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Discounting in the Pigeon:

Food-Specified Conditioned Reinforcers

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Abstract

Discounting has been observed across a wide range of species, procedures, and reinforcers. One of the main differences in the literature is that studies with humans use money (conditioned reinforcer) as the reinforcer being discounted. This is in contrast to studies with non-human animals where the discounted outcomes are usually directly consumable like food and water (primary reinforcers). At present, there is no non-human animal equivalent to money that has been identified in the discounting literature. To further bridge the remaining gaps in the methodology, a common currency is needed to study conditioned reinforcers in the discounting paradigm. An adjusting-amount procedure was used to examine the discounting of conditioned reinforcers with pigeons. Pigeons made choices of smaller, more immediate amounts of tokens or larger, more delayed amounts of tokens and then exchanged the tokens for food. Pigeons discounted token reinforcers evidenced by the decrease in subjective value as delay increased. Further, tokens were discounted less steeply than real food reinforcers. The results indicate that pigeons can discount food-specific tokens and is an important first step towards developing a generalized token reinforcer for discounting procedures with non-human animals.

Key words: discounting, tokens, conditioned reinforcers, pigeons

Discounting in the Pigeon: Food-Specified Conditioned Reinforcers

Discounting

A pervasive finding in psychology is that humans and non-human animals prefer more immediate rewards compared to rewards that are received after a delay. Further, when confronted with the choice of a smaller and larger reward, available at the same time, research predicts that the larger reward will be selected (Green, Myerson, Holt, Slevin, & Estle, 2004). Predicting behavior becomes more complicated, however, when an organism is presented with a smaller, more immediate reward and a larger, more delayed reward. Delay discounting has been established as a framework that affords researchers the ability to predict behavior related to difficult, multi-dimensional choices (e.g., Green, Fry, & Myerson, 1994; Green et al., 2004; Mazur, 2000; Myerson & Green, 1995; Odum, 2011; Vanderveldt, Oliveira, & Green, 2016). Within this framework, it is predicted that choices are influenced by the delay until the receipt of the larger reward. That is, according to delay discounting, as the delay to receipt increases, value of a reward systematically decreases.

Discounting functions can be derived from the hyperbolic equation $V=A/(1+k D)$ which has been substantiated across species and rewards—including, but not limited to, food rewards for pigeons (Mazur, 1987). In the formula, V represents the subjective (present) value of a reward or outcome, A is the total amount of the reward or outcome that was delayed, k is a free parameter that indicates the rate of discounting, and D is the length of the delay interval. The hyperbolic model accounts for the faster decrease in subjective value at shorter delays compared to longer delays (Green et al., 2004, Green, Myerson, & McFadden, 1997; Kirby, 1997; Vanderveldt, et al., 2016).

Discounting has been observed across a variety of species including humans (e.g., Green et al., 1994), pigeons (e.g., Oliveira, Green, & Myerson, 2014), rats (e.g., Green et al., 2004; Richards, Mitchell, de Wit, & Seiden, 1997), and non-human primates (e.g., Woolverton, Myerson, & Green, 2007). Impulsive behaviors such as gambling and drug abuse have also been associated with discounting (MacKillop, Amlung, Few, Ray, Sweet, & Munafò 2011; Petry & Madden, 2010; Reynolds, 2006; Yi, Mitchell, & Bickel, 2010). While the rate of discounting varies, the form of the function (i.e. the hyperbolic-like shape) is similar across species and outcomes. That is, regardless of species or reinforcer, the value of an outcome systematically decreases as the delay to its receipt increases.

The procedures used to study discounting, like the form, are also similar across species. Titration procedures (Mazur, 1987) have been well established for both humans and non-human animals—a common procedure being adjusting-amount. In an adjusting-amount procedure, two choices are presented to each individual: a smaller, more immediate outcome and a larger, more delayed outcome. Based on choices made during experimental sessions, the smaller, more immediate choice will adjust (increase or decrease) systematically in value while the larger, more delayed choice provides a standard amount of the reward after a fixed delay. Adjusting-delay procedures use similar logic; instead of amount, the delay is adjusted across trials. Studies with animals have also established concurrent-chains procedures as viable methods for measuring choice behavior (e.g., Oliveira et al., 2014; Ong & White, 2004). Concurrent-chains procedures present the choice of two different schedules of reinforcement and have the added advantage that choice behavior under such procedures displays preference for the different schedule outcomes (Grace, Sargisson, & White, 2012).

The most notable difference between discounting research with humans and non-human animals is the types of reinforcers employed by researchers. Typically, primary reinforcers are used with non-human animals in discounting procedures. Primary reinforcers or unconditioned reinforcers are stimuli that are inherently reinforcing due to some biological necessity. For example, water, food, and sexual stimulation (Mazur, 2015) are prevalent primary reinforcers. Food rewards are the most commonly utilized reinforcers in studies with non-human animals (e.g., Grace, 1999; Green et al., 2004; Oliveira, et al., 2014; Mazur, 1987; Stevens, Rosati, Ross, & Hauser, 2005), though some have employed water or saccharin (e.g., Calvert, Green, & Myerson, 2010; Farrar, Kieres, Hausknecht, de Wit, & Richards, 2003; Freeman, Green, Myerson, & Woolverton, 2009; Richards et al., 1997). In discounting with humans, researchers utilize a host of *hypothetical* outcomes such as vacations (Raineri & Rachlin, 1993), air quality (Berry et al., 2017), music and books (Charlton & Fantino, 2008), and health (Chapman, 1996). Notably, research with humans has generally avoided using food or water with discounting due to the need to deprive participants beforehand. Recently, however, researchers have begun to study real, directly consumable primary reinforcers like juice (e.g., Jimura, Myerson, Hilgard, Braver, & Green, 2009; McClure, Ericson, Laibson, Loewenstein, & Cohen, 2007). These studies have found similar results as previous research; specifically, the form of the function was similar across real and hypothetical primary and conditioned reinforcers with humans. Interestingly, the two studies addressing real liquid rewards also found that discounting by people was similar to that of non-human animals when the delays and amounts of the reinforcer were similar to the delays and amounts used in research with non-humans.

