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THE SUNK COST EFFECT IN PIGEONS AND HUMANS

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The sunk cost effect is the increased tendency to persist in an endeavor once an investment of money, effort, or time has been made. To date, humans are the only animal in which this effect has been observed unambiguously. We developed a behavior-analytic model of the sunk cost effect to explore the potential for this behavior in pigeons as well as in humans. Each trial started out with a short expected ratio, but on some trials assumed a longer expected ratio part way through the trial. Subjects had the (usually preferable) option of ''escaping'' the trial if the longer expected ratio had come into effect in order to bring on a new trial that again had a short expected ratio. In Experiments 1 through 3, we manipulated two independent variables that we hypothesized would affect the pigeons' ability to discriminate the increase in the expected ratio within a trial: (a) the presence or absence of stimuli that signal an increase in the expected ratio, and (b) the severity of the increase in the expected ratio. We found that the pigeons were most likely to persist nonoptimally through the longer expected ratios when stimulus changes were absent and when the increase in the expected ratio was less severe. Experiment 4 employed a similar procedure with human subjects that manipulated only the severity of the increase in the expected ratio and found a result similar to that of the pigeon experiment. In Experiment 5, we tested the hypothesis that a particular history of reinforcement would induce pigeons to persist through the longer expected ratios; the results suggested instead that the history of reinforcement caused the pigeons to persist less compared to pigeons that did not have that history.

Key words: sunk cost, Concorde fallacy, escalation, choice, diminishing returns, discriminative stimuli, pigeons

The sunk cost effect is the tendency to persist in an endeavor once an investment of effort, time, or money has been made. The effect is considered maladaptive because only marginal costs and benefits, not past costs, should factor into rational decision-making. Alternatively called escalation of commitment or entrapment, this effect has been documented in numerous studies with humans (Arkes & Blumer, 1985; Moon, 2001; Staw & Hoang, 1995). Theories accommodating the effect include self-justification (Staw, 1976), prospect theory (Whyte, 1986), and a desire to avoid waste (Arkes & Blumer, 1985).

In nonhuman animals, the effect is called the Concorde fallacy. A review by Arkes and Ayton (1999) concluded that there are no clear-cut instances of the Concorde fallacy in nonhumans. They examined purported instances of the Concorde fallacy in the behavioral ecology literature and showed that in every case, behaviors thought to be influenced by past investment could be explained in terms of future gains. They suggested that animals might not fall prey to the sunk cost effect because they do not follow rules or norms unique to humans, such as ''don't waste.''

In spite of the lack of evidence for the Concorde fallacy, certain lines of research with humans suggest the possibility that nonhuman animals could display this effect. For example, reinforcement history has been shown to affect suboptimal persistence in an investment (Goltz, 1992, 1993, 1999). Both the partial reinforcement extinction effect (Goltz, 1992) and behavioral momentum (Goltz, 1999) have been implicated as mechanisms through which reinforcement history could result in persistence.

Second, it often appears that uncertainty is at the root of persistence. For example, human subjects will persist in an unprofitable research and development project in its early stages, but as losses mount subjects *de*-escalate commitment (McCain, 1986). Given that these subjects eventually behave correctly by de-escalating commitment, the incorrect persistence in the early stages of the project may

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indicate that the subjects do not yet know in those early stages that the project is unprofitable. McCain concluded that escalation and de-escalation are learning processes in which optimal behavior surfaces only when the economics of the situation become clear. Bragger and her associates (Bragger, Bragger, Hantula, & Kirnan, 1998; Bragger, Bragger, Hantula, Kirnan, & Kutcher, 2003) explored this hypothesis further in their studies on hysteresis. Their subjects had to choose whether to continue with or abandon hypothetical investments while receiving negative economic feedback concerning the investments. In one condition, subjects received unambiguous feedback—the investment consistently produced losses of a similar magnitude. In another condition, subjects received ambiguous feedback—the investment produced losses of varying magnitude, and occasionally produced a gain, though the average return was equal to that of the former condition. Subjects with ambiguous feedback persisted in the project significantly longer than subjects with unambiguous feedback, and subjects with the opportunity to purchase additional feedback quit the project significantly sooner than subjects without that opportunity. To explain these results, Bragger and her associates cited Bowen's (1987) equivocality theory of escalation. Similar to McCain's hypothesis, equivocality theory posits that decision-makers in escalation situations are trying to make sense out of uncertain information. While trying to decipher variable feedback on an investment, decision-makers may be better off continuing to invest until it is certain that the investment is suboptimal.

We propose that if uncertainty and reinforcement history can influence persistence in humans, these variables may plausibly bring about persistence in nonhuman animals. This reasoning forms the basis for our resent study.

