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Insensitivity to Post-Reinforcement Delay in the Choices of Pigeons and Humans

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Abstract

Research on choice behavior has helped us to identify many of the variables that determine the decisions we make, leading to better predictions of these behaviors and the development of technologies for their modification. However, research on decision-making in situations of negative punishment is scarce compared to other conditions, such as reinforcement or positive punishment, at least in studies with non-human subjects. The present paper tries to address this question through four experiments on choice behavior by pigeons and humans. The aims of the first experiment (with four pigeons) were to study the validity of considering the duration of access to the reinforcer as the length of the delay of the consequence, and the duration of the inter-trial interval as the degree of negative punishment, in a concurrent program in which these parameters were varied. Results showed insensitivity to the length of the inter-trial interval, a phenomenon that was replicated with forty-seven human participants under an analogous procedure in experiment 2. Experiment 3 (with four pigeons and fifty-one humans) and experiment 4 (with twelve pigeons and one hundred ninety-seven humans) explored the efficacy in increasing this sensitivity of including differential contexts during post-reinforcement delays and/or commitment response. Results revealed a greater isolated effect of the commitment response and a markedly reduced effect of the differential contexts. The main conclusion of this work is that choices are affected very little by the duration of the post-reinforcement delay, although this insensitivity can be slightly reduced by requiring a commitment response.

Key words: self-control, post-reinforcement delay, commitment response, pigeons, humans.

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Novelty and Significance

What is already known about the topic?

- Research on choice behavior has largely focused on positive reinforcement procedures.
- Very little is known about choice under negative punishment situations.

What this paper adds?

- Post-reinforcement delay has little effect on choice behavior.
- Requiring a commitment response slightly reduce insensitivity to post-reinforcement delay.

Laboratory research on choice behavior has largely been carried out by analyzing the behavior of subjects when faced with concurrent reinforcement programs. The earliest studies in this field (Herrnstein, 1961) supported that subjects' choices, measured as the localization of their responses in the first or second of two options, were a function of the relative frequency of reinforcement of each available alternative. The results of those experiments generated the definition of the *Matching Law* (Herrnstein, 1970): (B1/B2) = (r1/r2), where 1 refers to one of the alternatives and 2 to the summation, B are the choices, and r is the value of the reinforcer (usually frequency, though it may also be magnitude or quality).

Extensive empirical support immediately accrued to this relation between the frequency of positive reinforcement and subjects' choices (Catania, 1963; Schneider,

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1973; Stubbs & Pliskoff, 1969). In addition to developing studies with the goal of proving the validity of this law using other types of procedures, such as negative reinforcement, escaping from shocks under a concurrent IV-IV program (Baum, 1973; Hutton, Gardner, & Lewis, 1978; Logue & De Villiers, 1978), or positive punishment, this approach has been combined with protocols that apply positive reinforcement in each component (Deluty, 1976; Holz, 1968).

One topic that has generated enormous interest in choice research is the phenomenon of self-control, closely related to "delay discounting" (Green, Myerson, Lichman, Rosen, & Fry, 1996). In contrast to impulsive behavior, self-controlled behavior has traditionally been conceived as the choice of the option with greater relative reinforcement value but also a longer delay. This means that concurrent programs (usually with two components) have been used in protocols that manipulate the time between the emission of the response and the appearance of the consequence (delayed reinforcement), and the value of the positive reinforcer (in terms of quantity, frequency, duration, or quality). This type of approach thus entails contingencies of positive reinforcement (Green & Snyderman, 1980; Ito & Asaki, 1982; Navarick & Fantino, 1975; 1976; Rachlin & Green, 1972) and considers impulsive behavior as choosing the option that has lower, but more immediate, reinforcement magnitude. It further holds that based on subject's choices it is possible to calculate the subjective value of the reward in relation to the time of delivery as a hyperbolic function (Mazur, 1987).

