Published in final edited form as:

Learn Motiv. 2011 August 1; 42(3): 245–254. doi:10.1016/j.lmot.2011.03.002.

Sub-Optimal Choice by Pigeons: Failure to Support The Allais Paradox

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Abstract

Pigeons show a preference for an alternative that provides them with discriminative stimuli (sometimes a stimulus that predicts reinforcement and at other times a stimulus that predicts the absence of reinforcement) over an alternative that provides them with non discriminative stimuli, even if the non discriminative stimulus alternative is associated with 2.5 times as much reinforcement (Stagner & Zentall, 1910). In Experiment 1 we found that the delay to reinforcement associated with the non discriminative stimuli could be reduced by almost one half before the pigeons were indifferent between the two alternatives. In Experiment 2 we tested the hypothesis that the preference for the discriminative stimulus alternative resulted from the fact that, like humans, the pigeons were attracted by the stimulus that consistently predicted reinforcement (the Allais paradox). When the probability of reinforcement associated with the discriminative stimulus that predicted reinforcement was reduced from 100% to 80% the pigeons still showed a strong preference for the discriminative stimulus alternative. Thus, under these conditions, the Allais paradox cannot account for the sub-optimal choice behavior shown by pigeons. Instead we propose that sub-optimal choice results from positive contrast between the low expectation of reinforcement associated with the discriminative stimulus alternative and the much higher obtained reinforcement when the stimulus associated with reinforcement appears. We propose that similar processes can account for sub-optimal gambling behavior by humans.

Keywords

Sub-optimal choice; the Allais paradox; certainty effect; contrast; delay reduction; conditioned reinforcement; pigeons

There is considerable evidence that animals prefer alternatives that result in signals for the availability or unavailability of food over those that are less informative (e.g., Dinsmoor, 1983; Roper & Zentall, 1999). Roper and Zentall (1999) gave pigeons a choice between two alternatives. A response to one alternative resulted in presentation of discriminative stimuli: either a red light for 10 sec followed by food 50% of the time, or a green light for 10 sec followed by the absence of food the remaining 50% of the time. A response to the other alternative resulted in the presentation of non discriminative stimuli: either a blue light or a yellow light for 10 sec, each of which was followed by food 50% of the time. Thus, although choice of either alternative was associated with food 50% of the time, the pigeons

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showed a strong preference for the alternative that provided discriminative stimuli. It could be argued that because both choices were associated with the same probability of reinforcement, there was no cost to the pigeons' preference, however, when "cost" was introduced, Roper and Zentall found that the response requirement to produce the discriminative stimuli relative to the non discriminative stimuli could be increased to as much as 16:1 before there was a significant reduction in preference for the alternative associated with the discriminative stimuli.

Furthermore, there is evidence that pigeons will prefer an alternative that is followed by the discriminative stimuli even when the "cost" involves the loss of food (Belke & Spetch, 1994; Fantino, Dunn, & Meck, 1979; Gipson, Alessandri, Miller, & Zentall, 2009; Mazur, 1996; Spetch, Belke, Barnet, Dunn, & Pierce, 1990; Spetch, Mondloch, Belke, & Dunn, 1994; Stagner & Zentall, 2010). For example, Gipson et al. found a consistent preference for an alternative that produced a stimulus always followed by reinforcement on 50% of the trials and a different stimulus never followed by reinforcement on the remaining trials over an alternative that produced non discriminative stimuli (one of two stimuli each of which was followed by reinforcement 75% of time). In addition, Stagner and Zentall found an even stronger preference for an alternative that produced a stimulus always followed by reinforcement only 20% of the time and a different stimulus never followed by reinforcement 80% of the time over an alternative that produce one of two stimuli both of which were followed by reinforcement 50% of time. Thus, the alternative that produced the discriminative stimuli was preferred, even when the alternative that produced the non discriminative stimuli was associated with 2.5 times the amount of food as the alternative associated with the discriminative stimuli. Furthermore, Stagner and Zentall showed that the pigeons' preference for 20% reinforcement depended on the presence of discriminative stimuli, one associated with 100% reinforcement and the other associated with 0% reinforcement. In the last phase of their procedure, when both of those stimuli were associated with 20% reinforcement (such that the probability of reinforcement associated with choice of that alternative remained at 20%) Stagner and Zentall found that the pigeons now preferred the alternative associated with 50% reinforcement.

