.5 cm high $\times$ 3.0 cm wide) were separated from each other by 1.0 cm, and behind each key was a 12-stimulus inline projector (Industrial Electronics Engineering, Van Nuys, CA) that projected red, yellow, blue, and green hues (Kodak Wratten Filter Nos. 26, 9, 38, and 60, respectively). In each chamber, the bottom of the center-mounted feeder was 9.5 cm from the floor. When the feeder was raised, it was illuminated by a 28-V, 0.04-A lamp. Reinforcement consisted of 1.5 sec of Purina Pro Grains. An exhaust fan mounted on the outside of the chamber masked extraneous noise. A microcomputer in an adjacent room controlled the experiment.

Procedure

Pretraining. All of the pigeons received two sessions of pretraining in which they had to peck once to each discriminative stimulus on each side key (yellow, red, green, and blue hues). Each peck to

Figure 2. Experiment 1: Preferences by pigeons for the initial-link alternative that always provided a stimulus correlated with 100% reinforcement over the alternative that sometimes provided a stimulus correlated with 100% reinforcement ($p = .5$) and sometimes provided a stimulus correlated with 0% reinforcement ($p = .5$). For Group Unambiguous, the unchosen key in the initial link was darkened in the terminal link. For Group Ambiguous, the unchosen key in the initial link remained lit in the terminal link.

only 51.9% ($SEM \pm 6.25\%$) of the trials, a preference that was not significantly different from chance [$t(7) < 1$]. A t test performed on the data from the two groups indicated that Group Unambiguous chose the alternative correlated with 50% reinforcement significantly less than did Group Ambiguous [$t(14) = 2.89$, $p = .01$, Cohen's $d = 1.54$, $r = .61$].

We then tested the hypothesis that during the terminal link, when the stimulus correlated with nonreinforcement was present, the pigeons pecked the unchosen initial-link alternative. The pigeons in Group Unambiguous did not peck the dark unchosen initial-link key at all, whereas the pigeons in Group Ambiguous pecked the lit unchosen initial-link key an average of 1.80 times per trial ($SEM \pm 0.32$) when the stimulus correlated with nonreinforcement was present, but they never pecked it when the stimulus correlated with reinforcement was present.

The peck rates to the three discriminative stimulus hues were also recorded. It should be noted that the DRO 2-sec contingency at the end of each terminal link resulted in a very low peck rate to all of the hues. The pecks to the 100% reinforcement alternative averaged 0.73 pecks per trial ($SEM \pm 0.13$) for the pigeons in Group Unambiguous and 1.39 pecks per trial ($SEM \pm 0.43$) for the pigeons in Group Ambiguous. The pecks to the 100% reinforcement stimulus on the 50% reinforcement alternative averaged 2.59 pecks per trial ($SEM \pm 0.54$) in Group Unambiguous and 2.12 pecks per trial ($SEM \pm 0.63$) for the pigeons in Group Ambiguous. For each pigeon, the individual keypecking data for each of the three terminal-link stimuli, pooled over the two testing phases, also appear in Table 1.

The difference between the peck rate to the stimulus correlated with 100% reinforcement on the 50% alterna-

tive and that on the 100% alternative was statistically significant for Group Unambiguous [$t(7) = 3.30$, $p = .01$, Cohen's $d = 2.49$, $r = .78$] and for Group Ambiguous [$t(7) = 2.53$, $p = .04$, Cohen's $d = 1.91$, $r = .69$]. Thus, for both groups, the presence of the stimulus correlated with 0% reinforcement (on other trials) was associated with an increase in responding to the stimulus correlated with 100% reinforcement (relative to the other stimulus correlated with 100% reinforcement). Some pecking also occurred to the stimulus correlated with 0% reinforcement. The pecks to the stimulus correlated with 0% reinforcement averaged 1.15 pecks per trial ($SEM \pm 0.40$) for the pigeons in Group Unambiguous and 0.66 pecks per trial ($SEM \pm 0.17$) for the pigeons in Group Ambiguous. The difference was not statistically significant [$t(14) < 1$].