BEHAVIOR-ANALYTIC ANALOG OF THE SUNK COST EFFECT

In the present study, we set out to explore conditions of uncertainty and reinforcement history under which pigeons might persist in a losing course of action. To this end, we began by designing an operant procedure that models the sunk cost decision scenario. We define a sunk cost decision scenario as one in which an investment has been made towards a goal, negative feedback concerning the investment has been received, and the investor can persist in the investment or abandon it in favor of a new one. In our procedure, pigeons begin a trial by pecking on a key for food. The schedule on the food key arranges a course of action with initially good prospects that turns unfavorable. On a given trial, one of four fixed-ratio (FR) schedules is in effect: short, medium, long, or extra long. On half the trials, the short ratio is in effect; on a quarter of the trials, the medium ratio is in effect; and on a quarter of the trials either of the two long ratios is in effect. With these parameters, after the pigeons have emitted the response number required by the short ratio, if no reinforcement has occurred (because one of the longer ratios happens to be in effect), then the initially easy endeavor has become more arduous—the expected number of responses to food is now greater than it had been at the onset of the trial.

We gave pigeons the option of escaping the now less favorable endeavor by allowing them to peck an ''escape'' key that initiates a new trial. If the short ratio does not happen to be in effect on a given trial, then once the value of the short ratio has been met the optimal choice is to peck the escape key (and then begin anew on the food key). That is, the expected ratio given escape is lower than the expected ratio given persistence. Note that at this choice point the pigeons encounter a sunk cost decision scenario. Namely, they have made an initial investment, they have received negative feedback—no reinforcement—and they can either persist in the venture or abandon it in favor of a better one.

This general procedure allows us to examine the role of uncertainty in the sunk cost effect in two ways. One way is through the presence or absence of stimulus changes. If a stimulus change occurs at the moment when escape becomes optimal, then the economics of the situation should be more salient than if no stimulus change occurs. We hypothesized that pigeons responding on this procedure with no stimulus change would persist more than pigeons responding on this procedure with a stimulus change present. A second way to manipulate uncertainty is by varying the difference between the expected value of persisting and the expected value of escaping. The closer these expected values are to each other, the less salient the advantage of escaping and the more likely the pigeons should be to persist.

This procedure also allows us to examine the role of reinforcement history in the sunk cost effect. Specifically, how would escape behavior change in pigeons that are first trained on this procedure without the escape key? These pigeons would have a history of reinforcement for persistence on the food key, which ultimately leads to food. We hypothesized that this history of reinforcement would lead to greater persistence when the escape key is later introduced, compared with pigeons that are placed directly in the escape procedure.

Finally, by modifying this procedure for use with human subjects, we can extend previous findings with human subjects to a novel format. In particular, we replicate with humans one of the pigeon experiments manipulating economic salience. Our hypothesis is that both pigeon and human subjects should persist more as the salience of economic information decreases.

EXPERIMENT 1

In our first test, we compared persistence on the food key when stimulus changes were present versus when stimulus changes were absent.

METHOD

Subjects

The subjects were 4 naive White Carneau pigeons maintained at about 80% of their free-feeding weights. They were individually housed and had free access to water and grit.

Apparatus

Four square operant chambers were used, measuring 37 cm long by 37 cm wide by 37 cm high. All chambers had three keys on one wall. The left key was 11 cm from the left edge of the wall, the right key was 11 cm from the right edge of the wall, and the center key was exactly in between. All keys were 25 cm above the chamber floor and measured 2.5 cm in diameter. Only the left and center keys were used. The left key could be illuminated with a white "X," and the center key could be illuminated with white, red, blue, or green light. A minimum force of approximately 0.15 N was required to operate each key. All chambers had a houselight on the wall 5 cm above the center key for general illumination, and a grain magazine with an opening 5 cm by 6 cm centered 14 cm below the center key. During magazine operation, the houselight and all keylights turned off and a magazine light turned on. The chambers were controlled from an adjacent room by an IBM®-compatible computer programmed in Turbo Pascal®.

Procedure

On every trial, one of four FR schedules was in effect on the center (food) key. Completion of an FR schedule resulted in 3 s of access to grain, followed by a 1-s blackout and a new trial. On one half of the trials, the schedule was FR 10; on one fourth of the trials, the schedule was FR 40; on one eighth of the trials, the schedule was FR 80; and on one eighth of the trials, the schedule was FR 160. These schedules were presented randomly.

Throughout every trial the left (escape) key also was active. One response to this key produced a 1-s blackout followed by a new trial.

We employed a within-subject design in which we manipulated the presence or absence of stimulus changes. The 4 pigeons first were placed in this procedure with stimulus changes present. The stimulus changes signaled a change in the expected value of the ratio on the food key. At the start of a trial, the food key was white and the expected value was 45 ($45 = .5*10 + .25*40 + .125*80 + .125*160$). After the 10th response, if no reinforcement occurred (because one of the longer ratios happened to be in effect), the food key turned red, and the expected value became 70 ($70 = .5*30 + .25*70 + .25*150$). After the 40th response, if no reinforcement occurred, the food key turned blue, and the expected value became 80 ($80 = .5*40 + .5*120$). After the 80th response, if no reinforcement occurred, the food key turned green, and the expected value remained at 80.

