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DISCOUNTING OF SHARED REWARDS IN PIGEONS

DESCUENTO DE RECOMPENSAS COMPARTIDAS EN PALOMAS

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Abstract

Pigeons chose between shared (communal) and unshared patches. In the shared patch, the pigeon would share 14 food pellets with zero to seven other pigeons. In the unshared patch, the pigeon had access to food pellets by itself, in an amount that depended on the given trial. The number of food pellets in the unshared patch was increased or decreased depending on the pigeon's choices, and the indifference point (the subjective value of the shared reward), where the pigeon chose the shared and unshared patches equally often, was reached. The subjective value of the shared rewards decreased systematically as the number of pigeons sharing the

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rewards increased. The discounting of the shared rewards was well- described using both hyperbolic and exponential functions. The results suggest that food sharing is a discounting factor, and the mathematical function that describes the social discounting of hypothetical monetary rewards in humans described social discounting in pigeons receiving real rewards.

Keywords: sharing, social discounting, pigeon, decision-making, discount function

Resumen

Palomas eligieron entre parches compartidos (comunales) y no compartidos. En el parche compartido, una paloma compartía 14 pellets de comida con ninguna, o de una a siete palomas. En el parche no compartido, la paloma tenía acceso a comida por sí misma, en una cantidad que dependía del ensayo. El número de gránulos de comida en el parche no compartido aumentó o disminuyó según las elecciones de la paloma y el punto de indiferencia (el valor subjetivo de la recompensa compartida), también se describe el punto de equivalencia y valor subjetivos donde la paloma eligió los parches compartidos y no compartidos con la misma frecuencia. El valor subjetivo de las recompensas compartidas disminuyó sistemáticamente a medida que aumentó el número de palomas que compartían las recompensas. El descuento de las recompensas compartidas se describe bien utilizando funciones tanto hiperbólicas como exponenciales. Los resultados sugieren que compartir alimentos es un factor de descuento, y la función matemática que describe el descuento social de recompensas monetarias hipotéticas en humanos describe el descuento social en palomas que reciben recompensas reales.

Palabras clave: compartir, descuento social, palomas, toma de decisiones, función de descuento.

Discounting refers to the process through which the value of a reward outcome decreases as a function of time or as the odds against receiving it increase. Rachlin (1993) posited that sharing is a factor in discounting reward in social situations, as described by the following equation:

$$V = A/(1+sN) \qquad (1)$$

where V is the discounted value of the reward; A is the amount of the reward; N is the number of other individuals who share the reward, or the social distance relative to the individual with whom a reward is to be shared; and s is a measure of the discount rate, or the degree of selfishness. The concept of social discounting describes the decrease in the perceived value of the reward as the number of others who share it increases or as the social distance between individuals increases. On the one hand, if decisions are made based on the assumption that shared rewards are equally distributed among individuals, the indifference point would be the amount of shared reward divided by $1 + N$ ($s = 1.0$). If shared rewards are more valuable than the equal distribution of rewards (altruistic), s would be smaller than 1.0 ($s < 1.0$). On the other hand, if shared rewards are less valuable than equal distribution (selfishness), s would be greater than 1.0 ($s > 1.0$).

Discounting functions other than hyperbolic ones (Equation (1), for example) have been developed through economic approaches. One such function is as follows:

$$V = Ae^{-kD} \qquad (2)$$

where V and A are as in Equation (1), D is the delay of the reward, k is the measure of the discounting rate, and e is the base of the natural logarithm. The exponential function predicts that the value of the reward is discounted at the same rate, regardless of the length of the delay. Conversely, the hyperbolic function predicts that the reward value will be discounted more rapidly with shorter delays than with longer delays. Apart from the differences in the shape of their curves, the two discounting functions differ in their prediction of preference reversals, in which an immediate reward is preferred when delays to both rewards are short, but a larger delayed reward is preferred when delays to both rewards are long. The hyperbolic function can predict this phenomenon, but the exponential function cannot. However, if the discounting rate varies inversely with the amount of the reward, the exponential function can also predict preference reversals (Green & Myerson, 2004).

