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Environmental Enrichment Affects Suboptimal, Risky, Gambling-Like Choice by Pigeons

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Abstract

Pigeons prefer a risky option with a low probability of a high payoff over a less risky option that results in more food. This finding is analogous to suboptimal human monetary gambling because in both cases there appears to be an overemphasis of the occurrence of the winning event and an underemphasis of the losing event. In the present research we found that pigeons that were exposed to an enriched environment (a large cage with three other pigeons for 4 hrs a day) were less likely to show this suboptimal choice behavior compared with typically housed laboratory pigeons in a control group. These results have implications for the mechanisms underlying suboptimal choice by humans (e.g., problem gamblers) and they suggest that a enriched environment may allow for enhanced self-control.

Keywords

environmental enrichment; suboptimal choice; gambling; self-control; pigeons

In a variety of experiments, pigeons show a preference for stimuli associated with a risky, sub-optimal choice. For example, pigeons show a strong preference for suboptimal alternatives that provide them with signaled 50% reinforcement (a stimulus that always precedes a “win” or a stimulus that always precedes nonreinforcement) over unsignaled 75% reinforcement (an unpredictable 75% reinforcement rate) (Gipson et al. 2009). For example, a pigeon is given a choice between the left and right white response key. If it pecks the left key it turns red 50% of the time and after a few seconds reinforcement is provided or it turns green 50% of the time and after a few seconds the trial ends. If the pigeon pecks the right key 50% of the time it turns blue, 50% of the time it turns yellow and in either case after a few seconds reinforcement is provided 75% of the time. Thus, choice of the left key provides reinforcement 50% of the time, choice of the right key provides reinforcement 75% of the time. The design of this experiment is presented in Figure 1.

Pigeons even have a strong preference for signaled 20% reinforcement over unsignaled 50% reinforcement (Stagner and Zentall 2010). Furthermore, they also show a strong suboptimal preference for an alternative that on 20% of the trials provides them with 10 pellets of food and on the remaining trials provides them with no food (an average of 2 pellets) over a second alternative that provides them with a certain 3 pellets of food (Zentall and Stagner 2011). Thus, their preference does not depend on the uncertainty of reinforcement associated with the optimal choice. In addition, the preference for the suboptimal alternative is not merely a preference for the more variable outcome (10 pellets or 0 pellets vs. 3 pellets) because when the discriminative alternative is made nondiscriminative (e.g., both the red

and green stimuli are followed by 10 pellets 20% of the time) the pigeons now prefer the optimal alternative.

The choice of a low-probability, high-payoff alternative over a high-probability, low-payoff alternative is similar to human gambling behavior in which choosing to gamble (e.g., buying a lottery ticket or playing a slot machine) is associated with a lower net payoff than not gambling. The similarity between the pigeons' choice task and human gambling behavior suggests that human gambling behavior may have a basic behavioral basis. Signals for reinforcement that occur immediately upon choice produce conditioned reinforcers (Dinsmoor 1983) and those signals that predict a large magnitude (10 vs. 3 pellets) or high probability (100% vs. 75%) of reinforcement are better conditioned reinforcers. To account for this suboptimal behavior, it can be suggested that for pigeons, as well as for humans, signals for reinforcement (winning) appear to have greater positive value than logically they should have and, given that signals for the absence of reinforcement (losing) often occur much more often (sometimes 80% of the time), they appear to have less negative value than they should have (Stagner and Zentall 2010; Zentall and Stagner 2011a, b). This strong attraction to the conditioned reinforcer and relative ineffectiveness of conditioned inhibition may account for what has been considered in the psychiatric literature as the potentially addictive nature of gambling behavior by humans (Black and Moyer, 1998; Blanco et al. 2001; Greenberg and Rankin, 1982; Moran, 1970).

The effect of socially and physically enriched environments has long been of interest to scientists. From the earliest debates of nature versus nurture, authors have pointed to the effects of environment on behavior. Early on, Hebb (1947), Forgas and Forgas (1951), and others demonstrated that rats raised in an enriched environment displayed enhanced problem-solving abilities as adults. There is also evidence that enrichment alone is sufficient to cause differences in learning and memory in the rat (Gardner et al. 1974).

There is some suggestion from research with rats that various extra-experimental environmental factors such as social and physical enrichment can affect a rat's propensity to self-administer drugs of addiction (Stairs and Bardo 2009). Rats that are housed in an enriched group environment (a large cage with other rats and objects that are changed regularly) show a significantly reduced tendency to self administer drugs than rats that are normally (individually) housed. The mechanism responsible for the reduced self-administration of drugs by environmental enrichment appears to be a reduction in impulsive behavior (Perry and Carroll 2008) as well as a reduced effectiveness of conditioned reinforcers (Jones et al. 1990). Impulsivity has also been implicated in human gambling behavior (Steel and Blaszczynski, 1998) and, as already noted, conditioned reinforcement has been proposed to account for suboptimal choice by animals (Dinsmoor, 1983). Furthermore, there is evidence that similar physiological mechanisms underlie compulsive gambling and drug addiction (Potenza, 2008).