More recently, Zentall and Stagner (in press) tested the hypothesis that the alternative associated with the discriminative stimuli was preferred, not because of the attraction of the stimulus associated with 100% reinforcement, but because of the aversion to the ambiguity of the outcome associated with the alternative followed by the non discriminative stimuli. That is, reinforcement associated with the non discriminative stimuli was uncertain, whereas reinforcement (or nonreinforcement) following choice of the other alternative was certain, even when it signaled nonreinforcement. To avoid the uncertainty of the alternative that provided the greater amount of food, Zentall and Stagner manipulated the magnitude of reinforcement associated with each alternative, rather than the probability of reinforcement. In their experiment, for the discriminative stimulus alternative, on 20% of the trials, a stimulus appeared that was followed by 10 pellets of food, whereas on 80% of the trials, a different stimulus appeared that was never followed by food. For the non discriminative stimulus alternative, one of two stimuli appeared, both of which were followed by 3 pellets of food. Thus, one alternative was associated with an average of 2 pellets, whereas the other alternative was associated with a certain 3 pellets. In spite of this difference, most pigeons showed a strong preference for the discriminative stimulus alternative.

The choice procedures used in the reviewed experiments provides a measure of the preference that the pigeons have for the outcomes provided by the two alternatives. Often, however, it is difficult to compare preferences for the discriminative stimuli between procedures because those preferences are often almost near 100% (see e.g., Roper & Zentall, 1999, Experiment 1). Roper and Zentall (Experiment 2) attempted to obtain a more sensitive

measure of preference for discriminative stimuli by increasing the response requirement to obtain the discriminative stimuli while keeping the response requirement to obtain the non discriminative stimuli at a single peck.

Alternatively, when researchers study delay discounting functions they typically start with alternatives that differ in magnitude and delay of reinforcement, one alternative being strongly preferred, and ask how much more immediate the less preferred alternative must be for the subjects to be indifferent between the two alternatives. This procedure provides a sensitive measure of the subjective value of the two alternatives that avoids ceiling effects. The purpose of the present experiments was first to assess the strength of the pigeons' preference for discriminative stimuli using a delay to reinforcement procedure in which the delay to reinforcement associated with the non discriminative stimulus alternative was progressively reduced until that alternative was preferred over the discriminative stimulus alternative. Such a procedure has been used effectively to assess discounting functions under a variety of conditions (e.g., Rachlin, Raineri, & Cross, 1991; see also Mazur, 1996).

In Experiment 2, we proposed to test an account of the pigeons' preference for a lower probability of food based on the Allais paradox (Allais, 1953) or the certainty effect (Shafir, Reich, Tsur, Erev & Lotem, 2008). An example of the Allais paradox can be described as follows: If humans are given a choice between a 100% chance of earning \$5 or an 80% chance of earning \$10, although the net return on the 80% chance of earning \$10 is higher (\$8), most people choose the certain \$5. But here is where the paradox occurs. If one reduces both of the probabilities by one half (i.e., a choice between a 50% chance of earning \$5 and a 40% chance of earning \$10), the opposite preference will typically be found. According to expected utility theory, the results of the second choice should be the same as the first choice but it is not.

The explanation typically given for this paradoxical behavior is that there is something special about certainty. Said differently, should one opt for the 80% chance of earning \$10 and lose, it would be very disappointing because one could have had a certain \$5. On the other hand, in the case of the 40% chance of earning \$10, if one should lose, one could have also lost if one had chosen the 50% chance of earning \$5.

Could a similar preference for a stimulus associated with a certain outcome account for the pigeons' choice of the lower probability option in the Stagner and Zentall (2010) study? In this case, the certain reinforcement associated with one of the stimuli following the low probability of reinforcement alternative may have been particularly attractive. In Experiment 2 we tested this hypothesis.