Equation (2) can be extended to describe the situation in which value is discounted by social variables:

$$V = Ae^{-sN} \qquad (3)$$

where V, A, N, and s are as defined in Equation (1), and e is defined as in Equation (2). Several experiments using hypothetical and real rewards have been conducted with both human and nonhuman subjects to identify the discounting function of delay and the probability of discounting. In most of these, however, the hyperbolic function describes the data more accurately than does the exponential function (see Green & Myerson, 2004, for review).

Research on social discounting thus far has been conducted only by using hypothetical monetary rewards with humans (Ito & Saeki, 2000; Ito, Saeki, & Green, 2011; Jones & Rachlin, 2006, 2009; Ostaszewski & Osiński, 2011; Rachlin & Jones, 2008a, b). Jones and Rachlin (2006, 2009) and Rachlin and Jones (2008) defined social discounting as social distance (or social intimacy) between individuals. For example, Jones and Rachlin (2006) used a paper-and-pencil test to examine the degree of social discounting in college students. The participants first were asked to imagine a list of 100 people (without needing to physically create it), with whom they were the most intimate (e.g., close friends or relatives) and those with whom they were not (mere acquaintances). The participants then choose between a hypothetical unshared monetary reward and a hypothetical monetary reward to be shared with the person at the Nth ($N = 1, 2, 5, 10, 20, 50,$ or 100) position on his or her list. The indifference point at which participants would switch from choosing the unshared option to choosing the shared option was obtained. Participants were inclined to forgo a smaller amount of money for another person as social distance increased. These results were well described by the hyperbolic function of Equation (1).

By contrast, Ito et al. (2011) and Ostaszewski and Osiński (2011) defined social discounting as the number of individuals among whom a reward is shared. Ito et al. (2011) employed a paper-and-pencil test to investigate social discounting in Japanese and American college students. Participants chose between a hypothetical unshared monetary reward and a hypothetical monetary reward that would be shared with either relatives or strangers (the number of other people varied from 1 to 24). The discount rates in the stranger condition were higher than those in the relative condition. Furthermore, the subjective value of the shared reward decreased hyperbolically as the number of other people increased.

For social discounting using hypothetical rewards with humans, the hyperbolic function better describes discounting data. Discounting functions that describe social discounting in nonhuman animals using real rewards are uninvestigated. The purpose of the present experiment therefore was to examine social discounting in a group of pigeons using real (food) rewards. The hyperbolic and exponential functions were compared to determine which could better fit the resulting social-discounting data.

Method

Subjects

Eight male pigeons without prior experience of group experimentation were used. All pigeons were assigned to the role of shared pigeons when they were not the experimental pigeons. The flock of pigeons was housed together in a flying cage (2.5 m long, 2.0 m wide, and 1.9 m high) with birdhouses under a 12:12 h light/dark cycle. Grit and water were freely available. The pigeons were maintained at 80% of their free-feeding body weights throughout the experiment.

Apparatus

A novel operant chamber was fabricated to assess the discounting of shared rewards in a group of pigeons (Figure 1). The chamber was comprised of three compartments: a shared (communal) patch, an unshared patch, and a neutral zone. Microswitches were placed under the trapezoidal floor of each of the patches to detect the pigeons' movements. Up to seven shared pigeons were placed in the shared patch, and the experimental pigeon was placed in the neutral zone. Only the experimental pigeon could move freely between the shared and unshared patches and record movements via the microswitches under the floor.