If the modest preference for the initial link associated with 100% reinforcement by the pigeons in the unambiguous group resulted from contrast, one might expect to see a positive correlation between the preference for the initial link correlated with 50% reinforcement and the relative response rate to the stimulus correlated with 100% reinforcement on the 50% alternative (the response rate to the stimulus correlated with 100% reinforcement on the 50% alternative divided by the total response rate to the stimulus correlated with 100% reinforcement on the 50% alternative plus the response rate to the stimulus correlated with 100% reinforcement on the 100% alternative). Surprisingly, that correlation was negative, but given the small number of subjects in Group Unambiguous, it was not statistically significant ($r = -.62$, $p > .05$). It should also be noted that the relative response rate to the stimulus correlated with 100% reinforcement on the 50% alternative was not normally distributed (it was above .70 for all but 2 pigeons).

Discussion

The results of Experiment 1 support Fantino et al. (1979), who found that under ambiguous terminal-link conditions, pigeons were virtually indifferent between initial links associated nominally with 50% versus 100% reinforcement. The results of Experiment 1 show that under unambiguous conditions (the stimuli available during the terminal link were all different from those present in the initial link), when reinforcement is signaled, pigeons show a modest but significant preference for an alternative correlated with 100% reinforcement over an alternative correlated with 50% reinforcement. They also show that when stimulus conditions are ambiguous (the unchosen stimulus from the initial link remains illuminated during the terminal link), pigeons are relatively indifferent between the high and low density of reinforcement alternatives (although there are clear individual differences).

The relatively small preference that the pigeons in Group Unambiguous showed for the 100% reinforcement alternative over the 50% alternative is consistent with the mixed findings from other research (e.g., Belke & Spetch, 1994; Fantino et al., 1979; Mazur, 1995) and is in contrast to the strong preference for the 100% reinforcement alternative over the 50% alternative when the 100% rein-

forcement and 0% reinforcement components of the 50% alternative are unsignaled (about 91%; Dunn & Spetch, 1990). The failure to find a stronger preference for the 100% reinforcement alternative may result from a contrast effect—that is, from the added value given to the stimulus correlated with 100% reinforcement on the low density of reinforcement alternative—because, on other trials, that alternative is associated with the presence of a stimulus correlated with 0% reinforcement. Although there was not a negative correlation between the preference for the initial link correlated with 100% reinforcement and the relative response rate to the stimulus correlated with 100% reinforcement on the 50% alternative as one might expect if contrast were involved, the small number of subjects in Group Unambiguous and the skewed distribution of relative response rate scores may have been responsible.

EXPERIMENT 2

Although individual pigeons have been shown to prefer alternatives associated with 50% reinforcement over 100% reinforcement under unambiguous reinforcement conditions, a statistically reliable preference at the group level has not been demonstrated. The purpose of Experiment 2 was to ask whether under unambiguous and signaled reinforcement conditions associated with the alternative correlated with the lower probability of reinforcement, pigeons could be induced to prefer a lower density of reinforcement alternative by somewhat reducing the density of reinforcement associated with the high density of reinforcement alternative. Thus, in Experiment 2, the density of reinforcement correlated with the high density of reinforcement alternative was reduced to 75%, whereas the density of reinforcement correlated with the low density of reinforcement alternative remained at 50% (on half of the trials there was a terminal-link stimulus correlated with 100% reinforcement, whereas on the remaining trials there was a terminal-link stimulus correlated with 0% reinforcement).

A second purpose of Experiment 2 was to rule out an alternative account of the preference for 50% reinforcement over 100% reinforcement—that pigeons prefer stimulus variability. In most prior research, the terminal link associated with the 50% alternative has involved the random presentation of one of two stimuli that signaled either reinforcement or its absence, whereas the terminal link associated with the 100% alternative has involved a single stimulus. But Mazur (1996, Part C) found that the preference for the 50% reinforcement alternative is reduced when the terminal link associated with the 100% reinforcement alternative also involves the random presentation of either of two stimuli. Thus, in Experiment 2, either of two stimuli could appear in the terminal link of the high density of reinforcement alternative, but the reinforcement correlated with both stimuli was the same (75%). Also, in Experiment 2, each trial began with a peck to a vertical line on the center key to ensure that the pigeon was located at the midpoint between the choice keys at the start of each choice trial to reduce the likelihood

of position biases and to increase the likelihood of exposure to both initial-link alternatives. In addition, the DRO requirement was eliminated from the last 2 sec of each fixed interval presentation of the terminal-link stimulus to make it easier to detect differences in the rate of pecking among the terminal-link stimuli, and the terminal link was increased to 30 sec. Finally, to give the pigeons experience with choice trials during training, the choice trials were interspersed with the training trials throughout training.