Despite the wide variety of outcomes present in the literature, hypothetical money is the most common reinforcer used in human discounting research (e.g., Green et al., 1997; Green, Myerson, Oliveira, & Chang, 2013; Johnson & Bickel, 2002; Kirby & Maraković, 1996; Raineri & Rachlin, 1993; Thaler, 1981). A lower rate of discounting for money has been well established across multiple studies suggesting a relatively greater value associated with money compared to other reinforcers (e.g., Bickel, Odum, & Madden, 1999; Estle, Green, Myerson, & Holt, 2007; Odum & Rainaud, 2003). Interestingly, Lagorio and Madden (2005) reported that people tend to display the same patterns of discounting across both real and hypothetical outcomes (cf. Baker, Johnson, & Bickel, 2003). Taken together, all of the previous discounting research with humans suggests that both tangible and intangible non-primary reinforcers are reliable reinforcers.

Similar to psychologists, economists typically study human behavior involving money but some have also utilized rats and pigeons. Kagel, Battalio, and Green (1995) outline several examples of cross species similarities in regards to economic principles usually studied with people. For instance, it is possible to determine the reinforcing value and substitutability of different reinforcers/commodities (e.g., Green & Freed, 1993; Hursh, 1978), different reinforcers are subject to different levels of elasticity (e.g. Raslear, Bauman, Hursh, Shurtleff, & Simmons, 1988), and uncertainty is similar among rats, pigeons, and humans (e.g. Kagel, Green, & Caraco, 1986). In regards to the latter, non-human animals display risk-averse behavior when faced with gains, and risk-loving behavior when faced with losses. Currently, there is no clear way to establish a translation of gains to losses (or vice versa) with non-human animals—again, like the magnitude effect, developing a money-like reinforcer with non-human animals might be the key. This research, in concert with theories of adaptation from biology and psychology, indicates that non-human animals behave in a comparable manner to humans under similar economic constraints.

A robust finding in human discounting research is the presence of magnitude effects. That is, larger amounts of a reward are discounted less steeply than smaller amounts (e.g. Kirby, 1997; Kirby & Maraković, 1996; Raineri & Rachlin, 1993). Research has found magnitude effects across a variety of hypothetical outcomes {e.g. cigarettes (Baker et al., 2003; Bickel et al., 1999), music and books (Charlton & Fantino, 2008), beer and candy, (Estle et al., 2007) and vacations (Raineri & Rachlin, 1993)} as well as real money (Baker et al., 2003) and liquid rewards (Jimura et al., 2009; McClure et al., 2007). Comparatively, magnitude effects are most clearly displayed when money is the reinforcer in question. Although pervasive within the discounting literature studying humans, research with non-human animals has yet to reliable provide evidence for a magnitude effect in discounting—establishing a money-like reinforcer with animals could be the key.

Money, unlike food or water, is a conditioned reinforcer. Conditioned reinforcers derive value from the association between that conditioned reinforcer and a primary reinforcer (Wolfe, 1936). More specifically, money is a generalized conditioned reinforcer meaning that the reinforcing value of money is dependent on its relationship with all of the possible stimuli for which it can be exchanged (Ferster & Perrott, 1968; Kelleher & Gollub, 1962; Mazur, 2015; Skinner, 1953). Thus, a gap in the discounting literature remains due to the fact that studies with humans have investigated primary and conditioned reinforcers as well as real and hypothetical reinforcers, and non-human animal research has utilized only real, primary reinforcers. Specifically, within a discounting framework, a comparable reinforcer to money does not exist with non-human animals. Researchers need to examine the use of conditioned reinforcers, in a discounting framework, with non-human animals to garner a more complete understanding.

Token Economies

Since humans made the transition to less transient lifestyles (i.e., agricultural), tokens—as a form of currency—have been the foundation of economic interactions (Hackenberg, 2009) and, in more recent history, have been employed in behavior analysis and behavior management (Ayllon & Azrin, 1968). In the token economic framework, behavior analysts present arbitrary tokens (e.g., points, poker chips, stickers, etc.) to participants when predetermined behaviors are emitted. Accumulated tokens can then be exchanged for a range of reinforcers (e.g., food, access to TV, toys, money, etc.). Token economies have proven to be useful tools in a multitude of settings such as hazardous work environments (Fox, Hopkins, & Anger, 1987), schools, hospitals, prisons, student housing, and across various populations (Kazdin, 1977; Kazdin & Bootzin, 1972). An advantage of token economies is the possible application of a common currency. Since tokens are fungible, a standardized unit of measure might allow researchers to compare token spending rates across individuals and species (Hackenberg, 2009). Establishing reliability and generalizability of tokens with non-human animals could lead to such a common currency.

As early as the mid 1930's researchers have investigated the effects of token reinforcement with non-human animals. In a series of experiments, Wolfe (1936) studied the relative effectiveness of token-reinforcement compared to food-reinforcement with chimpanzees. During one experiment, chimpanzees discriminated between tokens exchangeable for food and tokens exchangeable for nothing. The chimpanzees demonstrated greater preference for the tokens associated with food over the tokens that had no value. A subsequent experiment assessed behavior acquired and maintained using tokens and those behaviors maintained by food. That is, under different fixed ratio (FR) requirements to produce tokens, chimpanzees' responding was both acquired and maintained by conditioned token reinforcers in both experiments. Wolfe reported that tokens consistently and effectively produced similar levels of behavior as food—this effect however, was slightly less than that of food. Cowles (1937) provided further evidence of token effectiveness by implementing a delay to exchange. Chimpanzees worked for tokens in a similar manner as Wolfe (1936) but were required to wait until a certain amount of tokens had been accumulated (i.e. 10 or 30 tokens) before they could exchange for food. Behavior was also effectively maintained under such conditions. Research using set schedules of reinforcement to produce tokens with rats provided further evidence that token efficacy in maintaining behavior with non-human animals (Malagodi, 1967). Interestingly, Malagodi, and other researchers (e.g., Bullock & Hackenberg, 2006; Kelleher, 1958), reported that on various schedules of reinforcement non-human animals respond similarly (e.g., stop-and-go responding under FR conditions) for tokens as they do for primary reinforcers. Basic research such as the aforementioned experiments helps solidify the case for token reliability and generalizability across species provide foundational support for using tokens to study other procedures (e.g., discounting tasks) and other processes (e.g., impulsivity).