The use, or exclusion, of aversive stimulation does not affect the conceptualization of these two behaviors if the program components apply a reinforcement procedure. Concretely, using negative reinforcement procedures generates impulsive or self-controlled behavior of the type known as escape (or avoidance), though by the same token opting to escape from an aversive event that has lower relative (i.e., lower time of disappearance of the aversive event, lower reduction of the intensity of the aversive event, etc.) but more immediate value would be considered impulsive. Many of the studies that have evaluated these types of behaviors have been conducted with humans using irritating noises as the aversive event (Navarick, 1982; Solnick, Kannenberg, Eckerman, & Wailer 1980). Results have shown a higher proportion of impulsive choices compared to self-controlled ones.

Procedures that involve punishment, however, require modifying the consideration of the role of delay. Choosing the punishment with greater value (intensity or duration) but longer delay is deemed an impulsive response, while opting for the lighter but more immediate punishment is classified as a self-controlled behavior Mischel and Grusec (1967). In a pioneering study, Deluty (1978) evaluated the behavior of four rats exposed to a self-control situation with procedures of positive punishment. Results showed that the longer the delay the higher the number of self-controlled choices.

Though both paradigms –choice and self-control– have been tested in numerous studies using most of the operant conditioning procedures, the study of self-controlled behavior in situations of negative punishment has received less attention (at least in non-human subjects), even though this occurs in many everyday situations. A child, for example, may decide either to lend his brother a toy for a brief time, or to fight for its possession until his mother takes it away for a longer time upon finding out what was happening. Similarly, we may spend a certain amount of money to pay the fee for regulated parking, or opt not to, though this will entail a larger payment when we receive the corresponding fine.

In negative punishment procedures, the emission of a response maintains a negative contingency relationship with the appearance of a positive reinforcer; by responding the subject blocks the presentation of this event. Of course, the effect of these procedures is to reduce the response rate in the situation where it is applied. The positive reinforcer (e.g. food) may be present before the subject emits the response (which would lead to its disappearance) or may appear systematically (under a timed or operant program), in which case the emission of the punished response would seem to indicate that this criterion is not fulfilled. Under this type of procedure (as with positive punishment), responses would be considered impulsive if they implied a negative punishment of greater value, but more delayed, but deemed self-controlled if it led to a more immediate punishment of lower value. The value of negative punishment could be operationalized as the number of reinforcers omitted, or the degree of decrease in their quality or the duration of the period during which they cannot be accessed.

While theoretically simple to define, designing an experimental protocol for the contingencies represented in a situation of this kind entails certain complications: (a) measuring choice behavior requires that a subject emit a response between two or more alternatives. Any response must be reinforced (positively or negatively) in both its acquisition and maintenance for it to be emitted. As mentioned above, applying omission training requires omitting something. This makes it difficult to use access to food under timed programs (i.e., to later make its disappearance contingent upon the subject's response) since the presence of that reinforcer is necessary to sustain the choice behavior itself; (b) in this situation, the concept of delayed consequence (in this case, omission of the positive reinforcer) would have to be operationalized as the time allowed for access to the feeder before it is withdrawn. In this way, the event could be interpreted in terms of both delayed negative punishment and the duration of the reinforcer; and (c) The magnitude of the negative punishment could, in effect, be a reduction in the quantity or quality of the reinforcer to which the subject has access, but these two variables are difficult to quantify, one due to free access to the food, the other because it is more qualitative in nature.

Considering these challenges, one option that seems viable for studies of this kind would consist in manipulating the duration of both the reinforcement (considered as a delay) and the post-reinforcement delay (considered as the magnitude of the negative punishment) in a concurrent program. This would permit, for example, considering the choice of alternative A (3'' of access to the feeder and 30'' of time without access) as the self-controlled option, in contrast to alternative B (7'' of access to the feeder and 100'' of time without access).