Method

Subjects and Apparatus

The subjects were 16 pigeons similar to those that served in Experiment 1. The pigeons were maintained as were those in Experiment 1. The apparatus was the same as that used in Experiment 1.

Procedure

Pretraining. The pigeons were trained to peck each of the hues on a fixed interval schedule beginning at 1 sec and increasing to 5, 10, 20, and 30 sec. Individual pecks to a vertical line orientation stimulus were also reinforced. During each of 10 pretraining sessions, the pigeons received 10 presentations of each stimulus.

Training. All trials began with the vertical line stimulus presented on the center key. On forced trials, a single peck to the lit key illuminated a white hue on either the right or the left key. The other side key remained dark and was inoperative. One peck to the lit key initiated the terminal link. For half of the pigeons in one group, if the white key on the left was illuminated, on half of the trials, one peck turned the white key red, and the first peck after 30 sec (a fixed-interval 30-sec schedule) was followed by reinforcement. On the remaining left white-key trials, one peck turned the white key green for a fixed duration (30 sec) followed by no reinforcement. If the white key on the right was illuminated, one peck turned the white key blue or yellow and the first peck after 30 sec (a fixed-interval 30-sec schedule) was followed by reinforcement, but only 75% of the time (each hue occurred with a probability of .5). For the remaining pigeons in that group, the sides associated with the

Table 2
Experiment 2: Percentage Choice of the Alternative Associated With 50% Over 75% Reinforcement (Left Three Data Columns) and the Rate of Pecking the Four Stimuli Associated With Their Respective Probabilities of Reinforcement (Right Four Data Columns; cf. Figure 13)

Pigeon	Choice of 50% Alternative			Mean Pecks per Trial			
	Test		<i>M</i>	Alternative 1		Alternative 2	
	Phase 1	Phase 2		1.00	0	.75	.75
22748	100.0	3.2	52.6	31.5	2.3	43.6	54.4
17878	100.0	96.7	98.3	52.3	3.3	45.5	48.6
15196	20.0	98.3	59.2	31.2	1.1	25.6	32.4
19227	93.3	69.9	81.6	24.7	2.1	17.6	29.8
15953	74.9	94.9	84.9	26.9	2.0	29.4	26.0
19828	96.6	73.3	86.2	11.3	0.2	12.7	12.8
19834	63.2	73.3	68.2	34.1	2.6	35.0	39.3
19731	66.7	21.7	44.1	39.0	6.1	26.7	27.4
1140	90.0	20.0	55.0	75.8	3.7	68.1	55.5
583	41.7	25.0	33.3	19.5	2.3	25.0	23.3
1006	93.3	98.3	95.8	20.9	5.6	20.5	19.8
10896	76.7	66.7	71.7	39.6	6.8	21.2	23.5
8784	71.7	83.3	77.5	35.5	1.4	26.1	26.7
18434	71.7	1.7	36.7	33.1	2.2	34.6	31.5
15888	68.3	98.3	83.3	32.4	4.7	27.2	26.4
18798	91.7	75.0	83.3	20.7	0.8	31.7	28.9
Mean	76.2	62.5	69.3	33.9	3.0	30.6	31.6

Figure 3. Design of Experiment 2. The side keys and contingencies associated with the colors were counterbalanced over pigeons. $P(rf)$ = the probability of reinforcement.

two probabilities of reinforcement were opposite. The right key was associated with red and green hues, and the left key was associated with blue and yellow hues. The design of Experiment 2 appears in Figure 3.

For the pigeons in the counterbalancing group, blue and yellow stimuli were correlated with 100% and 0% reinforcement, respectively, and red and green stimuli were correlated with 75% reinforcement. Half of these pigeons initially received blue and yellow hues on the left and red and green hues on the right, and the remaining pigeons received the opposite treatment. There were 48 forced trials in each session, 12 involving each color.

For all of the pigeons, randomly mixed among the 48 forced trials were 12 choice trials per session. These trials also began with the vertical line on the center key. A peck to the vertical line illuminated both the left and right white keys, and a single peck to either side key resulted in the initiation of the terminal link on that side, as it did during a forced trial. The unchosen side was darkened and was inoperative.

All of the pigeons received these choice trials and forced trials for 15 sessions. To control for side preferences unrelated to the reinforcement contingencies correlated with the particular stimuli, the sides associated with the reinforcement probabilities were then reversed for an additional 15 sessions. Data analysis was conducted on the combined data from the last 5 sessions of each block of 15 sessions.