Several studies have directly assessed self-control and impulsivity—which have been implicated with discounting—using token economies. Flora and Pavlik (1992) manipulated reinforcement density across a more immediate (impulsive) and a more delayed (self-control) choice. The authors found that when greater reinforcement density was correlated with the self-control choice, adults displayed more self-control—a result consistent with previous literature (i.e., Logue, Pena-Correal, Rodriguez, & Kabela, 1986). Similarly, Hyten, Madden, and Field (1994) and Logue, King, Chavarro, and Volpe (1990) provided evidence that participants predictably choose larger, more delayed amounts of tokens when exchange delays are equal. A critical finding across self-control studies with humans has been that the delays to exchange stimuli are more influential than delay to conditioned reinforcer presentation (Hyten et al., 1994).

Experiments assessing self-control for tokens with pigeons have demonstrated similar results to those reported in the studies with humans. Like humans, pigeons show a preference for larger amounts (self-control) of tokens when exchange delays are held constant across choices. Additionally, pigeons' relative insensitivity to token presentation delays (Jackson & Hackenberg, 1996) is similar to experiments with humans and delivered points (Logue, 1988). Related to the previous research (i.e., Flora & Pavlik, 1992; Logue, 1988), the experiments with pigeons suggest that the aggregate amount of tokens accumulated across choices may be more reinforcing than individual presentations of tokens (Jackson & Hackenberg, 1996). Finally, and most importantly, pigeons' choices appear to be governed by the delay to exchange stimuli (cf. Bullock & Hackenberg, 2006; Hackenberg & Vaidya, 2003; Jackson & Hackenberg, 1996).

Holt, Glodowski, Smits-Seemann, and Tiry (2016) measured participants' subjective value for reinforcers and gift cards for those reinforcers (i.e., pizza/gift cards for pizza, candy/grocery store gift cards, and money/Visa gift cards) across several delays within an adjusting amount procedure. Gift cards, being conditioned reinforcers like money, can be conceptualized as tokens (see Hackenberg, 2009; Wolfe, 1936). The authors reported that as reinforcer fungibility increased, the rate of discounting decreased (the reinforcer maintained relatively greater value across greater delays). Specifically, the researchers found that rates of discounting for gift cards for pizza (specific conditioned reinforcers), while similar, were lower than the rates for actual pizza slices. The difference in rates of discounting between the grocery store gift cards (generalized conditioned reinforcers) and candy were greater than the former; in this case, grocery store gift cards were more generalizable than pizza gift cards, though still constrained. The lowest rate of discounting was found with Visa gift cards (generalized conditioned reinforcers), which, of the three types of gift cards, had the highest level of fungibility in the study. Since the pizza gift cards held little fungibility, the difference between pizza and pizza gift cards was likely a factor of the relatively greater durability of the cards—a trait typical of most tokens (Ayllon & Azrin, 1968).

DeFulio, Yankelevitz, Bullock, and Hackenberg (2014), provided the first evidence of tokens acting as generalized conditioned reinforcers with pigeons. The authors compared food-specific, water-specific, and generalized tokens for food or water across multiple different FR requirements. They found that, typically, generalized tokens held more value across increasing FR requirements than the specific-conditioned reinforcers. Specifically, as price (FR requirement) increased, generalized tokens remained relatively inelastic. DeFulio and his colleagues spanned the gap between human and non-human animal research by utilizing generalized conditioned reinforcers (compared to the previously exclusive use of specified conditioned reinforcers) and further established token economies as viable methods for the continued analysis of behavior with non-human animals.

The Present Study

Money is a ubiquitous reinforcer that has dominated discounting research with humans. At present, though, there is no equivalent reinforcer to money for non-human animals. In an attempt to bridge the methodological gap in the literature and create a common currency, research needs to establish tokens as viable reinforcers for non-human animals within the discounting paradigm so that more direct comparisons can be made across species. The present experiment sought to examine the effect of food-specified conditioned reinforcers on rates of discounting with pigeons. To investigate the effects, the current study utilized an adjusting-amount procedure in which choices produced tokens that could later be exchanged for food. If pigeons discount conditioned reinforcers, then the value of the tokens will decrease as a function of increasing delay. Further, the rate of discounting for food-specified conditioned reinforcers should be relatively lower compared to the rates of discounting for food.

Method

Subjects

Four White Carneaux pigeons were individually housed in a room with a 12:12 hour light and dark cycle. All of the pigeons were experimentally naive. Each of the pigeons was maintained at 80-85% of their free-feeding weights with supplemental feedings immediately after each session. Water and grit were continuously available in the pigeons' housing environment.

Apparatus

The present study utilized a Med Associates modular test chamber (ENV-007CT) which was 32.0 cm long, 25.5 cm wide, and 34.0 cm high and was placed inside a light and sound attenuating enclosure with a continuously running ventilation fan (F8025E24B). Chamber floors were stainless steel grids (ENV-005P). One 12-inch Acer brand monitor used Microsoft PowerPoint to display accumulated tokens during the session and consisted of 82 slides. Slides were operated by two sound clickers (ENV-135M) attached to a Makey Makey™ that was connected to a second computer.