In another experiment, a group of rats maintained in an enriched enclosure displayed what the authors referred to as a more *optimistic cognitive bias* than a group housed in an unenriched enclosure (Brydges et al. 2011). Following a rough-smooth discrimination, in which one stimulus led to a more preferred food than the other, when the rats were presented with an intermediate level of roughness, the group maintained in the enriched enclosure were more likely to respond to the novel roughness as they had learned to respond to the one that led to the more preferred food. Starlings too have been found to show similar *optimistic responding* on ambiguous trials when housed in enriched cages as compared to starlings maintained in smaller, unenriched cages (Matheson et al. 2008). Clearly environmental enrichment can affect choice.

The purpose of the present study was to determine if exposure to a enriched environment would affect adult pigeons' demonstrated tendency to choose suboptimally in a gambling-like task. Pigeons in our enriched group were placed in a large group cage with three other pigeons for 4 hr a day, 5 days a week but were otherwise individually housed (as were pigeons in the control group).

All of the pigeons were trained to choose between two alternatives. Choice of one alternative provided them with a stimulus 50% of the time that was always followed by food or a stimulus 50% of the time that was not followed by food (the gambling-like alternative). Choice of the other alternative provided them with a stimulus that was followed by food 75% of the time (the optimal alternative). Thus, the second alternative was 50% better than the first (Figure 1).

Method

Subjects

Eight experimentally naïve homing pigeons (*Columba livia*) between 1 and 2 years of age and of undetermined sex were randomly assigned to two groups, an enriched group and a control group. Pigeons in the control group were individually housed in wire cages 28 cm wide, 38 cm deep, 30.5 cm high, with free access to water and grit, in a colony room that was maintained on a 12:12-h light/dark cycle. Pigeons in the enriched group were similarly housed with the exception that 4 hrs a day, 5 days a week they were placed in a group flight cage described below. During the experiment, all pigeons were maintained at 85% of their free-feeding body weight and were cared for in accordance with the University of Kentucky's Animal Care Guidelines.

The flight cage was constructed from plastic pvc pipe that was covered with transparent plastic sheeting to confine the birds while providing space for social interaction. The flight cage was 2.13 m high, 1.22 m wide and 1.84 m deep. A 0.45 m wide perch spanned the width of the cage 1.52 m above the floor. A small table (0.6 m × 1.0 m) was placed inside the cage to give the birds more perching options.

Pigeons in the enriched group were placed together in the flight cage for one 4-hr session a day, 5 days each week, for 90 days prior to the start of task training. Once training began, the enriched pigeons were placed in the flight cage after they had all completed their training for the day.

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 deep. The response panel included a horizontal row of three response keys 25 cm above the floor. The rectangular keys (2.5 cm high × 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). The center projector projected a vertical white line on a black background. A center-mounted feeder behind the response panel delivered reinforcement. When food was available, the feeder was illuminated by a 28-V, 0.04-A lamp. Reinforcement consisted of 1.5 s access to Purina Pro Grains (Grey Summit, IL). An exhaust fan mounted on the outside of the chamber masked extraneous noise. A microcomputer in an adjacent room controlled the experiment.

Training and Testing

Pigeons were initially trained to peck each of five hues (red, green, blue, yellow and white) on both side keys and to peck the white vertical line on the center key for reinforcement. The pigeons were then trained to peck each color on the side keys on a fixed-interval 10 s schedule (the first peck after 10 s was reinforced). In training, all trials began with the vertical line stimulus on the center key, requiring a single peck to continue.

The pigeons were trained with two types of trial. On forced trials (48 trials per session) a single peck to the center vertical stimulus illuminated a white stimulus on either the right or the left key. The other side key remained dark and was inoperative. One peck to the lit key initiated one of the hues. If the white key on the left was illuminated, on half of the trials, one peck turned the key red, for example, and after 10 s was followed by reinforcement. On the remaining trials on which the left key was lit, one peck turned the key green and after 10 s no reinforcement was presented. If the white key on the right was illuminated, one peck turned the white key blue or yellow (with a probability of .5) and after 10 s was followed by reinforcement, 75% of the time. The design of the experiment is presented in Figure 1. For purposes of counterbalancing, the sides and hues associated with the contingencies were reversed for half of the pigeons in each group. All trials were separated by a 5-s intertrial interval. The inclusion of forced trials ensured that the pigeons adequately experienced the contingencies of reinforcement associated with the two alternatives.