In the shared patch, there were eight individual compartments (32.5 cm high, 23.0 cm long, and 25.0 cm wide for each compartment) separated by gray polyvinyl chloride. During the experiment, shared pigeons could not leave these compartments. One compartment was connected to the neutral zone (32.5 cm high, 25.0 cm long, and 25.0 cm wide), with the other side connected to the unshared patch (32.5 cm high, 23.0 cm long, and 25.0 cm). The food pellets (20 mg each) were delivered one by one at 0.8 s intervals in the center of the mortar-shaped food cup located in the center of each patch via a pellet feeder (H14-22M-2D Coulbourn Instruments). Each compartment had an aperture (12.0 cm high and 4.4 cm wide) on the front wall (28.0 cm high and 6.0 cm wide), into which the pigeons could put their heads and access the food pellets. In the shared patch, up to eight pigeons could put their heads into the undivided food cup at the same time, which allowed all of them, including the experimental pigeon, to compete for the food pellets together. By contrast, in the unshared patch, the experimental pigeon could access food pellets by itself.

The patches were illuminated by a 24-V dc lamp during the pellet-delivery period. Each patch, on both sides of the neutral zone, had a white LED as a trial lamp at a height of 22 cm from the floor, and an LED that glowed red and green

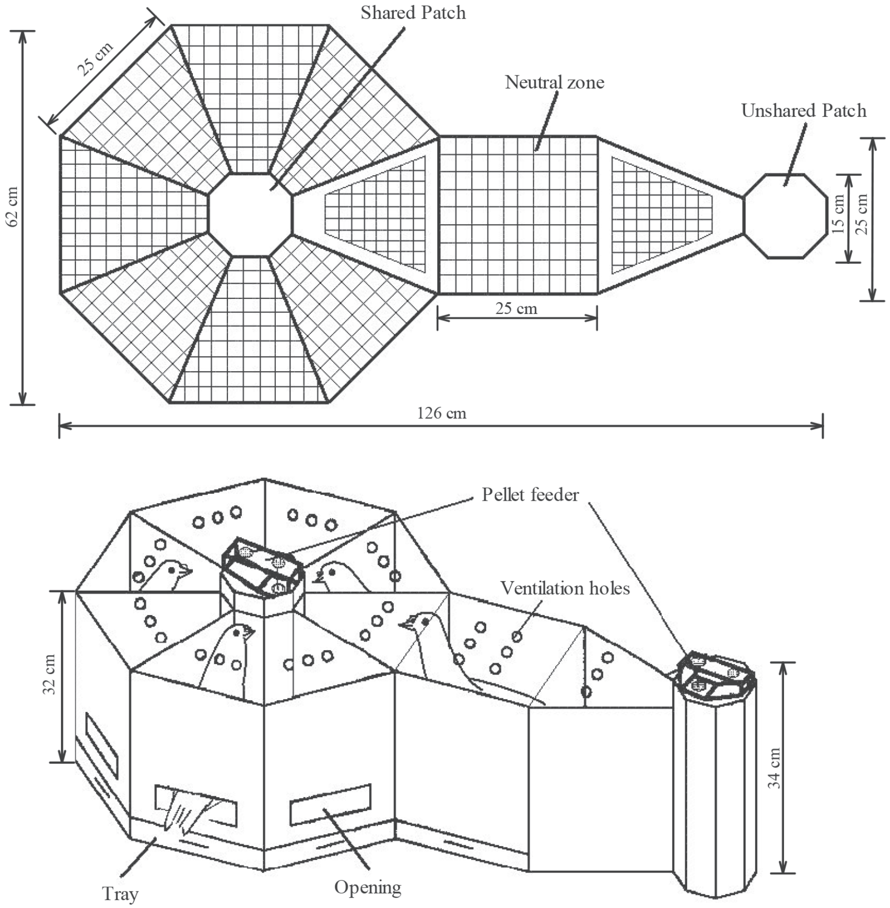

Figure 1. The operant chamber comprised three parts: a shared patch (left side), an unshared patch (right side), and a neutral zone. Microswitches were placed under the trapezoidal floor of each of the patches to detect the responses made by the pigeons.

was mounted 2 cm below the trial lamp as a discriminative stimulus. Stimuli were controlled and responses were recorded on IBM-compatible personal computers using the Visual Basic® programming language.