Experiment 1

Method

Subjects—The subjects were 8 White Carneaux pigeons that were retired breeders. Throughout the experiment, the pigeons were maintained at 85% of their free-feeding weight. They were individually housed in wire cages with free access to water and grit in a colony room that was maintained on a 12:12-h light: dark cycle. The pigeons were cared for in accordance with University of Kentucky animal care guidelines.

Apparatus—The experiment was conducted in a BRS/LVE (Laurel, MD) sound-attenuating standard operant test chamber with inside measurements 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 3 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). The left and right projectors projected red, yellow, blue, and green hues (Kodak Wratten Filter Nos. 26, 9, 38, and 60, respectively) and a white annulus and a white plus, both on a black background. The center projector projected a white vertical line on a black background. 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 s 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: Each pigeon was trained to peck each of five colors (red, yellow, green, blue, and white) and the white circle and plus shape for reinforcement on the left and right response keys and to peck the vertical line on the center key. All pigeons then were gradually trained to peck each of four colors (red, green, blue, and yellow) on the side keys on a fixed-interval 10-s schedule (the first response after 10 s was reinforced).

Training: All trials began with the vertical-line stimulus presented on the center key. On forced trials, a single peck to the vertical stimulus illuminated either a plus or a circle on either the left or right key. The other side key remained dark. One peck to the illuminated key initiated a 10-s colored stimulus of fixed duration. If it was the discriminative-stimulus alternative, on 20% of the trials a peck resulted in the presentation of one of the colored stimuli (S_{100}), and after 10 s, reinforcement was provided. On the remaining 80% of the trials with that alternative, a different colored stimulus (S_0) was presented, and after 10 s, the trial ended without reinforcement. Thus, for that alternative, reinforcement occurred 20% of the time. If it was the non discriminative-stimulus alternative that was illuminated following the peck to the vertical line, on 20% of the trials a peck resulted in the presentation of a third colored stimulus (S_{50-20}) and on the remaining 80% of the trials with that alternative, the presentation of a fourth colored stimulus (S_{50-80}). After 10 s with either stimulus, reinforcement was provided 50% of the time. Thus, for the second alternative, reinforcement always occurred 50% of the time. A 10-s intertrial interval separated the trials.

The side keys on which the two alternatives appeared were counterbalanced over subjects, as were the colors associated with the four stimuli S_{100} , S_0 , S_{50-20} , and S_{50-80} . There were 40 randomly alternating forced trials in each session (20 to the left and 20 to the right), with 4 Stimulus S_{100} trials, 16 Stimulus S_0 trials, 4 Stimulus S_{50-20} trials, and 16 Stimulus S_{50-80} trials. A schematic of the design of the experiment is presented in Figure 1.

For all pigeons, randomly mixed among the 40 forced trials were 20 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 keys, and a single peck to either side key turned on one of the two colors associated with that alternative (for 10 sec) in the same proportion and with the same outcome as on forced trials. The unchosen key was darkened. All of the pigeons received 25 sessions of training.

Testing with reduced delays: To assess the strength of the preference for the discriminative stimuli, the terminal link duration for the non discriminative stimuli was gradually reduced from 10 s to 0 s in 2-s steps, with 10 sessions of training at each step. The terminal link duration was then increased in 2-s steps back to 10 s, again with 10 sessions of training at each step. The terminal link duration for the discriminative stimuli remained at 10 s throughout this procedure. Of interest was the duration of the non discriminative stimuli for which the pigeons were indifferent between the discriminative and non discriminative stimuli.

Results

Acquisition—The pigeons showed a small initial preference for the high probability of reinforcement alternative associated with the non discriminative stimuli but quickly shifted their preference to the low probability of reinforcement alternative associated with the discriminative stimuli. The acquisition data are presented in Figure 2. Although the preference for the low probability of reinforcement alternative fell to 38.8% on Session 4, because of large individual differences, the effect was not significantly different from chance, $t(7) = 1.06$, $p > .05$. However, on Sessions 3 and 4 combined, 3 of the 8 pigeons each showed a significant preference for the high probability of reinforcement alternative (65% or higher), $p < .05$, and 7 of the 8 pigeons showed some preference for the high probability of reinforcement alternative. By Session 12, the pigeons showed an 81.9% preference for the low probability of reinforcement alternative. When the data were pooled over the last 10 sessions of training (Sessions 15–25), the pigeons showed an 81.2% preference for the low probability of reinforcement alternative, $t(7) = 4.04$, $p = .005$.