Results

Of the 16 pigeons, 13 showed some preference for the alternative correlated with 50% reinforcement, whereas only 3 showed a preference for the alternative correlated with 75% reinforcement (binomial $p = .01$). Overall, the pigeons chose the alternative correlated with 50% reinforcement on 69.3% ($SEM \pm 5.11\%$) of the trials, and this was significantly different from chance [$t(15) = 3.79$, $p = .002$, Cohen's $d = 1.96$, $r = .70$]. The data from each pigeon for the last five test sessions of each of the two blocks of test sessions appear in Table 2. The mean choice data for each pigeon appear in Figure 4.

On forced training trials, the pigeons pecked the 100% reinforcement stimulus an average 33.0 pecks per trial, and pecked the 0% reinforcement stimulus an average of 3.0 pecks per trial. The pecks to the two 75% reinforcement stimuli averaged 29.4 and 32.8 pecks per trial. Although the peck rate to the 100% reinforcement stimulus was higher than that to the two 75% reinforcement stimuli, a comparison of the peck rate with the 100% reinforcement

stimulus with the combined average of the two 75% reinforcement stimuli revealed that they were not significantly different ($t < 1$). The peck rates to the four terminal-link stimuli for each pigeon also appear in Table 2.

If the preference for the alternative correlated with 50% reinforcement resulted from a contrast between the initial and terminal links, one might also expect the relative response rate to the 100% reinforcement stimulus to be correlated with the preference for the 50% reinforcement initial link. However, although the correlation was positive, it was not statistically reliable ($r = .32$, $p = .11$).

Discussion

The results of Experiment 2 indicate that pigeons will show a reliable preference for 50% reinforcement over 75% reinforcement when, on half of the trials, the 50% reinforcement alternative involves a terminal-link stimulus correlated with 100% reinforcement and, on the remaining trials, involves a different terminal-link stimulus correlated with 0% reinforcement. The results suggest that the mixed preference for 50% reinforcement found in earlier research

Figure 4. Preferences by pigeons for an alternative that sometimes provided a stimulus correlated with 100% reinforcement ($p = .5$) and sometimes provided a stimulus correlated with 0% reinforcement ($p = .5$) over an alternative that provided one of two stimuli, each correlated with 75% reinforcement.

(Belke & Spetch, 1994; Fantino et al., 1979; Spetch et al., 1990) can be made more reliable by reducing the probability of reinforcement associated with the high-density alternative. Furthermore, the preference found in Experiment 2 cannot be explained by a preference for stimulus variability associated with the low density of reinforcement, because in Experiment 2, the choice of the alternative correlated with 75% reinforcement also resulted in the presentation of either of two stimuli, each 50% of the time. To our knowledge, this is the first evidence of a statistically reliable preference for 50% reinforcement over a higher percentage of reinforcement in which a delay of reinforcement and the magnitude of reinforcement have been equated.

In Experiment 1, there was a higher rate of pecking to the 100% reinforcement terminal-link stimulus associated with the 50% reinforcement initial link than to the 100% reinforcement terminal-link stimulus associated with the 100% reinforcement initial link. However, in Experiment 2, the rate of pecking to the 100% reinforcement terminal-link stimulus associated with the 50% reinforcement initial link was comparable to that to the 75% reinforcement terminal-link stimuli. An important difference between the two experiments was the required absence of pecking (the DRO contingency) during the last 2 sec of the terminal link in Experiment 1 but not in Experiment 2. This difference resulted in a pecking rate more than 15 times as great in Experiment 2. Nevertheless, if preference for the initial link associated with 50% reinforcement over the initial link associated with 75% reinforcement in Experiment 2 resulted from a contrast between the initial link and the terminal link on the 50% reinforcement side, one might have expected to see it reflected in a larger difference in the terminal-link peck rate. Furthermore, although there was a positive correlation between the preference for the 50% reinforcement initial link and the relative response rate to the 100% reinforcement terminal link, it was not statistically reliable. A contributing factor to the absence of a significant correlation was the relatively restricted range of relative response rates shown by the pigeons in Experiment 2. On the other hand, one might not expect to find a positive correlation between initial-link choice and terminal-link response rate, because Williams (1992) found that those measures may not be correlated.