Procedure

In the shared patch, the experimental pigeon would always share 14 food pellets with other pigeons (except when the number of sharing pigeons was zero) ; in the unshared patch, it was given access to variable numbers of food pellets for itself.

A discrete-trial adjusting-amount procedure was used to measure the discounting of shared rewards. In this procedure, the number of unshared food pellets was increased or decreased depending on the pigeon's choices. The adjusting amount could range from a minimum of one to a maximum of 45, determined by the following procedure. At the start of each session, the adjusting amount was set at either 1 or 14. Table 1 shows the sequence of conditions. After every two free-choice trials, the number of pellets available at the unshared patch could be changed. If the shared patch was chosen during two consecutive free-choice trials, a forced-choice trial to the unshared patch was inserted. During this forced-choice trial, the number of unshared food pellets was increased by one. Conversely, if the unshared patch was chosen during two consecutive free-choice trials, a forced-choice trial to the shared patch was inserted. During the next free-choice trial, the number of unshared food pellets was decreased by one. If the pigeon did not chose the same patch twice in succession, a forced trial was not inserted and no change was made in the number of unshared food pellets. The number of pellets in the unshared patch when 60 free-choice trials were completed was defined as the indifference point that was used as the estimate of the value of the shared 14 food pellets in the session. At the beginning of the next session, the number of food pellets for the unshared patch was reset to the initial value (1 or 14).

The number of other pigeons sharing the shared patch varied from zero to seven, during four conditions (N = 0, 1, 4, 7). For half of the pigeons, the number of shared pigeons in the shared patch ran from zero to seven (ascending order). For the other half, the number of the shared pigeons at the shared patch ran in the reverse order (descending order). Each condition lasted for a minimum of 14 sessions (see stability criteria below). The procedures were conducted on four pigeons a day, 6 days a week. M9686, M9636, M9607, and M9468 were placed in the first group and M9681, M9221, M9460 and M9463 were placed in the second group. Therefore, it took 2 days for all pigeons to complete one session. This is because if eight pigeons were tested per day, the number of times they have access to food increases, and they become satiated, precluding their body weight from returning to 80% by the next session.

During each session, sharing pigeons and their placement locations in the compartments were determined by the following rules. When the number of sharing pigeons was one, the sharing pigeon was randomly selected from a group that did not participate in the experiment on that day. When the number of sharing pigeons was four, all pigeons in the group became sharing pigeons. Under the condition where there were seven sharing pigeons, all pigeons other than the experimental

Table 1. Experimental conditions for each pigeon. The number of sessions and indifference points for each condition are shown.

Subject	Experimental group	Order	Number of pigeons at shared patch	Initial amount of pellets at unshared patch	Number of sessions	Indifference point
M9686	1	1	0	1	20	15.8
		2	1	1	14	6.2
		3	4	1	15	2.5
		4	7	1	14	1.2
M9681	2	1	0	1	14	16.3
		2	1	1	14	8.7
		3	4	1	16	2.5
		4	7	1	14	1.0
M9221	2	4	0	1	18	26.7
		3	1	1	20	7.7
		2	4	1	14	2.2
		1	7	1	15	2.0
M9636	1	4	0	1	17	21.3
		3	1	1	14	1.0
		2	4	1	14	1.0
		1	7	1	14	1.5
M9607	1	1	0	14	20	17.8
		2	1	14	14	1.8
		3	4	14	14	1.2
		4	7	14	14	1.0
M9460	2	1	0	14	20	18.2
		2	1	14	20	12.2
		3	4	14	14	1.3
		4	7	14	14	1.2
M9463	2	1	0	14	20	17.0
		2	1	14	20	22.7
		3	4	14	14	3.2
		4	7	14	14	1.0
M9468	1	1	0	14	20	10.8
		2	1	14	14	1.0
		3	4	14	14	1.2
		4	7	14	14	1.5

pigeon became sharing pigeons. Therefore, under this condition, there was a pigeon that became an experimental pigeon after having served as a sharing pigeon on that day. Which of the seven compartments the sharing pigeons were placed differed from session to session, and it was planned that all compartments were used within one condition.