Adopting this logic, we designed a first experiment in which 4 pigeons were exposed to different combinations of time of access to the feeder and inter-trial intervals (i.e., time without access, or post-reinforcement delay) with the goal of analyzing their choices when the different combinations were presented concurrently. Results of those trials showed such a high degree of indifference to the length of the post-reinforcement delay that additional studies were conducted to demonstrate this same response pattern in humans placed in an equivalent situation (Experiment 2). We then attempted to modify that pattern with an increase in the sensitivity to the delay –by including differential contexts during the inter-trial interval -ITI- (Experiment 3)– and/or by requiring a "commitment response" on the part of subjects (Experiment 4).

EXPERIMENT 1
SENSITIVITY TO POST-REINFORCEMENT DELAY IN CHOICES BY PIGEONS

METHOD

Participants

In this experiment, four experimentally naive pigeons (Columbia Livia) were maintained at 80-85% of their weight ad libitum. All subjects were 4-5-month-old females, called p1, p2, p3, and p4. The experiment was conducted in accordance with the Declaration of Helsinki and was approved by our institutional review board with code number 23.268. Applicable legal considerations concerning animal health and welfare were strictly followed.

Instruments

Four operant chambers for birds were used. Each cage had three response buttons located in the front panel that could be illuminated in up to eight colors, a removable feeder (on the same panel), and a computer touchscreen equipped to display stimuli and record responses.

The MedPC 2.0 for Windows© program was used to control the experiment. The discriminative stimuli utilized were the three blocks of illuminated buttons, each with two colors, one in each block with a cool tonality, the other with a hot tonality, for a total of six different colors (see Table 1). The function of each tonality was counterbalanced in each block. The reinforcer was a preparation of mixed grains for pigeons.

Design

The design applied was single case in which each subject was exposed to all experimental conditions. In each phase, the duration of the reinforcer and/or the post-reinforcement delay of each component was varied (see Table 1). In addition, the order in which each subject was exposed to them was partially counterbalanced. In Phase I, for example, choosing to press the green button displayed 5'' of access to the feeder and 50'' of post-reinforcement delay (5:50) –or ITI– while the other option (pressing the red button) offered 3'' of access to the feeder and 30'' of post-reinforcement delay (3:30).

Table 1. Features of the components of experiment 1 for each phase.

	Hue	Access to the feeder	ITI duration
Phase I	# 00b050	5''	50''
	# ff0000	3''	30''
Phase II	# e46c0a	10''	100''
	# 4f81bd	3''	30''
Phase III	# 604a7b	5''	100''
	# ffff00	3''	30''
Phase IV	# ff0000	3''	100''
	# 4f81bd	3''	30''

Notes: Hue= color code; ITI= inter-trial interval.

Shorter and longer ITIs, as well as the amounts of food, were presented counterbalanced across locations (left and right keys).

The dependent variable was the number of choices of each response option in the final test phase.

Procedure

Before beginning the experimental phases, all 4 subjects were exposed to an auto-shaping procedure in which the goal was to have the pigeons acquire the behavior of key-pecking. This phase consisted of sessions of 64 trials each in which the illumination of the keys (counterbalanced across locations) was paired with the appearance of the feeder for 4'' with an ITI of 58'' (the mean ITI in all phases of the experiment).

Once the key-pecking response was established, each subject was randomly assigned to one of the four sequences of presentation of the four phases: (1) I, II, III, IV; (2) II, IV, I, III; (3) III, I, IV, II; and (4) IV, III, II, I.

In each phase, four training blocks (E) and four test blocks (T) were alternated in 70-min sessions structured as follows: E (200 trials) - T (x60) - E (x200) - T (x60) - E (x200) - T (x60) - E (x200) - T (x200). The training sessions consisted of "forced choices" in which only one of the components (randomly presented in each trial) was available at a time. The stimuli remained present until the response was given by the animals. In the test sessions, in contrast, the two components of the phase were available simultaneously at the beginning of each trial. The choice of components was performed using a FR5 schedule, both in the training and test sessions. During reinforcement, the light on the feeder and the general light were activated, but during post-reinforcement delay all lights were turned off.