GENERAL DISCUSSION

The results of the present experiments indicate that pigeons can be induced to choose a low density of reinforcement over a higher density of reinforcement by signaling whether reinforcement will be coming or not following the choice. These results can be accounted for in several ways. Mazur's (1984) hyperbolic decay model was originally based on the delay of reinforcement, but the percentage of reinforcement can be substituted for delay in the sense that the absence of reinforcement means that reinforcement is delayed at least until the next trial. According to this model, the value of reinforcement declines rapidly and nonlinearly with delay (see Figure 5), and all of the terminal-link stimuli will have some association with reinforcement (even the S- stimulus will be associated with reinforcement if it oc-

Figure 5. Mazur's (1984) hyperbolic decay model. The delay correlated with the initial link (init link) 50% alternative produces an S+ ($p = .5$) with a value of V_{S+} or an S- ($p = .5$) with a value of V_{S-} and a mean value of V_{S+S-} . Although the initial link 75% is correlated with a higher value than the initial link 50%, it is associated with a lower value than V_{S+S-} .

curs on the following trial). Thus, the value of the stimulus correlated with 100% reinforcement (S+) on some trials, averaged together with the value of the stimulus correlated with 0% reinforcement (S-) on other trials, may be greater than the value of the stimulus correlated with 75% reinforcement. However, as Mazur (1995) noted, the hyperbolic decay model cannot account for the preference for 50% reinforcement over 100% reinforcement that some pigeons show (e.g., Belke & Spetch, 1994; Mazur, 1995), because, as can be seen in Figure 5, the value of 100% reinforcement together with the value of 0% reinforcement associated with one alternative cannot be greater than the value of 100% reinforcement itself, associated with the other alternative.

A second account of the preference for the low density of reinforcement alternative over a higher density of reinforcement alternative is Fantino's (1977) delay reduction theory, suggested by Dunn and Spetch (1990). Although the reduction in delay to reinforcement signaled by the two terminal-link stimuli correlated with reinforcement is the same, the *relative* reduction in delay to reinforcement on the appearance of the two terminal-link stimuli correlated with reinforcement is quite different. That is, because the initial-link 50% reinforcement alternative is correlated with a greater delay to reinforcement than is the initial-link 100% reinforcement alternative, when the 100% reinforcement stimulus appears following the 50% reinforcement initial link, it represents a greater relative reduction in delay to reinforcement than the appearance of the 100% reinforcement stimulus associated with the 100% reinforcement initial link.

A third mechanism that might induce pigeons to prefer an initial link correlated with a low density of reinforcement over one correlated with a high density of reinforce-

ment is positive contrast. Contrast occurs because the stimulus correlated with 100% reinforcement following the 50% reinforcement initial link occurs in the context of 0% reinforcement on other trials. It is the contrast between the 50% reinforcement initial link and the 100% reinforcement terminal link that gives the 100% reinforcement stimulus added value. This effect is most similar to the phenomenon of simultaneous incentive contrast in which rats run faster on signaled reinforcement trials (when on other trials there is signaled nonreinforcement) than other rats run on only consistently reinforced trials (Mellgren & Dyck, 1974).

The contrast account assumes that there is no compensating negative contrast associated with the 0% reinforcement stimulus, because if there were, the negative contrast would be expected to act in the opposite direction, and it should thus eliminate any preference for the initial link associated with 50% reinforcement. Although it is not clear why negative contrast should be absent, Schwartz (1975) suggested that positive and negative contrast may not be causally related; thus, under complementary conditions such as these, one may occur without the other. Furthermore, our observations of pigeons suggest that when the 0% reinforcement stimulus appears, the pigeons typically turn away from the stimulus. This avoidance behavior may lessen the negative contrast associated with that stimulus.

Consistent with the notion of positive contrast, the preference for the low density of reinforcement alternative is found only when reinforcement is signaled. When it is not signaled, a strong preference for the high density of reinforcement alternative has been reported (Fantino et al., 1979; Kendall, 1974; Spetch et al., 1990).

According to the contrast account, in both experiments, one might have expected to see a positive correlation between the degree of preference for the 50% alternative (over the higher probability alternative) and the relative rate of pecking the stimulus correlated with 100% reinforcement that followed. In Experiment 1, the correlation was actually negative, however, because the procedure involved a DRO requirement at the end of each terminal link (after Kendall, 1974); the relative pecking rate to all terminal-link stimuli was quite low (2.9–10.4 pecks per minute). Furthermore, the range of relative pecking rate was quite small, thereby reducing the likelihood of finding a meaningful correlation. In Experiment 2, without the DRO requirement during the terminal link, there was a reasonable positive correlation between the degree of preference for the 50% alternative and the relative rate of pecking the stimulus correlated with 100% reinforcement that followed. Although the correlation was not statistically reliable, it was consistent in direction with the contrast account.