Initially, each pigeon was trained to choose the shared and unshared patch with equal frequency. During this training, no other pigeons were placed in the shared patch. The equal frequencies were defined as choice proportions ranging from .45 to .55.

Either green or red stimulus lights mounted above the aperture were illuminated for each patch at the beginning of each choice trial and the movement of the pigeon was recorded. During the free-choice trials, the discriminative stimulus (green or red) was lit on both patches, but during the forced-choice trials, the discriminative stimulus was lit only on the patch that was able to choose. The combination of the color of discriminative stimulus and patches was counterbalanced between pigeons. This combination (shared patch green and unshared patch red or vice versa) was fixed for each pigeon throughout the experiment. During the reinforcement period, the feeder light was turned on, and one food pellet was delivered.

After completion of the preliminary training, the pigeons were exposed to the experimental conditions. Each session started with a forced-choice trial to both the shared and unshared patches to ensure sampling of both patches, after which the first-free-choice trial was presented. For each session, whether the forced-choice trial would lead first to the shared or unshared patch was randomly determined. After every reinforcement, the experimental pigeon had to return to the neutral zone to proceed to the next trial. In the free-choice trial, when the shared and unshared patch were chosen alternately, the free-choice trial continued, and the number of food pellets delivered to unshared patch did not change. Each trial lasted 30 s from the choice of a patch until the next choice trial became possible. Only after 30 s had lapsed from the choice of a patch and the experimental pigeon was in the neutral zone, could the next trial start.

Conditions remained in effect for at least 14 sessions (see Table 1 for number of sessions) and were changed only when the following stability criteria were met: the mean indifference points for the last three successive blocks of two sessions did not differ from each other by more than five food pellets, and neither a descending nor an ascending trend was apparent in the block means.

Results

Indifference points (measured as the number of pellets), where the pigeon chose the shared and unshared patches equally often, were obtained. Table 1 shows the mean adjusting pellets at the indifference point for each pigeon. The mean indifference points for the four conditions ($N = 0, 1, 4, 7$) of the shared patch were 18.0, 7.6, 1.9, and 1.3, respectively. When the number of pigeons sharing 14 food pellets was zero, the indifference point of four pigeons was above 14, indicating a spatial bias. That is, when the food was shared with zero pigeons, the pigeons preferred the shared patch with 14 food pellets to the unshared patch with 14 or more food pellets. The mean number of sessions, averaged over all pigeons and across conditions was 15.8.

Figure 2 shows the mean adjusting amount of the unshared patch that was subjectively equivalent to the shared patch for individual pigeons (the subjective value was plotted as a function of the number of sharing pigeons). The subjective value of the shared reward decreased systematically as the number of pigeons that shared the reward increased. On the one hand, when the number of pigeons sharing the reward increased from zero to one, the subjective value of the shared reward generally decreased the most. On the other hand, when the number of pigeons sharing the pellets increased from four to seven, the subjective value of the shared reward decreased the least. In other words, the presence or absence of one pigeon exerted the greatest influence on the subjective value of the shared reward. The only exception to this was M9463, for which the presence of one pigeon increased the subjective value of the shared reward.