The operant boxes included four circular response keys, all 2.5 cm in diameter; three (ENV-123AM) positioned on the left side of the chamber (production panel), one (ENV-130M) on the right side (exchange panel). The monitor displaying PowerPoint (token panel) was situated at the back of the operant box between the production and exchange panel. Response keys were located 12 cm from the top of the chamber and spaced equidistantly. On the production panel, the center key was illuminated white when active, and the left and right keys were illuminated red and green when active, respectively. Light emitting diodes (LEDs, ENV-222M) were located 5.5 cm above the left and right response keys (7.5 cm from the top) on the production panel and included the colors green, yellow, and red. The same color LED illuminated in accordance with the respective response key color. There were no LED cue lights on the exchange panel.

On the exchange panel, a single response key was located 12 cm from the top of the chamber. The exchange key was illuminated with a single white triangle on a black background. A directional light (ENV-315M) was located 3 cm from the top of the chamber on the exchange panel and 9 cm above the exchange key. A food magazine (ENV-200R2M) was located 7.5 cm below the exchange key and delivered 20 mg food pellets (Bio Serv Dustless Precision Pellets/Product #F0115). Food pellets were dispensed one at a time every 0.3 s during reinforcement (ENV-203-20).

Procedure

The present study used an adjusting-amount procedure with a key peck response requirement at four delay conditions (2, 6, 10, 16s). Across delay conditions, the standard alternative consisted of 20 tokens delivered after the current fixed delay. The adjusting alternative always began with 10 tokens delivered almost immediately but was either increased or decreased depending on how responding was distributed.

Sessions were conducted daily and consisted of 10 blocks. If all 10 blocks were not completed, the session terminated after 90 minutes. Blocks consisted of two forced-choice trials, an exchange trial, two free-choice trials, and a second exchange trial. Forced-choice trials served the purpose of demonstrating the current value of the standard alternative and the adjusting alternative before initiating the free-choice trials. Pseudo-random determination assigned the order of the forced-choice trials; initial presentation of the smaller-sooner option (adjusting amount) followed by the larger-later option (20 tokens, standard amount), or the reverse. Free-choice trials, presented after forced-choice trials, consisted of both choice alternatives being available simultaneously. An exchange period always followed both the second forced-choice trial and the second free-choice trial.

The illumination of the middle key on the production panel and house light signaled the start of a trial. A response on the middle key, during forced-choice trials, darkened the middle key and illuminated the left or right key. Responding on the middle key, during free-choice trials, darkened the middle key and illuminated both the right and left key. The standard response option (right key illuminated green) was associated with the larger-later reinforcement amount. A response on the standard alternative darkened the key and illuminated a green cue light signaling a delay (i.e., 2, 6, 10, or 16s). After the delay, the green cue light was extinguished and the standard 20 tokens were delivered and displayed on the token panel. Slide one had a plain black background. Slide two consisted of the same black background with a singular white circle in the top left corner. Subsequent slides consisted of the same black background as slides one and two, but contained one more white circle than the previous slide. White circles (tokens) were added in rows of 10 to the screen from left to right starting in the top left corner of the slide and continued to fill in row by row. Tokens were added to the monitor screen by moving forward through the PowerPoint slides. A maximum of 80 tokens could be earned per block (800 per session). An inter-trial-interval (ITI) followed a response on either the adjusting or standard response key ending after 35 s. A 30 s ITI began following a response on the exchange key. The rate of (or opportunity for) reinforcement by tokens was held constant regardless of choice.

The adjusting amount option (left key illuminated red) was arranged identically to the procedure for the standard alternative, except that token delivery was nearly immediate (≈0.05 s) and the distribution of choices, from the previous block of trials, determined the number of delivered tokens. The adjusting alternative increased by 1 token for the subsequent block if the standard alternative was chosen on both free-choice trials in the preceding block. The adjusting alternative decreased by 1 token for the subsequent block if the adjusting alternative was chosen on both free-choice trials in the preceding block. No change occurred to the adjusting alternative for the subsequent block if both alternatives were chosen in free-choice trials in the preceding block. All subsequent sessions, of the same condition, started at the adjusting amount of the last block of the preceding session. Regardless of the current number of tokens deliverable from adjusting alternative, any tokens delivered from responses to the adjusting alternative appeared on the monitor screen via the token panel (identical to the standard response).

The exchange trials consisted of the illumination of the exchange key (white triangle on a black background) on the panel opposite of the production panel. A response on the exchange key extinguished the key light and immediately exchanged all of the accumulated tokens during the block. As one pellet was delivered, one token was removed from the token panel by moving backwards through the PowerPoint slides. Pellets were delivered by a pellet hopper located outside of the test chamber to the magazine below the exchange key.

Conditions were in effect for a minimum of 20 sessions, and ended when the data from five consecutive sessions had met stability criteria. Stability was evaluated by dividing each session into two half-sessions consisting of five blocks each. The mean number of tokens delivered for a response on the adjusting amount key was calculated for each half session. Conditions terminated when the means of all 10 half-sessions were within plus or minus 2 tokens of the grand mean and no trends were visible. An indifference point was then calculated for every condition. Defined by the average number of delivered pellets from the smaller-sooner (adjusting) side from the previous five sessions, the indifference point served as the dependent variable.

Token Training I

Before beginning the full experimental procedure, all subjects were exposed to the training procedure in order to pair tokens with the food pellets. The training procedure functioned similarly to the full procedure. In this case, the difference being that instead of two forced-choices and two free-choices before an exchange period, an exchange period was available after every choice. Training sessions lasted for 10 blocks or 100 minutes like the full procedure. One block consisted of one forced choice and then an exchange period, a second forced choice and an exchange period, a free-choice and an exchange period, and a second free-choice and an exchange period. All subjects were exposed to Token Training I at a 2 second delay for a minimum of 10 days. Pigeons changed procedures only after completing full training sessions in 10 subsequent days.