Reduction in the Duration of the Non discriminative Stimuli—Progressively reducing the duration of the non discriminative stimuli shifted the preference from the low probability of reinforcement discriminative stimulus alternative to the high probability of reinforcement non discriminative alternative. Mean percentage preference for the low probability of reinforcement alternative on the last 5 sessions of each delay as a function of the duration of the non discriminative stimuli, plotted separately as the duration decreased and the duration increased, appears in Figure 3. To balance the carry-over effects produced by the preceding stimulus duration, the combined data from the last five sessions of the two common non discriminative stimulus durations are also presented in Figure 3 (dashed line). The indifference point was determined by taking the two durations closest to and on either side of 50% and calculating the proportion of the difference between them represented by the difference between the lower percentage and 50%. That proportion was then added to the shorter duration (see Wearden & Ferrara, 1995). The calculated indifference point for the decreasing duration of the non discriminative stimuli was 2.44 s, and it was 5.91 s for the increasing duration of the non discriminative stimuli (see Figure 3). As can be seen in the figure, there appeared to be some lag or hysteresis in the pigeons' response to the changing duration of the non discriminative stimuli. To adjust for this difference, the decreasing and increasing durations were combined and presented as the dashed line in Figure 3. The calculated indifference point for the combination of decreasing and increasing duration of the non discriminative stimuli was 4.37 s. Thus, for the pigeons to become indifferent between the discriminative stimulus alternative and the non discriminative stimulus alternative, the duration of the high probability of reinforcement alternative (i.e., the delay to reinforcement) had to be reduced by more than one half.

Discussion

The acquisition results of Experiment 1 replicate the results of earlier research (Stagner & Zentall, 2010) which showed that pigeons prefer an alternative that provides discriminative stimuli even if that alternative provides reinforcement on only 20% of the trials, whereas choice of the alternative that provides non discriminative stimuli provides 50% reinforcement. In the earlier research, the pigeons were trained originally with a simultaneous spatial discrimination in the initial link and after reversal training were transferred to a simultaneous visual shape discrimination. In the present experiment we started with a simultaneous visual shape discrimination and found similar results.

The tendency for the pigeons to have an initial preference for the alternative that provided a higher probability of reinforcement suggests that prior to learning about the contingencies associated with the discriminative stimuli, the pigeons were somewhat sensitive to the

overall probability of reinforcement associated with the two alternatives. Although Stagner and Zentall did not find such an effect, a similar effect was found by Zentall & Stagner (in press) in which magnitude of reinforcement rather than probability of reinforcement was manipulated.

When the delay of reinforcement associated with choice of a non discriminative stimulus alternative was reduced, choice of the discriminative stimulus alternative continued until the delay to reinforcement was less than half. Paradoxically, not only were the non discriminative stimuli worth more than 2.5 times the probability of reinforcement associated with discriminative stimuli but the delay to reinforcement associated with the non discriminative stimuli could be reduced by more than one half before the pigeons were indifferent between them. The delay manipulation provides an additional measure of the preference for the discriminative stimuli.

Experiment 2

In Experiment 2, we explored the possibility that the preference for discriminative stimuli found in Experiment 1 and in earlier research (Gipson et al. 2009; Stagner & Zentall, 2010; Zentall & Stagner, in press) could have resulted from the certainty of reinforcement associated with the positive discriminative stimulus. In Experiment 2 we reduced the probability of reinforcement associated with the positive discriminative stimulus from 100% to 80% such that the probability of reinforcement associated with choice of that alternative was reduced from 20% to 16%. We also reduced the probability of reinforcement associated with the non discriminative stimuli from 50% to 40% such that the ratio of the probability of reinforcement associated with choice of the discriminative stimuli and the probability of reinforcement associated with choice of the non discriminative stimuli remained 1:2.5. Similarly, the ratio of the probability of reinforcement associated with the S+ and the non discriminative stimuli remained 2:1 (80% to 40%).