Because the pigeons exhibited a spatial bias, the following discounting equations were used, adding the bias parameter (b).

$$V = \frac{bA}{1+sN} \qquad (4)$$

$$V = bAe^{-sN} \qquad (5)$$

These nonlinear regression analyses indicated that the data were generally well described by both the hyperbolic and exponential-discount functions. The values of the discount rate (s) obtained ranged from 0.43 to 14.29 for the hyperbolic function versus from 0.30 to 3.06 for the exponential function. The values for the median coefficient of determination (r^2) and discount rate (s) calculated across subjects were 0.977 and 2.12, respectively, for the hyperbolic function versus 0.982 and 1.06, respectively, for the exponential function. For summary purposes, Figure 3 shows the group mean indifference points for the shared patch as a function of the number of pigeons.

Coefficients of determination (r^2) were compared between the fitted functions to evaluate the fits of the hyperbolic and exponential discounting functions to the data. The values of the coefficient of determination (r^2) ranged from 0.647 to 0.999 for the hyperbolic function and from 0.762 to 0.999 for the exponential

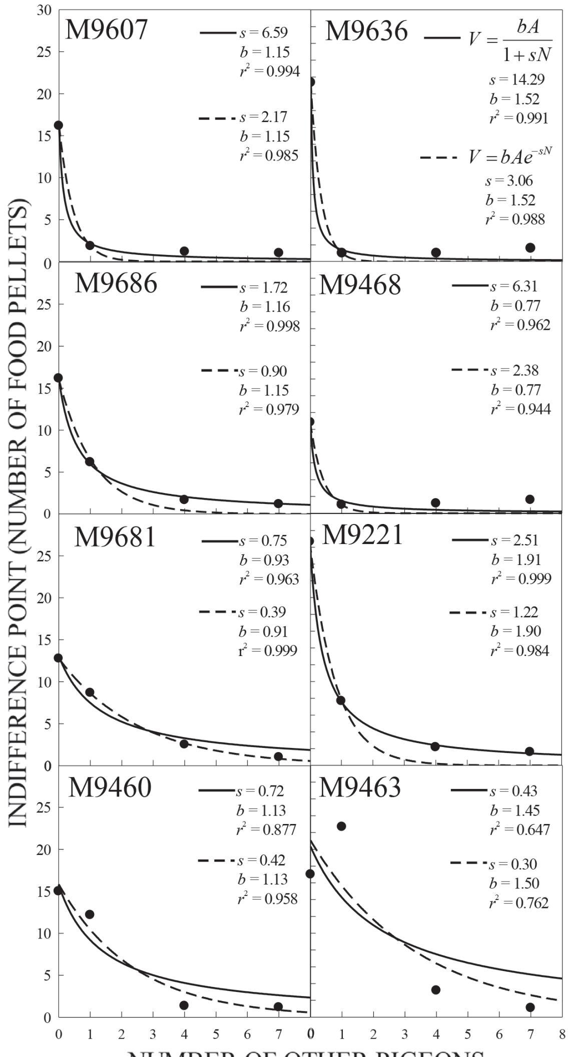

Figure 2. The mean adjusting amount for the unshared patch was subjectively equivalent to the shared patch for individual pigeons (subjective value plotted as a function of the number of pigeons). The data represent the average values over the last six sessions. The solid line represents the best-fitting hyperbolic-discount function (Equation (4)). The dotted line represents the best-fitting exponential-discount function (Equation (5)). *s* and *b* are the estimated discount rate and bias parameters, respectively. The coefficient of determination (r^2) is also presented.

function. The hyperbolic function more precisely described the data than the exponential equation for five out of eight comparisons. However, the values for r^2 were not significantly different between the functions.