The pigeons first were trained to peck the white response key by hand shaping, and then trained on white, red, blue, and green stimuli separately with increasingly large FR

Table 1

Percentage of trials with persistence in Experiment 1.

Session of stable period	Pigeon 361	362	363	364
Stimulus changes present[a]				
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
Stimulus changes absent				
1	3	100	97	100
2	4	100	100	100
3	1	100	100	100
4	1	100	100	100
5	2	100	100	100

Note. Persistence in a trial is defined as completion of that trial (excluding FR 10 trials).

[a] The data for the first five to eight sessions of this condition were lost because of a computer malfunction. The data shown here are from the first five sessions for which data are available. For this reason it is unknown for each pigeon whether "Session 1" is the first session of the stable period or is instead subsequent to the first session of the stable period.

schedules until they responded regularly to an FR 60. The pigeons received no training on the escape key or the white "X" stimulus. After training was completed, the pigeons were placed in the procedure one session per day, about 6 days per week, for a total of 30 to 33 sessions. Sessions were terminated after the delivery of 80 reinforcers.

In the stimulus-changes-absent condition, the same 4 pigeons were placed in the above procedure but without the stimulus changes. In this condition, the FR schedules and their corresponding probabilities were identical to those of the former condition, but the center key remained white throughout each trial. The 4 pigeons were placed in this condition for 27 sessions.

RESULTS

Nonoptimal persistence was defined as completion of an FR 40, FR 80, or FR 160 trial. Completion of an FR 10 trial does not count as persistence because escape does not become optimal until after the 10th food-key response. We visually determined when the pigeons' behavior had become stable. Table 1 displays the data for the first five sessions of the stable period. (The data from the first five to eight sessions of the stimulus-changes-present condition were lost because of a computer malfunction. The data shown in Table 1 for this condition are from the first five sessions for which data are available. Behavior in this condition already was stable during the first five sessions for which data are available.) Each datum is the percentage of the trials with an opportunity for persistence (FR 40, FR 80, and FR 160 trials) that the pigeon completed. When stimulus changes were present, behavior was optimal. That is, the pigeons always escaped during the FR 40, FR 80, and FR 160 trials. When stimulus changes were absent, the opposite was typically true. Three of the 4 birds completed virtually all of the persistable trials, while only Pigeon 361 retained optimal behavior.

DISCUSSION

Experiment 1 represents the first test of our operant analog of the sunk cost effect. For many trials, pigeons underwent a course of action that initially was likely to require few responses, but half of the time ended up requiring many responses. When the expected ratio increased, the pigeons could either persist in the trial or abandon it in favor of a new trial with better prospects. When stimulus changes were present that signaled increases in the expected ratio, the pigeons uniformly abandoned the nonoptimal endeavor. When stimulus changes were absent, 3 of the 4 pigeons nearly always persisted in the endeavor. These results suggest that stimulus changes may heighten the salience of changes in the schedule of reinforcement. In addition, the results are consistent with our hypothesis that by reducing this salience, pigeons can be induced to persist in a nonoptimal course of action.

There are two important limitations to Experiment 1. One limitation is that Experiment 1 was an AB design, which leaves open the possibility that factors other than our intended manipulation induced the overall change in behavior seen across conditions. Fortunately, the likelihood of this possibility is reduced considering that each condition is repeated in subsequent experiments in this paper. The stimulus-changes-present condition is repeated with different sets of pigeons in Experiments 2 and 5, and the stimulus-changes-absent condition is repeated in Experiment 3. In each case, the result of the corresponding condition from the present experiment is replicated. This suggests that the important determinant of the pigeons' behavior was our intended manipulation, not some other factor.

Another limitation to the present experiment is the following: it has been widely demonstrated that pigeons behave ''impulsively'' toward short delays to food (Fantino, 1966; Rachlin, 2000). The fact that pecking the escape key leads to the possibility of a very short FR on the food key may have overridden all other factors. That is, even if persistence on the food key were the optimal behavior, the possibility of a short FR on a new trial still may have led the pigeons to escape. Thus the pigeons in the stimulus-changes-present condition may have tended to escape not because they were sensitive to the true reinforcement contingencies, but because they behave impulsively toward short delays to food.

We addressed this possibility in Experiment 2 by retaining the stimulus changes and the short FR and by comparing behavior when escape is optimal, as in Experiment 1, with behavior when persistence is optimal.

EXPERIMENT 2

METHOD

Subjects

The subjects were 4 White Carneau pigeons with previous experience with unrelated procedures. They were maintained at about 80% of their free-feeding weights, were individually housed, and had free access to water and grit.