Hyperbolic decay, delay reduction, and contrast make similar predictions with regard to the results of the present experiments. The hyperbolic decay model is quite powerful, because it makes quantitative predictions on the basis of the probability of reinforcement, the delay of reinforcement, and one free parameter (the rate of loss in

value of reinforcement with increasing delay). But as was already noted, it has difficulty accounting for a preference for 50% reinforcement over 100% reinforcement. Conditioned reinforcement associated with the reduction in delay to reinforcement (Fantino, 1977) makes similar predictions if one considers the reduction in delay relative to what is expected for that alternative given the initial link. In principle, it can also account for the preference for 50% reinforcement over 100% reinforcement. Contrast is the least quantitative of the accounts, but it too can account for the preference for 50% reinforcement over 100% reinforcement. Furthermore, Singer, Berry, and Zentall (2007) have shown that contrast can account for results that cannot be explained by delay reduction. In Phase 1 of their experiment, pigeons chose between two schedules that were equated for delay to reinforcement. On some trials, they were required to peck to obtain reinforcement, whereas on other trials, they were required to refrain from pecking to obtain reinforcement. When tested for preferences, some pigeons preferred pecking, whereas others preferred not pecking. Each schedule (initial link) was then followed by a simple simultaneous discrimination ($S+S-$, terminal link), and finally, the pigeons were given a choice between the two $S+$ stimuli correlated with reinforcement. Singer et al. found that the pigeons showed a consistent preference for the $S+$ stimulus that followed the *least* preferred of the two initial-link schedules. They proposed that the greater contrast between the less preferred initial link and the $S+$ stimulus correlated with reinforcement caused it to be more preferred.

A better means of distinguishing among the three theories will have to await further research. However, for simplicity and convenience, for the remainder of this discussion, we will treat contrast as the mechanism responsible for the preference for an alternative correlated with a low density of reinforcement over one correlated with a higher density of reinforcement.

If a contrast-like mechanism is responsible for the preference for low density of reinforcement found in Experiment 2, it may be similar to the mechanism responsible for what has been called *observing behavior*. For example, Wyckoff (1952) reported that pigeons would step on a treadle, the sole function of which was to produce a discriminative stimulus that indicated what schedule was in effect on a response key. Technically, observing responses changed the schedule of reinforcement that was in effect from a mixed to a multiple schedule of reinforcement.

Observing behavior has been studied by Roper and Zentall (1999) with a procedure more similar to that used in the present experiments. In their experiments, pigeons could choose between two initial-link stimuli: one that either produced a stimulus that was correlated with 100% reinforcement or produced a stimulus correlated with 0% reinforcement, as in the present experiments, and the other that produced one of two stimuli, each correlated with reinforcement 50% of the time. Thus, the two initial-link stimuli were associated with the same probability of reinforcement. Roper and Zentall found that the pigeons had a strong preference for the alternative that produced stimuli

that reliably predicted reinforcement and the absence of reinforcement over stimuli each correlated with reinforcement 50% of the time.

Experiments on observing behavior have consistently shown that when the probabilities of reinforcement associated with two initial links are equal, several species, including humans, prefer the signaled reinforcement alternative over the unsignaled one (see Dinsmoor, 1983). When the probability of reinforcement associated with both initial-link alternatives is decreased (to as low as 12.5%), the preference for the signaled reinforcement alternative becomes even stronger, and conversely, when that probability is increased (to as high as 87.5%), the preference for the signaled reinforcement alternative actually decreases (Roper & Zentall, 1999, Experiment 1).

With regard to the present experiments, Roper and Zentall (1999, Experiment 2) asked whether they could eliminate the preference for the signaled reinforcement alternative by increasing the response requirement needed to initiate the terminal link relative to the response requirement needed to initiate the terminal link for the unsignaled reinforcement alternative. They found that it was not until the ratio of required pecks to the signaled reinforcement alternative versus the unsignaled reinforcement alternative reached 8:1 that the pigeons became indifferent between the two alternatives. Furthermore, when the overall probability of reinforcement was only 12.5%, a ratio of required pecks of 16:1 was not sufficient to produce a preference for the unsignaled reinforcement alternative. Thus, the results of that experiment complement the results of the present Experiment 2 (as well as Mazur, 1995, 1996) in showing that, when the cost of choosing the alternative that produces stimuli consistently correlated with reinforcement and nonreinforcement is greater than the cost of choosing the other alternative, pigeons maladaptively continue to choose the signaled reinforcement alternative.