Randomly intermixed among the forced trials were 24 choice trials. During these trials, a single peck to the center vertical stimulus illuminated both the left and right side keys. Choice of one of the keys produced one of the colors and the outcome associated with that color and simultaneously turned off the unselected key. All pigeons were trained for 36 sessions.

Results

The pigeons in the control group began choosing the suboptimal (50% reinforcement) alternative within three sessions (almost 65% of the time by Session 3), whereas pigeons in the enrichment group chose the optimal (75% reinforcement) alternative on most of the first 10 sessions (see Figure 2). When the data were pooled over the first 10 sessions for each group, the control birds chose the suboptimal alternative on 79% of choice trials ($SD=24\%$), whereas the enriched pigeons selected the suboptimal alternative on only 31% of choice trials ($SD=11\%$). The two groups differed significantly in their choice of the suboptimal alternative, $t(6)=3.68$, $P=.01$. Because of daily fluctuations in preference, especially for pigeons in the enriched group, there was considerable within-group variability in the scores; however, a sensitive criterion for development of a consistent preference for the suboptimal alternative is the session on which each pigeon showed a preference for the suboptimal alternative that persisted on all succeeding sessions. For pigeons in the control group, that criterion was reached in an average of 3.2 ($SD=1.1$) sessions, whereas for pigeons in the enriched group, that criterion was reached in an average of 18.0 ($SD=3.4$) sessions, significantly longer, $t(6)=3.61$, $P=.01$. By Session 30, all of the pigeons in both groups showed a strong preference for the suboptimal alternative. Thus, the effect of enrichment was to delay but not prevent suboptimal choice.

If choice of the optimal reinforcement alternative provided more reinforcement than the suboptimal alternative, pigeons in the environmental enrichment group should have received more reinforcement during the early sessions in which they tended to choose optimally. Of the 72 trials per session, 48 of the trials were forced (24 to the 50% reinforcement alternative, 24 to the 75% reinforcement alternative), which provided the pigeons with a fixed 30 reinforcements per session. Of the remaining 24 trials, if the pigeons had chosen the

75% reinforcement alternative exclusively they would have received an additional 18 reinforcements or a total of 48 reinforcements. However, if the pigeons had chosen the 50% reinforcement alternative exclusively they would have received an additional 12 reinforcements or a total of 42 reinforcements. Thus, exclusive choice of the suboptimal alternative would have resulted in 8 fewer reinforcements. When the number of reinforcements were averaged over the first 10 sessions for each group, the pigeons in the environmentally enriched group received significantly more reinforcements (45.9, $SD=1.72$) than the pigeons in the control group (43.2, $SD=0.66$), $t(6) = 2.94$, $P = .026$. The number of reinforcements per session for the environmental enrichment and control groups appears in Figure 3.

Discussion

The results of the experiment indicate that enrichment had a positive effect on the pigeons' suboptimal choice. Pigeons that were given 4 hrs of enrichment experience, five days a week, rejected the suboptimal alternative more often than control birds. However, it cannot be said that enrichment eliminated suboptimal choice, as all of the pigeons in the enrichment group finished the experiment with a strong preference for the suboptimal alternative. But the enrichment did substantially delay suboptimal choice for all pigeons.

The mechanism responsible for the delayed onset of suboptimal choice produced by enrichment is not clear but it may be that pigeons that live in isolation have been deprived of sufficient stimulation and the opportunity to obtain a conditioned reinforcer increases arousal more for them than for the enriched pigeons. If the value of the increased arousal outweighs the greater value of the higher reward alternative, the pigeons may choose suboptimally (Jones et al. 1990).

Alternatively, it may be that the suboptimal choice found in typically housed pigeons is due to the failure of the stimulus associated with non-reinforcement to become a conditioned inhibitor (Zentall 2011). A similar effect can be seen in humans who are persistent gamblers. They tend to ignore (or undervalue) losses and attend to (or overvalue) wins (Field and Cox 2008; Franken et al. 2003; Holst et al. 2010; Tversky and Kahneman 1974). It may be, as well, that enriched pigeons are more sensitive to the negative value of nonreward than normally housed pigeons because of the interactions that they had with other pigeons in the flight cage. That is, the enriched pigeons may have learned to inhibit certain behaviors (e.g., indiscriminate approach or aggression) in the presence of the other pigeons in the flight cage and the tendency to inhibit may have generalized to stimuli associated with the absence of reinforcement in the choice task.