Apparatus

Same as for Experiment 1.

Procedure

In a within-subject design, the pigeons faced two conditions: escape-optimal and persistence-optimal. The escape-optimal condition was identical to the stimulus-changes-present condition of Experiment 1.

In the persistence-optimal condition, the FR schedules and their corresponding probabilities were arranged such that persistence was the optimal behavior. On three twelfths of the trials, the schedule on the food key was FR 10; on seven twelfths of the trials, the schedule was FR 30; and on two twelfths of the trials, the schedule was FR 50. At the start of a trial, the food key was white and the expected ratio was 28.3; after the 10th response, if no reinforcement occurred (because one of the longer schedules happened to be in effect), the food key turned red and the expected ratio lowered to 24.4; after the 30th response, if no reinforcement occurred, the food key turned blue and the expected ratio lowered to 20. Thus as the pigeons progressed through a trial the expected ratio became shorter.

Of the 4 pigeons, 2 pigeons first faced the escape-optimal condition and subsequently faced the persistence-optimal condition. The other 2 pigeons faced these conditions in reverse order. The pigeons were placed in each condition for 29 sessions.

RESULTS

Persistence was defined as the completion of any ratio that was not the short ratio. Hence, in both conditions, the trials with opportunity for persistence were all trials except for the FR 10 trials. Table 2 displays the percentage of the trials with opportunity for persistence that each pigeon completed. For each condition, data are taken from the first five sessions of the period of stable behavior. In the escape-optimal condition, 3 of the 4 pigeons persisted on 0% of the trials throughout this period; the other pigeon (W524) persisted on roughly one fourth of the trials. In the persistence-optimal condition, 3 of the 4 pigeons persisted on nearly 100% of the trials during the stable period, and the other (W524) typically persisted on 80% to 85% of the trials during this period.

DISCUSSION

Experiment 2 served two functions. First, it provided a replication of the stimulus-changes-present condition of Experiment 1. In Experiments 1 and 2, pigeons correctly abandoned a course of action that had turned for the worse when stimulus changes were present that signaled the downturn. Second, Experiment 2 addressed the possibility that the results of the stimulus-changes-present condition of Experiment 1 could be explained in terms of impulsivity. In Experiment 1, because responding to the escape key produced

Table 2

Percentage of trials with persistence in Experiment 2.

Condition	Session of stable period	Pigeon			
		W501	G354	W524	W520
Escape optimal	1	0	0	26	0
	2	0	0	16	0
	3	0	0	14	0
	4	0	0	54	0
	5	0	0	5	0
Persistence optimal	1	100	100	83	98
	2	100	100	83	100
	3	100	100	85	100
	4	100	100	82	94
	5	100	100	81	98

Note. Persistence in a trial is defined as completion of that trial (excluding FR 10 trials).

the possibility of a very short FR schedule on the food key, pigeons in the stimulus-changes-present condition may have responded to the escape key not because it was optimal, but because they behave impulsively towards short delays to food. We tested this possibility by keeping the short FR in Experiment 2 but making persistence optimal. If responses to the escape key in Experiment 1 were caused by impulsivity, then the pigeons in Experiment 2 also should have responded to the escape key even though persistence was optimal. We found instead that the pigeons tended to behave optimally whether escape or persistence was optimal.

We do note that the FR 10 in the persistence-optimal condition of Experiment 2 had a relatively low probability of occurrence ($p = .25$) compared with the FR 10 in the escape-optimal condition ($p = .5$). Because of this difference, the persistence-optimal condition may have been less likely to generate impulsivity towards the FR 10. This may provide an alternative explanation for the relative absence of escape responses in the persistence-optimal condition. Nevertheless, our results are consistent with the hypothesis that behavior was dictated by optimality, not impulsivity.

Experiments 1 and 2 examine one way of manipulating economic uncertainty in a sunk cost situation: presenting or withholding stimulus changes that signal when a course of action has changed value. We hypothesized that when stimulus changes are present, the economics of a situation should be more salient and behavior should tend toward optimal. We found that pigeons indeed behaved optimally when stimulus changes were present, whether optimal behavior meant persisting or escaping. By withholding stimulus changes in Experiment 1, we induced 3 of the 4 pigeons to persist in a losing course of action.

EXPERIMENT 3

In Experiment 3, we examined a second way of manipulating economic salience—manipulating the difference between the expected ratio given escape and the expected ratio given persistence. We repeated the stimulus-changes-absent condition of Experiment 1 but with three different sets of FR schedules that narrowed or widened the mathematical difference in the expected value of persisting versus escaping. When these two values are more similar, the optimal choice should be less obvious. We hypothesized that the pigeons would be more likely to persist when these two values were more similar.