Token Training II

After completing 10 full sessions in a row, subjects were switched to the second token training procedure in order to pair tokens with the food pellets. The training procedure functioned similarly to the first token training procedure; in this case, instead of an exchange period after every choice subjects made, an exchange period was available after every two choices subjects made. Training sessions lasted for 10 blocks or 100 minutes like the full procedure. One block consisted of two forced choice trials followed by an exchange period and then two free-choice trials followed by an exchange period. The rationale for the second training procedure was to ensure that tokens and food were paired across forced and free choices (2:1 exchange ratio compared to 1:1). All subjects started the procedure at a delay of 2 seconds for a minimum of 10 days. After 10 subsequent days of full sessions, subjects were exposed to the same procedure at a 16 second delay. After 10 complete sessions, subjects began the full token discounting task.

Results

Figures 1 and 2 depict individual indifference points for pigeons 1, 2, 4, and 7. Indifference points are the point at which preference for the smaller, more immediate alternative is, subjectively, equivalent to the larger, delayed alternative. For pigeons 1, 2, and 4, previously collected data with food is also presented—pigeon 7 was not a subject in that study. Indifference points obtained for tokens in the present study are depicted as squares and indifference points obtained previously for food are depicted with triangles. At the individual level, indifference points decreased as the delay to the larger alternative increased. For pigeons 1, 2, and 4, tokens were discounted less steeply compared to food pellets. Pigeon 7 displayed a steeper rate of discounting for the tokens compared to the other three pigeons but was still qualitatively similar.

Figure 3 displays the mean indifference point at all four delays for all four pigeons. Using SigmaPlot, nonlinear regression was used to determine the goodness of fit of the hyperbolic equation to the average data. The predicted values are presented as a solid line. The data were well described by the hyperbolic discounting equation with an R^2 of .72. Again, at the group level, indifference points for tokens were discounted less steeply compared to those for food. The indifference points also decreased in a manner consistent with delay discounting. That is, subjective value of the tokens decreased as the delay increased.

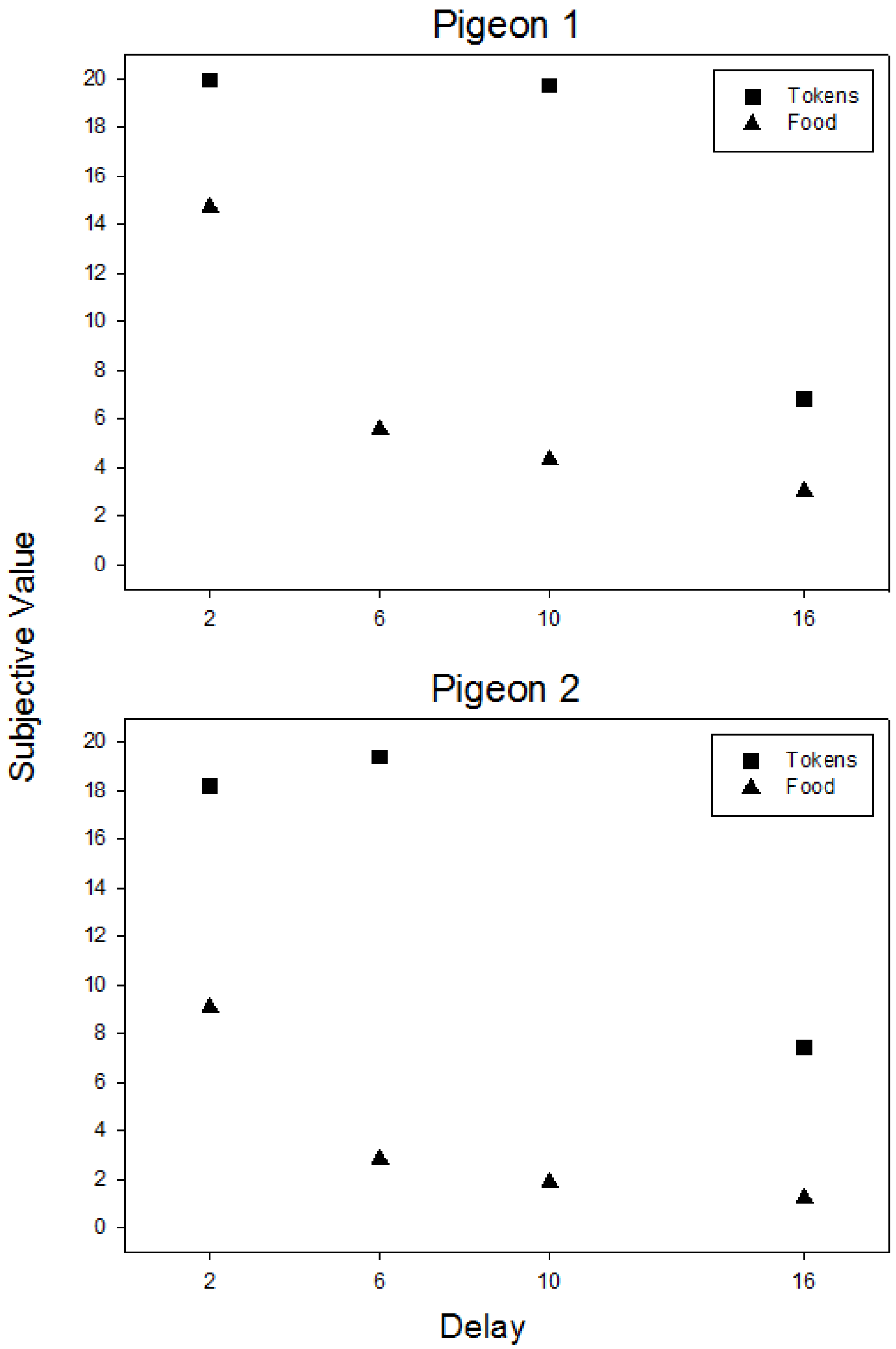

Figure 1. Indifference points for Pigeons 1 (top panel) and 2 (bottom panel) across all four delay conditions. For both panels, indifference points for tokens (squares) and food (triangles) are presented.