Method

Subjects—The subjects were 8 White Carneaux pigeons similar to those in Experiment 1. The pigeons were maintained as were the pigeons in Experiment 1. One pigeon became ill and was dropped from the study.

Apparatus—The experiment was conducted in the same sound-attenuating standard operant test chamber as was used in Experiment 1.

Procedure—Both the pretraining and training procedures that were used in Experiment 1 were also used in Experiment 2 with the following exceptions. If on a forced trial it was the discriminative-stimulus alternative that was presented, on 20% of the trials a peck resulted in the presentation of one of the colored stimuli (S_{100}), and after 10 s, the probability of reinforcement was 80% (rather than 100% as it was in Experiment 1). On the remaining 80% of the trials with that alternative, a different colored stimulus (S_0) was presented, and after 10 s, the trial ended without reinforcement. Thus, for that alternative, reinforcement occurred 16% of the time. If it was the non discriminative-stimulus alternative that was presented, on 20% of the trials a peck resulted in the presentation of a third stimulus (S_{50-20}) and on the remaining 80% of the trials with that alternative, the fourth colored stimulus (S_{50-80}) was presented. After 10 s with either stimulus, reinforcement was provided on 40% of the trials. Thus, for the first alternative the probability of reinforcement was 16% and for the second alternative the probability of reinforcement was 40% (2.5 times as great, as in Experiment 1).

Reduction in the Duration of the Non discriminative Stimuli—Following 16 sessions of training, the duration of the non discriminative stimuli was progressively reduced as it was for the pigeons in Experiment 1. Once again, the terminal link duration for the non discriminative stimuli was gradually reduced from 10 s to 0 s in 2-s steps, with 10 sessions of training at each step. The terminal link duration then was increased in 2-s steps back to 10 s, with 10 sessions of training at each step.

Results

Acquisition—The acquisition results in Experiment 2 were similar to those in Experiment 1. Once again, the pigeons showed an initial preference for the high probability of reinforcement alternative associated with the non discriminative stimuli but then shifted their preference to the low probability of reinforcement alternative associated with the discriminative stimuli. The acquisition data are presented in Figure 4. In Experiment 2 the preference for the high probability of reinforcement alternative was significant on each of the first 4 sessions of training (range 60.6% – 76.3), all $t_s(6) > 3.24$, all $p_s < .03$. When the training data were pooled over the last 5 sessions of training, the preference for the low probability of reinforcement alternative was 91.24% and was reliably greater than chance, $t(6) = 6.44$, $p < .001$.

Reduction in the Duration of the Non discriminative Stimuli—Progressively reducing the duration of the non discriminative stimuli shifted the preference from the low probability of reinforcement discriminative stimulus alternative to the high probability of reinforcement non discriminative alternative. Mean percentage preference for the low probability of reinforcement alternative on the last 5 sessions of each delay as a function of the duration of the non discriminative stimuli appears in Figure 5, plotted separately as the duration decreased and the duration increased. Again, to balance the carry-over effects produced by the preceding stimulus duration, the combined data from the last five sessions of the two common non discriminative stimulus durations are also presented in Figure 5 (dashed line). Once again, the indifference point was determined by taking the two durations closest to and on either side of 50% and calculating the proportion of that difference to the difference between the lower duration and 50%. That proportion was then added to the shorter duration to get the indifference point. The calculated indifference point for the decreasing duration of the non discriminative stimuli was 3.54 s and it was 6.29 s for the increasing duration of the non discriminative stimuli. The calculated indifference point for the combination of decreasing and increasing duration of the non discriminative stimuli was 5.17 s. Thus, for the pigeons to become indifferent between the discriminative stimulus alternative and the non discriminative stimulus alternative, the duration of the high probability of reinforcement alternative and thus, the delay to reinforcement, had to be reduced by almost a half.

The similar combination calculated indifference point in the first experiment when the positive discriminative stimulus predicted certain reinforcement was 4.37s or about 0.7 s less. Thus, the less certain (80%) outcome associated with the positive discriminative stimulus in Experiment 2 did not require quite as much shortening of the delay to reinforcement to reach the indifference point as the certain (100%) outcome associated with the positive discriminative stimulus in Experiment 1.