METHOD

Subjects

The subjects were the 4 White Carneau pigeons used in Experiment 1. They were maintained at about 80% of their free-feeding weights, were individually housed, and had free access to water and grit.

Apparatus

Same as for Experiments 1 and 2.

Table 3

Expected ratios as a trial progresses, Experiment 3.

Condition	Stage at which expected ratio takes effect (if no reinforcement occurs) Start of trial	After response number required by short FR	After response number required by medium FR	After response number required by long FR	Difference between persisting and escaping[a]
5, 50, 100, 220	55	100	110	120	100 − (55 + 1) = 44
10, 40, 80, 160	45	70	80	80	70 − (45 + 1) = 34
20, 50, 100, 200	60	80	100	100	80 − (60 + 1) = 19

[a] See text for explanation.

Procedure

In all conditions, the food key remained white throughout every trial. Three different sets of FR schedules were used in a within-subject design: 5, 50, 100, 220; 10, 40, 80, 160; and 20, 50, 100, 200. The corresponding probabilities of the short, medium, long, and extra-long ratios were equal to those used in Experiment 1; thus the 10, 40, 80, 160 condition was a replication of the stimulus-changes-absent condition of Experiment 1. Table 3 displays the sequence of the expected ratios in each condition. The critical factor distinguishing the conditions is the mathematical difference between the expected ratio given escape (i.e., one response to the escape key plus the expected ratio at the start of a trial) and the expected ratio given persistence (i.e., the expected ratio after the response number required by the short FR has been completed, if no reinforcement has occurred). In the 5, 50, 100, 220 condition, the mathematical difference is 44. That is, escaping as soon as it becomes optimal will lead to food on average in 44 fewer responses than persisting. In the 10, 40, 80, 160 condition, the difference is 34. In the 20, 50, 100, 200 condition, the difference is only 19. Thus the advantage of escaping had a different salience in each condition.

The order of conditions was 20, 50, 100, 200; 10, 40, 80, 160; and 5, 50, 100, 220. The first condition lasted 26 sessions; the second condition lasted 35 sessions; the third condition lasted 20 sessions.

RESULTS

As in Experiments 1 and 2, the trials with opportunity for persistence were the trials that did not have the short FR (in the 20, 50, 100, 200 condition, this was all but the FR 20 trials; in the 10, 40, 80, 160 condition, this was all but the FR 10 trials; in the 5, 50, 100, 220 condition, this was all but the FR 5 trials). Table 4 displays the percentage of the trials with opportunity for persistence that each pigeon completed. For each condition, the data are taken from the first five sessions of the period of stable behavior. In the 5, 50, 100, 220 condition, the percentage of trials with persistence was at or near zero for all 4 pigeons. In the 10, 40, 80, 160 condition, the percentage of trials with persistence was near zero for Pigeon 361, but at or near 100 for Pigeons 362, 363, and 364. In the 20, 50, 100, 200 condition, the percentage of trials with persistence was at or near 100 for all 4 pigeons.

DISCUSSION

The present experiment served two functions. First, the 10, 40, 80, 160 condition of this experiment replicated the findings from the stimulus-changes-absent condition of Experiment 1. Second, the present experiment tested the hypothesized role of economic salience in persistence by exploring a variable not manipulated in Experiments 1 and 2: The size of the mathematical difference between the expected ratio given escape and the expected ratio given persistence. As hypothesized, when this mathematical difference was larger the pigeons typically behaved optimally by abandoning the nonoptimal trials. When this mathematical difference was smaller, the pigeons did not behave optimally, but rather tended to persist in nonoptimal trials. To-

Table 4

Percentage of trials with persistence in Experiment 3.

Condition	Session stable period	Pigeon			
		361	362	363	364
5, 50, 100, 220	1	13	9	0	0
	2	4	15	0	0
	3	16	8	0	3
	4	9	8	0	0
	5	7	3	0	0
10, 40, 80, 160	1	0	90	100	100
	2	22	100	100	100
	3	19	89	96	100
	4	19	100	94	100
	5	1	100	100	100
20, 50, 100, 200	1	93	100	100	100
	2	91	100	100	95
	3	93	97	91	100
	4	100	100	98	100
	5	90	100	95	100

Note. Persistence in a trial is defined as completion of that trial (in the 5, 50, 100, 220 condition, excluding FR 5 trials; in the 10, 40, 80, 160 condition, excluding FR 10 trials; in the 20, 50, 100, 200 condition, excluding FR 20 trials).

gether with Experiment 1, the results from the present experiment are consistent with our hypothesis that uncertainty may induce pigeons to persist in a losing venture, or behave consistently with the sunk cost effect.

In the next experiment, we used a modified form of our procedure to repeat Experiment 3 with human subjects. Previous research has shown that humans in fact persist more under conditions of uncertainty. Experiment 4 explored this effect in a novel context.