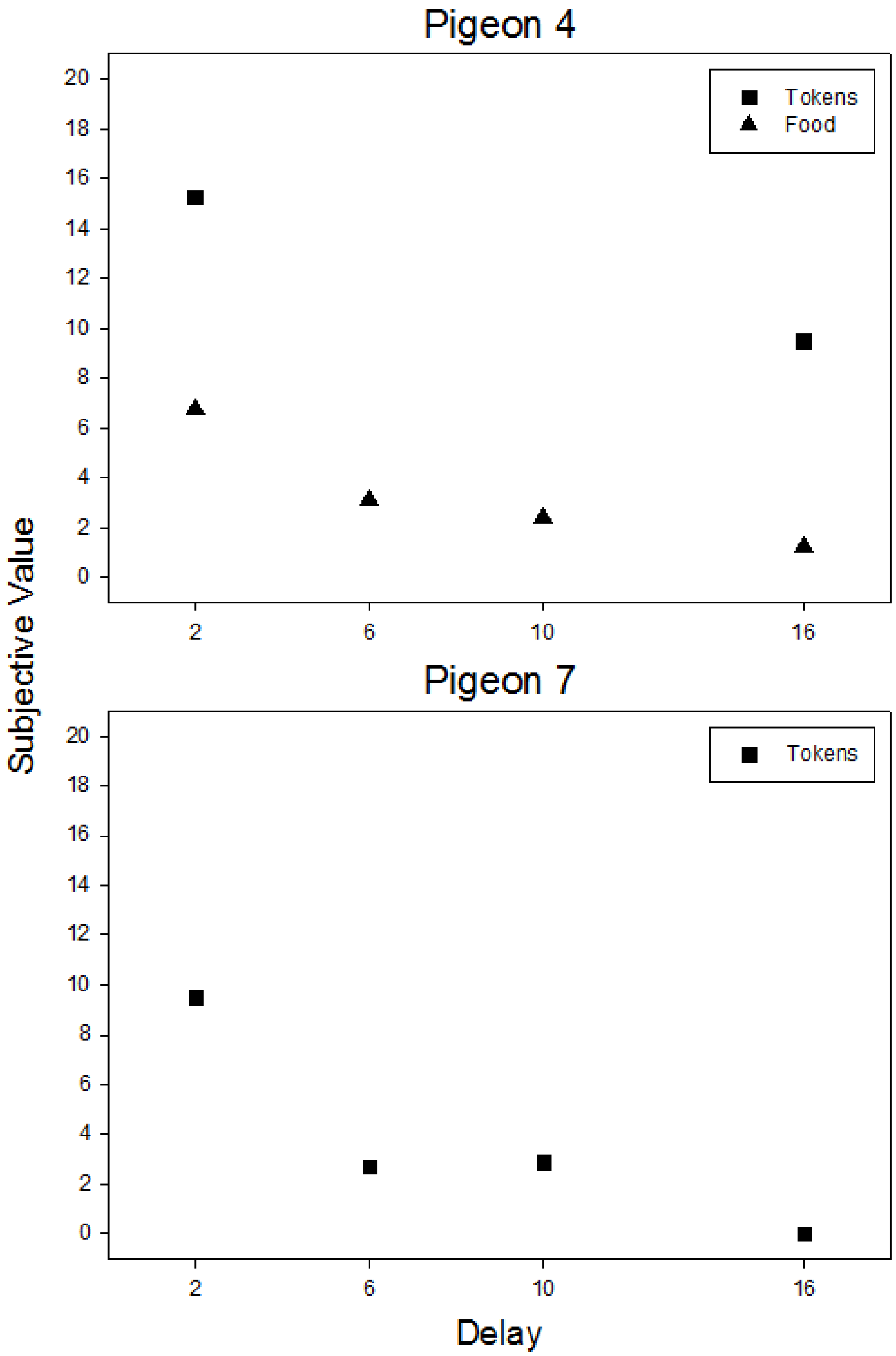

Figure 2. Indifference points for Pigeons 4 (top panel) and 7 (bottom panel) across all four delay conditions. For the top panel, indifference points for tokens (squares) and food (triangles) are presented. For the bottom panel, only indifference points for tokens are presented.

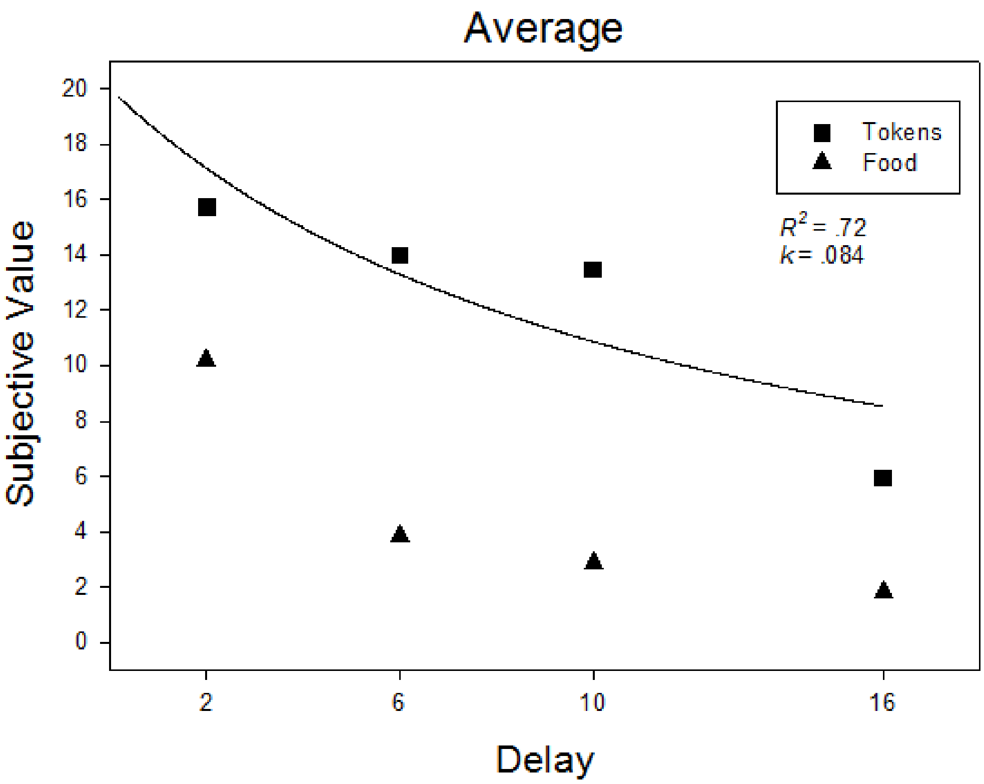

Figure 3. Mean indifference points for tokens (squares) and food (triangles) across subjects are presented for each delay. Predicted values displayed as a solid line.