Discussion

The results of Experiment 2 indicate that it is not necessary for an infrequent signal for high probability reinforcement to be associated with reinforcement 100% of the time. That is, to obtain a strong preference for the discriminative stimulus alternative it is not necessary for the S+ stimulus to signal certain reinforcement. Thus, under the present conditions, the

Allais paradox does not appear to hold for pigeons. When the probability of reinforcement associated with the S+ stimulus was only 80%, although the preference for the low probability of reinforcement alternative may have taken a bit longer to develop, it soon reached a level at least equal to the preference found in Experiment 1 when the probability of reinforcement associated with the S+ stimulus was 100%. The preference for the low probability of reinforcement alternative was further demonstrated by the finding that the delay to reinforcement associated with the high probability of reinforcement alternative had to be almost halved before the pigeons were indifferent to the choice between the low probability of reinforcement alternative that lead to a discriminative stimulus and the high probability of reinforcement alternative that lead to a non discriminative stimulus.

General Discussion

The results of the present experiments confirm and extend the findings of earlier research which shows that pigeons prefer to obtain discriminative stimuli even if that choice leads to a substantial loss of reinforcement. In the present research, pigeons preferred that alternative over one that would have provided them with 2.5 times as much food.

Two different mechanisms have been suggested to account for this effect. The first suggested by Dinsmoor(1983) is that the S+ stimulus has become a strong conditioned reinforcer because of the high probability of reinforcement associated with it. The fact that the S+ is a better predictor of food than any of the three other stimuli makes it a very attractive stimulus. But the question is why the S- stimulus which is associated with the absence of food does not become a particularly good conditioned inhibitor. Not only is it the best predictor of the absence of food, but it also occurs on 80% of the trials on which the low probability of reinforcement alternative is chosen. Furthermore, the stimuli that appear following choice of the high probability of reinforcement alternative should become relatively good conditioned reinforcers, given that both of them are associated with 50% reinforcement and 50% reinforcement is known to result in good conditioned reinforcers (Amsel, 1958; Zentall & Sherburne, 1994).

An alternative view has been proposed by Gipson et al. (2009) who suggested that the present effect could have resulted from the contrast between the expected probability of reinforcement associated with the initial link choice response and the probability of reinforcement associated with the stimulus that follows. Thus, the probability of reinforcement associated with choice of the low probability of reinforcement alternative in Experiment 1 was .20 and given the appearance of the S+ stimulus, the probability of reinforcement increased to 1.0. This change in the probability of reinforcement represents a large increase in the probability of reinforcement and such an increase in the probability of reinforcement should produce strong positive contrast (Zentall & Singer, 2007). Although there should also be negative contrast resulting from that appearance of the S- stimulus associated with the absence of reinforcement, as the difference between 20% reinforcement and 0% reinforcement is relatively small, the negative contrast also should be quite small, even if it occurs four times as often. Furthermore, for the high probability of reinforcement alternative, the expected probability of reinforcement was .50 but it remained .50 upon the appearance of either stimulus that followed, thus no positive or negative contrast would have been expected. The idea that behavior may be affected by the difference between what is expected and what occurs is an integral aspect of prospect theory, proposed by Kahneman and Tversky (1979) to account for related inconsistencies in human behavior.

It could be argued that the preference for the low probability reinforcement alternative is controlled not by the additional value given to the S+ stimulus that sometimes follows that choice, but by the low value attributed to the high probability of reinforcement alternative

because the stimuli that follow that choice provide ambiguous signals for reinforcement (they are associated with 50% reinforcement). To test this hypothesis we recently used a procedure similar to the one used in the present research but we substituted magnitude of reinforcement for probability of reinforcement (Zentall & Stagner, in press). With this procedure, choice of the low reinforcement alternative resulted in presentation of the S+ stimulus on 20% of the trials and after 10 s was followed by 10 pellets of food, or presentation of the S- stimulus on the remaining trials and after 10 s was never followed by food. Choice of the high reinforcement alternative resulted in presentation of one of two stimuli, either of which was always followed by 3 pellets of food. Thus, choice of the low reinforcement alternative resulted in 2 pellets of food, on average, whereas choice of the high reinforcement alternative always resulted in 3 pellets of food. Note that with this procedure, all of the stimuli were unambiguous with regard to reinforcement. That is, the stimuli always predicted a consistent outcome: 10 pellets, 3 pellets, or no pellets. Just as in the earlier experiments, these pigeons also showed a strong preference for the low reinforcement alternative. Thus, this sub-optimal choice does not depend on the ambiguity of the stimuli associated with the high probability of reinforcement alternative.