EXPERIMENT 4

METHOD

Subjects

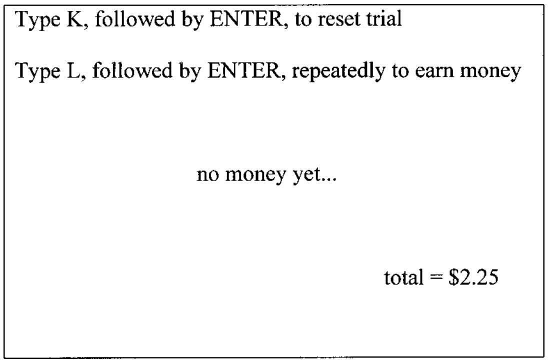
Thirty-two undergraduates participated in this study for course credit.

Apparatus

Four IBM®-compatible computers programmed in Turbo Pascal®.

Procedure

Subjects were seated individually at a computer in a small room containing four computers. One to 4 subjects performed the experiment simultaneously depending on how many subjects had happened to sign up for a given time slot. Subjects faced a computer task in which they had to respond on a keyboard in order to earn money. Subjects were instructed, truthfully, that for 30 min they had to press "L," followed by ENTER, an undetermined number of times until the screen flashed a 5¢ reward. They also were instructed that they could press "K," followed by ENTER, at any time to cancel the current trial and initiate a new one. At the end of the session, they would take home the total of their earnings. Figure 1 shows what the subjects saw on the computer screen as they responded during a trial. Upon completion of an FR schedule, the screen went blank and the sentence "you won 5 cents!" appeared at the center of the screen for 2 s. Next, the sen-



Type K, followed by ENTER, to reset trial

Type L, followed by ENTER, repeatedly to earn money

no money yet...

total = $2.25

Fig. 1. Stimulus presented on computer monitor to subjects in Experiment 4.

tence "new trial begins in a moment" appeared at the center of the screen for 2 s. Next, the screen displayed in Figure 1 reappeared with the total earnings incremented appropriately. If a subject canceled a trial, the screen went blank and the sentence "new trial begins in a moment" appeared at the center of the screen for 2 s, followed by the screen displayed in Figure 1.

Two conditions of Experiment 3 (5, 50, 100, 220; 10, 40, 80, 160) were repeated in this new format in a between-subject design. The corresponding probabilities were identical to those of the same two conditions of Experiment 3.

Subjects performed two 30-min sessions, which they were allowed to schedule either back-to-back or separately. Some subjects performed the sessions back-to-back, but most subjects performed them separately, usually 1 to 4 days apart.

RESULTS

Sixteen subjects participated in each condition; only 9 subjects and 12 subjects completed two sessions of Conditions 1 and 2, respectively. Average earnings in the second session of Conditions 1 and 2 were $6.00 and $4.53, respectively. Table 5 shows the percentage of trials with an opportunity for persistence that were completed during the second session for every subject, ordered in each condition from the subject with the lowest persistence to the subject with the highest persistence. In each condition, persistence was defined as the completion of any ratio that is not the short ratio for that condition. A one-way analysis of variance (ANOVA) revealed a significant effect of condition on the percentage of trials with persistence during the second session, $F(1, 19) = 6.55$, $p < .05$. In the 5, 50, 100, 220 condition, the average percentage of trials with persistence was 25.2% ($SD = 37.06$); in the 10, 40, 80, 160 condition, the average percentage was 67.9% ($SD = 38.38$).

DISCUSSION

The present experiment repeated with human subjects the procedure used with the pigeons in Experiment 3, using money as the reinforcer instead of food. The results mirror the trend found with the pigeons. When the mathematical difference between the expected ratio given escape and the expected ratio given persistence was large, the subjects tended to behave optimally. When this mathematical difference was smaller, the subjects instead tended to persist.

Note that the absolute level of persistence of the pigeon and human subjects cannot be compared directly. The pigeons were responding for a presumably more powerful reinforcer in food, and they also completed far more sessions than the human subjects before their data were analyzed. Nevertheless, the data of the human subjects show the same general trend as the data of the pigeons in Experiment 3. Thus these data suggest that in this analog of the sunk cost effect, uncertainty positively affects the level of persistence in humans as well as in pigeons.

In our final experiment, we returned to the pigeons to examine the role of reinforcement history in persistence.

EXPERIMENT 5

METHOD

Subjects

The subjects were 4 naive White Carneau pigeons maintained at about 80% of their free-feeding weights. They were individually housed and had free access to water and grit.

Apparatus

Same as for Experiments 1, 2, and 3.

Procedure

The basic procedure was the same as that used in the stimulus-changes-present condition of Experiment 1. The difference was that for the first 40 sessions the escape key was dark and inactive. During this training, persistence on the food key was the only option. After the 40th session, the escape key was introduced and the procedure was identical to that of the stimulus-changes-present condition of Experiment 1. The pigeons continued with this procedure, with the escape key active, for 17 sessions.