Discussion

The present experiment sought to examine the use of food-specified tokens in a discounting procedure with pigeons. An adjusting-amount procedure with two choice alternatives produced a smaller, immediate and a larger, delayed amount of tokens that could, later, be exchanged for food. The procedure was designed to investigate pigeons' ability to discount conditioned reinforcers. Further, the study also aimed to determine if those conditioned reinforcers would be discounted differently from real food reinforcers.

Overall, subjective value of the tokens decreased as the delay to the larger choice increased indicating that pigeons can discount conditioned reinforcers. This effect was evident across all four subjects at the individual level and the group level. Pigeons 1, 2, and 4 displayed less discounting relative to pigeon 7 but all subjects display qualitative similarities. Further, less discounting was displayed for the conditioned reinforcers relative to that of food reinforcers. This effect was evident at the individual level (for pigeons 1, 2, and 4) as well as the at the group level. The shallower rate of discounting for conditioned reinforcers is suggestive that the conditioned reinforcers may have been serving as tokens.

Given the current data it appears that the conditioned reinforcers used in the experiment were acting as token reinforcers. First, as previously mentioned, the rate of discounting for the tokens was less steep than the rate of discounting for food reinforcers. Research using token economies with humans and non-human animals evidences the fact that tokens bridge the delay between a behavior and the presentation of a terminal reinforcer (Hackenberg, 2009; Kazdin & Bootzin, 1972; Williams, 1994; Wolfe, 1936). That is, tokens serve to maintain behavior in the presence of extended delays to the terminal reinforcer and reduce the effects of extinction (Ferster & Perrott, 1968). The present results are also similar to the results reported by Holt et al. (2016). Specifically, pizza-specified gift cards maintained greater subjective value across increasing delays compared to slices of pizza. Food-specified tokens in the present experiment also maintained greater subjective value relative to food pellets.

Other evidence for the conditioned reinforcers acting as tokens is that latency to respond decreased as the presentation of exchange stimuli approached. Measuring response latency to the first choice trial and the second choice trial revealed a pattern consistent with previous research (DeFulio et al., 2014; Kelleher, 1958). Specifically, the time to respond to the first choice alternative in a set was consistently longer than the time to respond to the second choice alternative, across all four delay conditions, at both the individual and group level (see Table 1). Additionally, tokens display both a reinforcing and discriminative function within token economy arrangements. The current response latencies mirror the pattern reported by DeFulio and his colleagues that indicate, due to their temporal relation to the exchange stimuli and the terminal reinforcers.

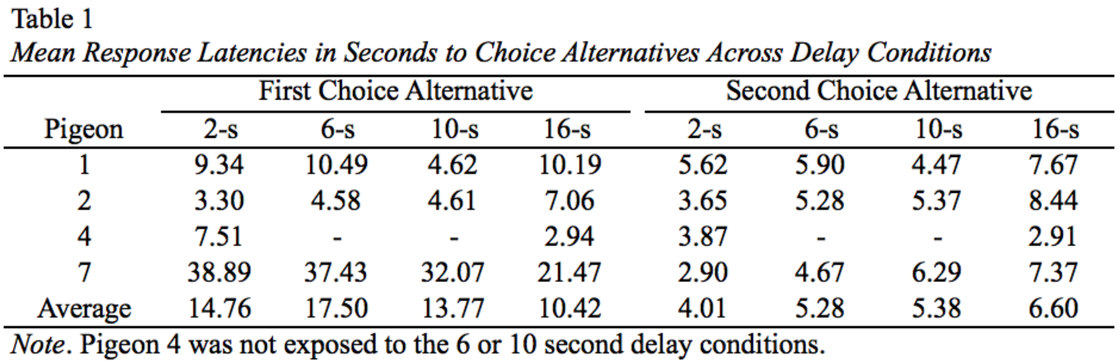

Table 1

Mean Response Latencies in Seconds to Choice Alternatives Across Delay Conditions

	First Choice Alternative				Second Choice Alternative			
Pigeon	2-s	6-s	10-s	16-s	2-s	6-s	10-s	16-s
1	9.34	10.49	4.62	10.19	5.62	5.90	4.47	7.67
2	3.30	4.58	4.61	7.06	3.65	5.28	5.37	8.44
4	7.51	-	-	2.94	3.87	-	-	2.91
7	38.89	37.43	32.07	21.47	2.90	4.67	6.29	7.37
Average	14.76	17.50	13.77	10.42	4.01	5.28	5.38	6.60

Note. Pigeon 4 was not exposed to the 6 or 10 second delay conditions.

Anecdotally, the pigeons in the current study typically oriented towards the tokens after being produced on the screen. Besides looking towards the token screen itself, the pigeons also attempted to peck at the tokens. This might be indicative of an auto-shaping like process that takes place with stimuli that are highly associated with primary reinforcers. Overall, these observations resemble those reported by Jackson and Hackenberg (1996) whose pigeon subjects also oriented toward and pecked at the token stimuli as well as other elicited consummatory behavior (Cowles, 1937; Kelleher, 1958).