But perhaps the preference for the low reinforcement alternative is driven not by the additional value given to the high magnitude of reinforcement outcome but by the pigeons' preference for signaled but variable outcomes. That is, it may be that reinforcer variability is preferred over reinforcer consistency (see Kacelnik & Bateson, 1996). To test this hypothesis, Zentall and Stagner (in press) removed the discriminative function for the low reinforcement alternative. That is, the outcome following both stimuli was now 10 pellets but in either case the 10 pellets occurred on only 20% of the trials. Thus, the probability of reinforcement following choice of the low reinforcement alternative remained as it was but the probability of reinforcement was no longer differentially associated with the two stimuli that followed the choice response. Under these conditions the pigeons reversed their preference and showed a strong preference for the high reinforcement alternative. This result indicates that the pigeons' preference did not result from an attraction to the variability of reinforcement but to the signaling function of the S+ (and perhaps also the S-) stimulus.

Although we have interpreted the sub-optimal choice by pigeons with the present procedure in terms of contrast between the initial link and the terminal link stimuli, it is also possible to interpret the present results in terms of the reduction in the delay to reinforcement signaled by the positive discriminative stimulus (Fantino & Abarca, 1985). In the present design, great care was taken to equate the delay to reinforcement for choice of the initial link at 10 s, however, if one considers the task as a continuous procedure rather than as a series of discrete trials, one can consider the absence of reinforcement as the delay of reinforcement until the next trial, or later. When reinforcement occurred on a given trial, it always came 10 s after choice of the initial link. When reinforcement did not occur on a given trial, it may have occurred on the next trial or the following trial with a given probability but with random ordering of trials one can consider the delay of reinforcement variable but with a similar distribution on all trials, thus $(10 + t)$ s. The effect of various terminal link stimuli is shown in Figure 6. As can be seen in Figure 6, if there were no discriminative stimuli, the value of 20% reinforcement would be a mixture of 20% 10 s trials and 80% $(10 + t)$ trials, and the value of 50% reinforcement would be a mixture of 50% 10 s trials and 50% $(10 + t)$ trials. However, with discriminative stimuli, the value of 20% reinforcement would be a signaled 100% reinforcement 20% of the time and a signaled 0% reinforcement 80% of the time. See the values of S_{100} , S_{50} , and S_0 in Figure 6. Given the hyperbolic shape of the delay discounting function, the value of S_{100} would be much greater than the value of S_{50} , whereas the value of S_{50} would be only somewhat greater than the value of S_0 . And even with the greater number of S_0 trials, it is possible for the weighted average of S_{100} and S_0 trials to have a greater value than the S_{50} trials (see estimate of the weighted mean, M_{wtd} in Figure 6).

Although this account based on delay discounting can account for the sub-optimal choice by pigeons with this procedure, it assumes that the pigeons have a very steep discounting function and that the discounting function carries over from one trial to succeeding trials.

A behavioral ecologist might argue that pigeons show maladaptive choice behavior in these experiments only because the laboratory conditions under which they are trained are artificial. They might argue that such conditions would not occur in nature and thus, animals would not be expected to have evolved the ability to detect the differential probabilities of reinforcement under such conditions. In fact, it may be that natural conditions would tend to favor such behavior. For example, one could imagine that in nature, choice of a low probability but high payoff alternative might increase the probability of encountering the high payoff outcome (e.g., by bringing the animal closer to a patch that contains a greater density of the high payoff). Thus, although in the laboratory, choice of the alternative that provides discriminative stimuli does not yield the best outcome, one could argue that in nature, it more than likely would. That is, animals may have evolved an attraction to stimuli that signal high value outcomes because in nature that attraction is likely to make those outcomes more probable.