Discussion

The present experiment used real, as opposed to hypothetical, rewards to investigate social discounting in pigeons. The indifference point (interpreted as subjective value) for a shared reward decreased systematically as the number of pigeons that shared the reward increased. The results were well described both the hyperbolic and exponential functions. Therefore, the same mathematical functions that have been used to describe the social discounting of hypothetical monetary rewards in humans appears also to adequately represent social discounting among pigeons choosing between real rewards. One way to identify the social-discounting function, which the present experiment did not employ, is to examine the presence of preference reversals and the reward-amount effect wherein larger amounts of shared rewards are dis-

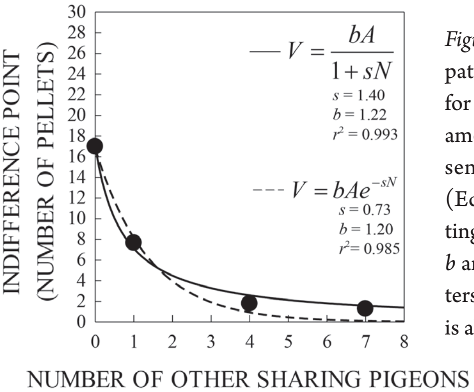

Figure 3. The mean adjusting amount for the unshared patch was subjectively equivalent to the shared patch for the group of pigeons. The data represent the median amounts among eight individuals. The solid line represents the best-fitting hyperbolic-discount function (Equation 4). The dotted line represents the best-fitting exponential-discount function (Equation 5). *s* and *b* are the estimated discount rate and the bias parameters, respectively. The coefficient of determination (r^2) is also presented.

counted less than smaller amounts. This relates to the finding in social-discounting studies with humans that more proximate social distance between individuals discounts less than less proximate social distance (Rachlin & Jones, 2008b). It remains unknown whether this same effect can be obtained in animals when real rewards are used. If the amount effect does appear in social discounting using real rewards with animals, the discounting function must be determined by the presence or absence of preference reversals. In future research, the amount effect and preference reversals in social discounting could be investigated in animals.

Because a stable dominance hierarchy exists in groups of pigeons in a food sharing or competitive context (Yamaguchi, Ito, Saeki, & Onishi, 2008), it is likely that the amount of food that is consumed by each pigeon varies depending on the combination of individuals sharing the food pellets. However, in the present investigation, of the 14 food pellets that were delivered, neither the number consumed by each pigeon nor the patterns of such consumption were known. The question of the dominance hierarchy and the assessment of the actual interaction among subjects are essential topics when considering social discounting. As noted in the introduction, in humans social-discounting rates vary, depending on whether the people who share the rewards are relatives or strangers (Ito et al., 2011). In the present experiment, the kinship relations between the individuals were unknown, but since the pigeons lived together in the flying cage, this circumstance may have influenced the results.

Under the seven shared pigeon condition, there was a pigeon that became an experimental pigeon after experiencing the shared pigeon. Therefore, there was a possibility that the pigeon was saturated when it became an experimental pigeon. Although all pigeons were maintained at 80% of their free-feeding body weights throughout the experiment, the preexposure to food pellets may affect pigeons' choices. Because of the experimental design, the present study cannot clarify this issue. It can be solved by separating experimental and sharing pigeons and the experimental pigeons do not become shared pigeons.

The paradigm of the present study is closely related to the notion of the ideal free distribution in behavioral ecology (Fretwell & Lucas, 1970). The ideal free distribution predicts that, at equilibrium, the proportion of individuals in a habitat or patch will be equal to the proportion of resources, such that the individual's fitness is maximized. Certain variables that influence ideal free distribution have been studied: the travel cost between patches (Kennedy & Gray, 1997), differences in competitive ability among individuals (Grand, 1997), and information about patches (e.g., the amounts of food and the numbers of other individuals at each patch) (Abrahams, 1986). Because these variables affect the distribution of individuals among foraging environments, they also may affect social discounting. It may be possible to predict the distribution of individuals from the degree of social discounting. For instance, Critchfield and Atteberry (2003) examined the relation between delay discounting and group foraging in college students. The patterns in patch visit duration and the probability of a switch to another patch in group foraging were highly correlated to the degree of impulsiveness interpreted from delay discounting functions. It could be expected that the degree of social discounting would be highly correlated with group foraging behavior. Furthermore, future research might usefully explore the relations among social, delay, and probability discounting.

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