Although the results support the notion that the tokens are functioning as tokens, other explanations cannot be ruled out. One alternative explanation is that the delay to the exchange stimuli is more important than the delay to the tokens (Hyten et al., 1994; Jackson & Hackenberg, 1996; Logue et al., 1990). In an extension of Jackson and Hackenberg's experiment, Hackenberg and Vaidya (2003) also reported similar effects. Specifically, the researchers note that when delays to exchange stimuli and delays to food are equal choices appear to be governed by the amount of the reinforcer (i.e. self-control). In the current procedure, regardless of the delay to tokens for either choice alternative, the delay to the exchange key was held relatively constant. That is, after the standard or adjusting keys were pecked on a choice trial, a thirty five second ITI started. In this arrangement a minimum of 70-s was required to elapse before the exchange key was illuminated and active—regardless of the previous two choices. Food was also immediately delivered after a peck to the exchange key keeping the delay to food after the exchange stimulus equal as well. It flows logically then that, given the present experimental arrangement, the choices could be influenced by the reinforcer amount and increase self-control (i.e. choosing the larger, delayed alternative more often).

The procedure itself may account for another possible explanation of the obtained results. Specifically, the adjusting-amount procedure utilized in the experiment is also an added-stimulus schedule (Ferster & Skinner, 1957; Foster, Hackenberg, & Vaidya, 2001) within an extended-schedule. A possible explanation for the difference between rates of discounting for tokens and the rates of discounting for food could be that the pigeons' behavior is under the control of the overall delay to the terminal reinforcer as in extended-chain schedules. Research with humans (Green, Myerson, & Macaux, 2005) and pigeons (Calvert, Green, & Myerson, 2011) using double delay procedures indicate that increasing the delay to reinforcement for both alternatives reduces rates of discounting. The extended delay to primary reinforcement in the current procedure, which is similar to previous research (e.g. Jackson & Hackenberg, 1996) might be influencing relative preference for the larger, delayed alternative.

Another consideration must be the arrangement of the token economy itself. First, Kagel, et al. (1995) note that token economies are systematically affected by similar constraints as typical economic systems. Changes in price and wage could have drastic effects on behavior within the economy. Additionally, the degree of use for the tokens outside of the economy can impact choice behavior. For example, when tokens can be used outside of an economy, saving behavior is observed among participants. In contrast, when tokens have no use outside of the economy, consumption increases, and saving is almost nonexistent.

Second, tokens delivered after the first choice trial—before an exchange—were present during the second choice trial. According to Mazur (1997), some subjects may learn a discrimination when conditioned reinforcers that are present at times when no primary reinforcers are ever delivered (e.g. tokens from the first choice trial present during the second choice trial). It's possible that the choice trials and token presentation arrangement produced some discriminative function such that it influenced preference towards the larger, delayed alternative. The discriminative functions bear important behavioral influences such as patterns of discriminated responding (DeFulio et al., 2014) and continued token production (Yankelevitz, Bullock, & Hackenberg, 2008).

Third, research has provided evidence that token density and accumulation have effects on behavior. Density can be defined as the number of tokens earned per second and calculated as the amount of the reinforcer divided by the total amount of time between reinforcements. The results of Flora and Pavlik's (1992) experiment indicate that the choice associated with a greater density will be preferred. However, when postreinforcer delays are used, preference favors self-control choices (i.e. larger, delayed alternative) due to relatively greater density. Again, the thirty five second ITI that was required to elapse before another choice trial or exchange trial were available might be influencing the preferred larger, later option in the present experiment. Tokens that accumulate before an exchange serve several discriminative purposes related to the second point above. A repeated result reported in the literature is that accumulated tokens enhance the discriminative functions of those tokens (e.g. Jackson & Hackenberg, 1996). Yankelevitz et al. (2008) manipulated their procedure to remove the presentation of tokens while maintaining all other contingencies. Under such manipulations, accumulation among the pigeons decreased suggesting that delivered tokens may functions as discriminative stimuli for continued work for tokens. Taken together, the overall greater token density associated with the larger, delayed choice in the procedure, and the fact that tokens accumulated between the two choice trials prior to exchange, may be influencing the observed differences in rates of discounting.

Future research should focus on further investigating the effects, and control, of tokens within a discounting framework. An important manipulation would be to remove the token stimuli (see Yankelevitz et al., 2008) while preserving the contingencies of the adjusting-amount procedure. This would serve two purposes simultaneously: (a) it would investigate the control of the tokens as conditioned reinforcers and (b) it would help parse apart the issue of the extended delay to terminal reinforcement. If choice behavior extinguished, then the removal of the tokens would evidence the tokens as being effective reinforcers controlling choice behavior. Furthermore, it would also suggest that the influence of the delay to the primary reinforcer was not the driving factor behind the observed differences in rates of discounting.

Research should also target other uses of tokens within a discounting framework. Specifically, to complement the present results, experiments should test the ability of pigeons to discount tokens specified for water reinforcers. This would be a necessary step to ensure that tokens can be paired with other reinforcers besides food for non-human animals. Experiments investigating pigeons' discounting rates for generalized tokens is another crucial step. Since most of the discounting research, and economic research, with humans uses money as the reinforcer, it is important that science develop a money-like analogue (common currency) for use with non-human animals. Investigating the actual value of food, water, and token reinforcers with non-human animals (e.g. rapid demand curves, Raslear et al., 1988). Overall, developing generalized tokens within a discounting framework could help provide insight behind economic variables and other observed phenomena (e.g. magnitude effects) under more experimental control typically afforded to research with non-humans.

The present study evaluated the ability of pigeons to discount token reinforcers using a standard adjusting-amount procedure. Continued research is required to better understand the observed effects as well as the nature of token reinforcers in a choice context with non-human animals. Token economies have been well developed with human populations and even relatively well established with non-humans. However, the lack of a validated, money-like analogue for non-humans prohibits complete cross-species comparisons and constrains our understanding of human behavior. A generalized conditioned reinforcer (e.g. money) would help close the methodological gap that presently separates human and non-human animal discounting research.

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