The present research does not identify what aspects of the enriched environment were responsible for the initial reduced attraction to the suboptimal alternative. Our enrichment manipulation included both a larger more stimulating environment and a social environment. We suspect that the social aspects of the enrichment played an important role because there was considerable social interaction in the enriched environment, however, it would be informative to determine if a similar delay of suboptimal choice effect would be found if the pigeons were exposed to the larger more stimulating environment in the absence of social stimuli.

It could be argued that the degree of enrichment provided pigeons in the present study was considerably less than it might have been. In some studies, animals spend 24 hrs a day in their enriched environment (e.g., see Stairs and Bardo 2009). It would be of interest to know if additional exposure to the enriched environment would lead to enhanced or longer lasting optimal choice.

There is evidence from research with rats that environmental enrichment can produce long-lasting physiological effects on the brain. For example, Diamond et al.(1966) have found an increase in cortical thickness and an increased number of glial cells. Similarly, Briones et al. (2004). have reported that environmentally enriched rats increased number of synapses and increased dendritic elaboration. It is very likely that environmental enrichment also produces changes in the pigeon brain and it would be interesting to know what characteristics of the brain are modified by enrichment procedures.

Although the present procedures differ in some details from human gambling, we believe that the differences are not conceptual. For example, it could be argued that humans choose to bet or not to bet with money that they already have, whereas pigeons choose between two alternatives, neither outcomes of which they already have. Technically, the procedural difference is between a go/no-go procedure (human gambling) and a two-alternative choice procedure but in fact, the choice to gamble actually involves saving one's money and choosing not to engage in *some other activity*.

Another difference is that humans often describe gambling as an enjoyable activity rather than as a way to make money. This difference is difficult to address directly because the emotion of enjoyment is difficult to define (especially in pigeons). The question is, when it comes to games of chance, would humans gamble if it were not possible to win money (or a prize)? The possibility of winning money (or the anticipation of the possibility of winning money) certainly contributes to what makes the game enjoyable. People may also gamble for social rewards (being the best, earning the most points), but even with such games (e.g., poker), many prefer to play for money rather than points alone.

Although perhaps not obvious, as it is with pigeons, conditioned reinforcers also play an important role in human gambling (e.g., the symbols that show up on the wheels of slot machines, the numbers on lottery tickets, watching the horse race). If the only feedback gamblers received when they won was being given money or not, it is unlikely that they would they be as inclined to gamble. Furthermore, like pigeons, for humans, losses appear to contribute much less conditioned inhibition than they should based on reinforcement theory (Holst et al. 2010).

One can calculate the cost of suboptimal choice (gambling) by the pigeons in terms of the loss of food on choice trials. In the present experiment, choice of the suboptimal alternative results in 1/3 less food (50% is 2/3 of 75%) and we have shown a strong suboptimal choice even when the suboptimal choice results in even less food (Stagner and Zentall, 2010; 20% is only 40% of 50%). This represents a considerably greater cost than the "house take" in typical casino gambling and is more similar to "cost" of buying a lottery ticket. To further support the claim that the task we have used with pigeons is analogous to human gambling, we have recently found that when humans play a game based on the pigeon procedure (Zentall and Stagner 2011), self-reported gamblers choose more like pigeons than self-reported nongamblers (Molet et al. in press). In this study we instructed subjects to try to get as many points as possible and, like the pigeons, we gave them a choice between two alternatives, one that on 20% of the trials resulted in a stimulus that predicted that they would receive 10 points or on 80% of the trials, a stimulus that predicted that they would receive no points (thus a mean of 2 points), and the other alternative for which they could obtain 3 points on all trials. We found that self-reported non-gamblers chose the 3-point option most of the time, whereas self-reported gamblers chose the risky 2-point option significantly more often.

Thus, the choice task with pigeons involving discriminative versus nondiscriminative stimuli appears to provide a useful analog to suboptimal gambling by humans. And the reduction in

suboptimal choice by pigeons when exposed to social enrichment may not only help to determine the mechanisms underlying suboptimal choice but it could also lead to possible treatment of the suboptimal choice characterized by pathological human gambling behavior. References Black D.W., Moyer T. (1998). Clinical features and psychiatric comorbidity of subjects with pathological gambling behavior.

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Figure 1. Design of the experiment. Sides and colors were counterbalanced over pigeons in each group.

Figure 2.

Percent choice of the suboptimal alternative (50% over 75% session. Data from the environmentally enriched group is represented by filled Data from the control group is represented by open circles. Error bars represent standard error of the mean.

Figure 3. Number of reinforcements per session for pigeons in the environmentally enriched (filled circles) and control group (open circles). Error bars represent ± 1 standard error of the mean.