RESULTS

As in the previous experiments in this paper, persistence was defined as the completion of any ratio that is not the short ratio. Hence the trials with opportunity for persis-

Table 5

Percentage of trials with persistence in Experiment 4, second session. Individual data ordered from subject with lowest second session datum to subject with highest second session datum.

Conditions	Individual data	Mean	*SD*
5, 50, 100, 220	0([a]), 0(3), 0(6), 0(8), 5(47), 7(13), 54(23), 61(40), 100(93)	25.2	37.06
10, 40, 80, 160	0(19), 6([a]), 37(30), 46(87), 56(24), 70(76), 100(89), 100(97), 100(100), 100(100), 100(100), 100(100)	67.9	38.38

Note. Persistence in a trial is defined as completion of that trial (in the 5, 50, 100, 220 condition, excluding FR 5 trials; in the 10, 40, 80, 160 condition, excluding FR 10 trials). Parentheses = first-session data for each subject.

[a] Data not available because of an error in the data recording process.

tence were all trials except for the FR 10 trials. The dependent variable of interest was the percentage of trials with opportunity for persistence that each pigeon completed *after* the introduction of the escape key. From the fourth escape-key session onward, this measure was at 0% throughout every session for all 4 pigeons.

DISCUSSION

The present experiment explored the effect of reinforcement history on persistence. With stimulus changes present, the pigeons in Experiment 1 and the pigeons in the escape-optimal condition of Experiment 2 did not persist, but they did not have a reinforcement history for persisting. In the present experiment, we trained the pigeons in our procedure first without the opportunity for escape, with the hypothesis that reinforced persistence, or behavioral momentum, might lead the pigeons to persist later when the escape key was introduced. Our hypothesis was not supported. The pigeons in this experiment behaved optimally when the escape key was introduced, just like the pigeons in Experiment 1 and in the escape-optimal condition of Experiment 2 that had the opportunity for escape in the very first session.

Instead of creating behavioral momentum, the no-escape training actually may have facilitated optimal behavior when the escape key was finally introduced. Table 6 shows the level of persistence during the first three sessions with the escape key, both for this group and for the 2 pigeons from the analogous condition of Experiment 2 that faced this condition with no prior history. During the first session with opportunity for escape, the average percentage of trials with persistence (across pigeons) in the present experiment was 5%, whereas the average percentage in Experiment 2 was 61%. By the third session, the average percentage in this experiment bottomed out at 0%, whereas the average percentage in Experiment 2 was still at 57%. A possible reason for this is that during the no-escape training, the pigeons in the present

Table 6

Average percentage of trials with persistence during the first three sessions with opportunity for escape: Comparison of pigeons having reinforcement history with pigeons having no reinforcement history.

	Pigeon					
	History of no escape[a]				No prior history[b]	
Session	367	368	369	370	W524	W520
1	0%	15%	2%	5%	68%	55%
2	1%	6%	1%	1%	93%	45%
3	0%	0%	0%	1%	60%	55%

Note. Persistence in a trial is defined as completion of that trial (excluding FR 10 trials).

[a] Data taken from Experiment 5.

[b] Data taken from Experiment 2 from the escape-optimal condition from the 2 pigeons that experienced this condition first.

experiment were exposed to the correlations between the food key colors and the delay to food that each color signaled. Experience with these correlations apparently facilitated acquisition of the escape response.

GENERAL DISCUSSION

The present experiments represent a relatively novel way of studying choice in a situation of diminishing returns. Previously, this has been studied by presenting a concurrent progressive ratio (or interval) fixed ratio (or interval) schedule, whereby completion of the fixed ratio (interval) results in a resetting of the progressive ratio (interval) (Hackenberg & Hineline, 1992; Hodos & Trumbule, 1967). The critical difference between that procedure and the one used in the present experiments is that in a progressive schedule, the ratio (or interval) increases after each reinforcement, whereas in the present experiments the schedule ''increased'' prior to reinforcement and was reset after reinforcement. This difference precludes us from discussing our results in terms of previous findings in this area.

Some researchers have concluded that the sunk cost effect is strictly a human phenomenon (Arkes & Ayton, 1999). However, certain lines of research with humans suggest the possibility that this effect may be brought about in nonhuman animals. Namely, it appears that the sunk cost effect is sometimes caused by uncertainty and/or reinforcement history. We hypothesized that if these variables influence the sunk cost effect in humans, they also might promote the effect in nonhuman animals. To this end, we employed an operant procedure that allowed pigeons and humans to continue with or to abandon a course of action that had started out with good prospects but turned sour.