Finally, the sub-optimal choice shown by pigeons with this procedure is functionally similar to organized gambling behavior shown by humans. Generally, humans forgo money that they have for the low probability of obtaining more. Many humans gamble, even though most examples of organized gambling (e.g., lotteries, slot machines, roulette tables) are games of chance in which the gambler's skill is not involved. For this reason, the mechanisms responsible for human gambling behavior are likely to be similar to those that govern the present sub-optimal choice behavior in pigeons. For example, in both species, anything that draws attention to the S+ stimulus should increase choice of the low probability of reinforcement (gambling) alternative. In this regard, it is interesting that lottery winners are often mentioned on the news and slot machine wins are often signaled by flashing lights and sirens. On the other hand, losses go unannounced. In fact, gamblers typically have very good memory for their wins but they tend to underestimate their losses (Blanco, Ibáñez, Sáiz-Ruiz, Blanco-Jerez, & Nunes, 2000). If poor memory for losses plays a role in gambling behavior and our sub-optimal choice task is a good model of gambling behavior, it suggests that with the present procedure there should be less conditioned inhibition that accrues to the S- stimulus or more conditioned reinforcement that accrues to the S+, than in a typical successive discrimination involving S+ and S- stimuli.

In any case, it is important to understand the mechanisms responsible for the counterintuitive finding that pigeons prefer an alternative that provides less food over one that provides more food. From a theoretical perspective it would allow us to determine how this phenomenon fits into theories of learning. From an adaptionist perspective it would allow us to determine how this phenomenon fits into evolutionary theory. And from an applied perspective it would allow us to understand how better to treat human gambling addictions.

Acknowledgments

This research was supported by the National Institute of Child Health and Human Development Grant HD060 996.

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Highlight

- Pigeons show a preference for an alternative that provides them with discriminative stimuli.
- Even if non discriminative stimulus alternative has 2.5 times as much reinforcement.
- We asked if pigeons prefer stimuli that consistently predict reinforcement (the Allais paradox).
- We reduced reinforcement from 100% to 80%.
- The pigeons still showed a strong preference for the discriminative stimulus alternative.

Figure 1.
Design of Experiment 1. The contingencies and colors associated with each shape were counterbalanced over subjects.

Figure 2.

Experiment 1: Acquisition of the preference for the alternative associated with the lower probability of reinforcement and discriminative stimuli.

Figure 3.

Experiment 1: Choice of the alternative associated with the lower probability of reinforcement and discriminative stimuli as the duration of the terminal link for the non discriminative stimuli was reduced from 10 s to 0 s and back to 10 s pooled over the last 5 sessions at each duration. The duration of the discriminative stimuli remained at 10 s throughout. The dashed line represents the average of the two measures of preference at each duration of the terminal link for the non discriminative stimuli. The vertical lines represent the duration at which there was indifference between the discriminative stimulus and non discriminative stimulus alternatives.

Figure 4.
Experiment 2: Acquisition of the preference for the alternative associated with the lower probability of reinforcement and discriminative stimuli.

Figure 5.

Experiment 2: Choice of the alternative associated with the lower probability of reinforcement and discriminative stimuli as the duration of the terminal link for the non discriminative stimuli was reduced from 10 s to 0 s and back to 10 s pooled over the last 5 sessions at each duration. The duration of the discriminative stimuli remained at 10 s throughout. The dashed line represents the average of the two measures of preference at each duration of the terminal link for the non discriminative stimuli. The vertical lines represent the duration at which there was indifference between the discriminative stimulus and non discriminative stimulus alternatives.

Figure 6.

Hypothetical delay discounting function indicating the value of various stimuli according to their predictive value in terms of delay of reinforcement. The subscript represents the probability that the stimulus (S) will be followed by reinforcement. V represents the value of the stimulus. M_{wtd} represents the mean weighted value of the S_{100} and S_0 stimuli. In diff. Point is the calculated terminal link duration for the non discriminative stimuli at which the pigeons are indifferent between that alternative and the 10 s terminal link duration associated with the discriminative stimulus alternative.