Dinsmoor (1983) proposed that the mechanism responsible for the preference for the signaled reinforcement alternative is conditioned reinforcement associated with the 100% reinforced stimulus. One can think of this as the change in value from the lower probability of reinforcement associated with the initial link to the higher probability of reinforcement associated with the 100% reinforced stimulus in the terminal link. Thus, for the signaled reinforcement alternative, when the overall probability of reinforcement is 12.5% (on seven of eight trials, choice of that alternative produced a stimulus correlated with nonreinforcement, whereas on the remaining trial, choice of that alternative produced a stimulus correlated with reinforcement), the change in value on the trials that produce the stimulus correlated with 100% reinforcement is 87.5%. In contrast, when the overall probability of reinforcement is 87.5%, the change in value on the trials that produce the stimulus correlated with 100% reinforcement is only 12.5%. On the other hand, for the unsignaled reinforcement alternative, there is no change in value between the initial link and terminal link.

But if the positive change in value signaled by the 100% reinforcement stimulus increases the value of the initial link, why does the negative change in value signaled by the 0% reinforcement stimulus not correspondingly decrease the value of the initial link? Perhaps it is because, typically, pigeons turn away from stimuli that predict the absence of reinforcement. Also, if one considers nonreinforced pecking as a source of inhibition or negative contrast, there should be little nonreinforced pecking to the 0% reinforcement stimulus, whereas pecking would be expected to occur on nonreinforced trials to the alternative associated with unsignaled reinforcement.

The mechanism responsible for the present findings is also likely to be involved in the results reported by Clement and Zentall (2002). In that research, on some trials, pigeons pecked vertical lines that produced either food or a simple simultaneous discrimination that we can refer to as $S+_{\text{food}} S-_{\text{food}}$, with a 50% probability of reinforcement for choice of the correct stimulus. On other trials, the pigeons pecked horizontal lines that produced either no food or a different simple simultaneous discrimination that we can refer to as $S+_{\text{nofood}} S-_{\text{nofood}}$, again, with a 50% probability of reinforcement for choice of the correct stimulus. When the pigeons were given a choice between the two $S+$ stimuli, $S+_{\text{food}}$ and $S+_{\text{nofood}}$, they showed a strong preference for $S+_{\text{nofood}}$. Although both $S+$ stimuli were correlated with the same contingencies of reinforcement, $S+_{\text{nofood}}$ followed a stimulus that predicted either no reinforcement or 50% reinforcement (nominally 25% reinforcement). Thus, relative to the probability of reinforcement associated with the initial link, the appearance of $S+_{\text{nofood}}$ represented an increase in the probability of reinforcement (from 25% to 50%). On the other hand, $S+_{\text{food}}$ followed a stimulus that predicted either 100% reinforcement or 50% reinforcement (nominally 75% reinforcement) and the appearance of $S+_{\text{food}}$ represented a decrease in the probability of reinforcement (from 75% to 50%).

With regard to the present study, it appears that positive contrast produced by the appearance of the stimulus correlated with 100% following choice of the 50% initial-link alternative was sufficient to overcome the difference between the overall 50% probability of reinforcement associated with that initial link alternative and the probability of reinforcement associated with the 75% reinforcement alternative. In earlier research, it appears that, for some pigeons, the contrast was even sufficient to overcome the difference between 50% and 100% reinforcement (Belke & Spetch, 1994; Spetch et al., 1990).

Finally, the possibility that the conditions of reinforcement inherent in the design of Experiment 2 produced positive contrast but not symmetrical negative contrast may have implications for human monetary risk-taking behavior. Many people make less than optimal choices when they purchase lottery tickets or gamble at casinos where the average payoff is less than 1.0 (i.e., they would be better off not gambling). In those cases, the increase in value associated with the anticipation of a possible high payoff (positive contrast) may outweigh the high prob-

ability of a small decrease in value associated with a loss (there is little negative contrast) such that gambling (the low probability payoff) is judged to be favored over abstaining (the high probability payoff). Although some may argue that there is inherent reinforcement in the activity of gambling beyond winning or losing, the argument would be convincing only if those who experience pleasure in the activity would do so as readily if there were no potential monetary reinforcers involved.