In Experiments 1, 2, and 3 (with pigeons), and Experiment 4 (with humans), we manipulated economic uncertainty in two separate ways. One way was by manipulating whether or not stimulus changes occurred that signaled when the course of action had gone sour. The second way was by manipulating the expected value of abandoning versus persisting in the sour course of action. Consistent with our hypotheses, persistence was greater when no stimulus changes occurred and when the expected values of abandoning and persisting were more similar.

In Experiment 5, we examined with pigeons the potential role of reinforcement history in persistence. The pigeons initially had to persist in the losing course of action without the option of escaping. Later, they faced the same procedure with the option to escape available. We hypothesized that the initial training would create a history of reinforcement for persisting that would in turn cause these pigeons to persist more than the pigeons in Experiments 1 and 2 that did not have this history. This hypothesis was not supported, as both groups came to respond optimally once the escape key was available.

Despite our null finding, the role of reinforcement history in the nonhuman Concorde fallacy represents a potentially fruitful area of research. The form of reinforcement history we used in our experiment was qualitatively different from the types used by Goltz in her studies with humans (Goltz, 1992, 1993, 1999). In her studies, subjects typically faced a schedule of positive reinforcement during training, followed by an extinction phase during which persistence was measured. In our procedure, the schedule of reinforcement on the food key did not change between the training phase and the testing phase. The testing phase simply offered a second key that the pigeons could press to reset the trial and thereby reduce the expected ratio on the food key. Procedures more analogous to those of Goltz may prove more successful in eliciting the Concorde fallacy.

At this time, we note that two variants of the sunk cost effect have been pointed out in the literature: adoption decisions and progress decisions. Adoption decisions involve the choice of which of several already-purchased items to consume. The sunk cost effect is manifested in the adoption decision by the consumption of the most expensive item despite it having a value equal to or lower than the less expensive items (Arkes, 1996; Arkes & Blumer, 1985). Progress decisions involve the choice of whether or not to continue pouring investments toward an ongoing course of action. For example, in a common procedure subjects read a scenario in which they have spent a certain amount of money towards a project that appears to have a bleak chance for success, and the subjects must decide whether or not to continue funding the project (e.g., Arkes & Blumer, 1985; Garland, 1990; Garland & Newport, 1991). The basic finding in these studies is that the likelihood of persistence increases as sunk cost size—that is, the amount of money spent so far—increases. The experiments we have presented in the present paper are most analogous to progress decisions, in that subjects had the option of either continuing or abandoning an ongoing endeavor.

Although our procedure is most analogous to a progress decision, there is an important distinction between our procedure and the common progress decision employed in most studies with humans. In most studies with humans, the sunk cost decision scenario is arranged such that there remains the possibility that persistence will be rewarded quickly. In our procedure, after the response requirement of the short ratio has been met and no reinforcement has occurred, there is zero chance that persistence will be rewarded quickly. It is certain that persistence will not bear fruit for a relatively long time. Put differently, in our procedure there was a black-and-white distinction between the moment when the course of action was still profitable and the moment when the course of action turned unprofitable. In most human studies the distinction is more blurred. This procedural difference does not limit our conclusions, however, because the main purpose of our procedure was to explore how certain variables affect the ability of the subject to discriminate the decrease in the value of the endeavor. Also, future research might eliminate this procedural difference by employing variable-ratio schedules instead of FR schedules.

Our experiments represent the first analog of the sunk cost effect developed for nonhuman animals. Although we are not prepared to conclude that pigeons should be added to the list of species that commit the sunk cost effect, our experiments suggest at least that pigeons may behave consistently with the sunk cost effect given the right conditions. The present experiments extend the generality of previous studies (Bragger et al., 1998; Bragger et al., 2003; Goltz, 1992) indicating that some instances of the sunk cost effect may not require norms or rules unique to humans. Altogether, the general conclusion is that when an animal is engaging in a course of action, it may persist in that course of action until a clearly better alternative becomes available. Our experiments with pigeons and humans are consistent with this hypothesis. We do acknowledge that some instances of the sunk cost effect in humans may be best explained by social-psychological or other factors. For example, the human literature suggests that personal responsibility is an important factor in the sunk cost effect. Specifically, subjects who face a sunk cost decision scenario will persist more if they are personally responsible for the sunk costs than if somebody else is responsible for the sunk costs (Bazerman, Giuliano, & Appleman, 1984; Davis & Bobko, 1986; Staw, 1976). This finding is typically interpreted in terms of self-justification, in which subjects persist in order to prove their own past behavior correct (Brockner, 1992). Our experiments did not manipulate any factor expected to induce or affect motives of self-justification, but nevertheless it seems unlikely that pigeons would exhibit this motive. Indeed, it might be the case that the range of factors that contribute to the sunk cost effect is smaller for pigeons and other nonhuman animals than it is for humans. Nevertheless, developing operant models of the sunk cost effect may prove helpful in understanding some of the variables that influence this behavior, and in exploring the generality of this behavior across species.

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