AUTHOR NOTE

This research was supported by National Institute of Mental Health Grant 63726. Correspondence concerning this article should be addressed to T. R. Zentall, Department of Psychology, University of Kentucky, Lexington, KY 40506-0044 (e-mail: zentall@uky.edu).

REFERENCES

- BELKE, T. W., & SPETCH, M. L. (1994). Choice between reliable and unreliable reinforcement alternatives revisited: Preference for unreliable reinforcement. *Journal of the Experimental Analysis of Behavior*, **62**, 353-366.
- CLEMENT, T. S., & ZENTALL, T. R. (2002). Second-order contrast based on the expectation of effort and reinforcement. *Journal of Experimental Psychology: Animal Behavior Processes*, **28**, 64-74.
- DINSMOOR, J. A. (1983). Observing and conditioned reinforcement. *Behavioral & Brain Sciences*, **6**, 693-728.
- DUNN, R., & SPETCH, M. L. (1990). Choice with uncertain outcomes: Conditioned reinforcement effects. *Journal of the Experimental Analysis of Behavior*, **53**, 201-218.
- FANTINO, E. (1977). Conditioned reinforcement: Choice and information. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 313-339). Englewood Cliffs, NJ: Prentice Hall.
- FANTINO, E., DUNN, R., & MECK, W. (1979). Percentage reinforcement and choice. *Journal of the Experimental Analysis of Behavior*, **32**, 335-340.
- KENDALL, S. B. (1974). Preference for intermittent reinforcement. *Journal of the Experimental Analysis of Behavior*, **21**, 463-473.
- MAZUR, J. E. (1984). Tests of an equivalence rule for fixed and variable reinforcer delays. *Journal of Experimental Psychology: Animal Behavior Processes*, **10**, 426-436.
- MAZUR, J. E. (1995). Conditioned reinforcement and choice with delayed and uncertain primary reinforcers. *Journal of the Experimental Analysis of Behavior*, **63**, 139-150.
- MAZUR, J. E. (1996). Choice with certain and uncertain reinforcers in an adjusting delay procedure. *Journal of the Experimental Analysis of Behavior*, **66**, 63-73.
- MCDIVITT, M. A., SPETCH, M. L., & DUNN, R. (1997). Contiguity and conditioned reinforcement in probabilistic choice. *Journal of the Experimental Analysis of Behavior*, **68**, 317-327.
- MELTGREN, R. L., & DYCK, D. G. (1974). Reward magnitude in differential conditioning: Effects of sequential variables in acquisition and extinction. *Journal of Comparative & Physiological Psychology*, **86**, 1141-1148.
- ROPER, K. L., & ZENTALL, T. R. (1999). Observing response choices in pigeons: The effect of reinforcement density and response cost. *Learning & Motivation*, **30**, 201-220.
- SCHWARTZ, B. (1975). Discriminative stimulus location as a determinant of positive and negative behavioral contrast in the pigeon. *Journal of the Experimental Analysis of Behavior*, **23**, 167-176.
- SINGER, R. A., BERRY, L. M., & ZENTALL, T. R. (2007). Preference for a stimulus that follows a relatively aversive event: Contrast or delay reduction? *Journal of the Experimental Analysis of Behavior*, **87**, 275-285.
- SPETCH, M. L., BELKE, T. W., BARNET, R. C., DUNN, R., & PIERCE, W. D. (1990). Suboptimal choice in a percentage-reinforcement procedure: Effects of signal condition and terminal link length. *Journal of the Experimental Analysis of Behavior*, **53**, 219-234.
- SPETCH, M. L., MONDLOCH, M. V., BELKE, T. W., & DUNN, R. (1994). Determinants of pigeons' choice between certain and probabilistic outcomes. *Animal Learning & Behavior*, **22**, 239-251.
- WILLIAMS, B. A. (1992). Inverse relations between preference and contrast. *Journal of the Experimental Analysis of Behavior*, **58**, 303-312.
- WYCKOFF, L. B., JR. (1952). The role of observing responses in discrimination learning: Part I. *Psychological Review*, **59**, 431-442.

(Manuscript received December 10, 2008;
revision accepted for publication March 2, 2009.)