Results

During the pre-experimental, auto-shaping phase, all 4 subjects acquired the key-pecking response. Figure 1 shows the percentage of choice of each component in the final evaluation (200 trials) of each phase (mean for the 4 subjects). Individual results are depicted in Figure 2.

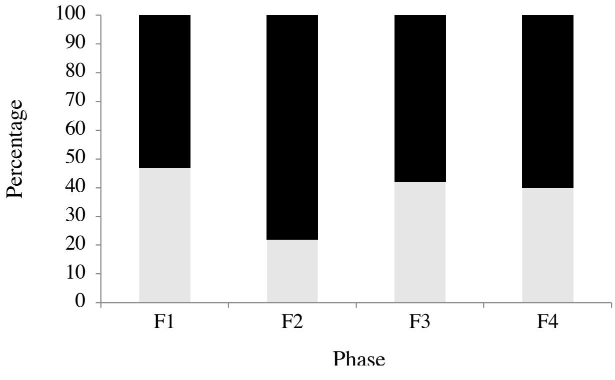

Figure 1. Mean percentage of choices to each component along the four phases (F1, F2, F3, F4). Black gray represents the choices of the component with the longest post-reinforcement delay. Light gray represents the choices of the component with the shortest post-reinforcement delay.

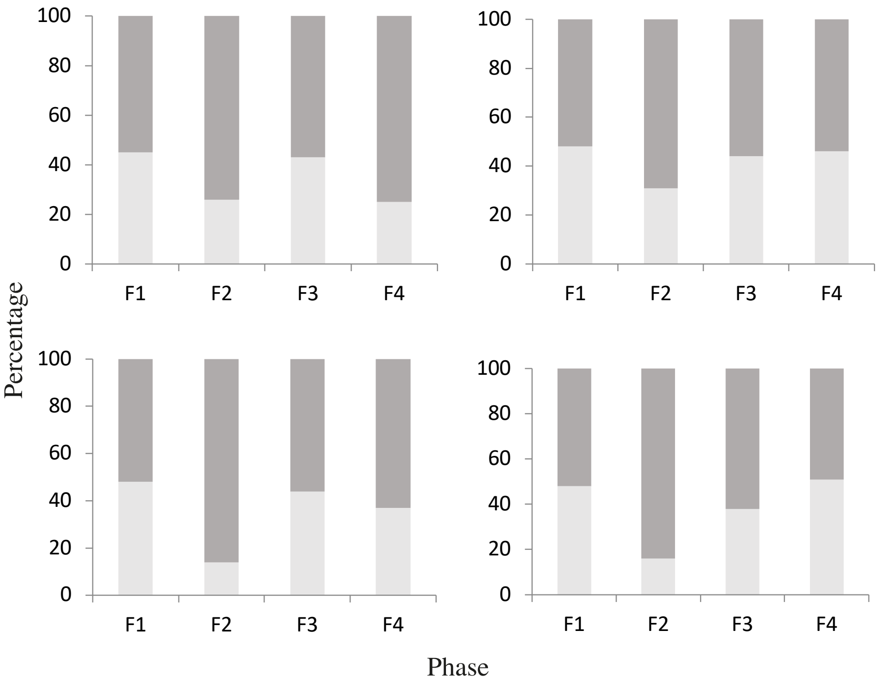

Figure 2. Percentage of choices to each component along the four phases (F1, F2, F3, F4). Individual subject data: a) p1, up to the left; b) p2, up to the right; c) p3, down to the left; d) p4 down to the right. Dark gray represents the choices of the component with the longest post-reinforcement delay. Light gray represents the choices of the component with the shortest post-reinforcement delay.

Results indicate that the order in which the different phases were presented to the subjects did not affect their behavior; that is, exposure to a certain combination of time of access to the feeder/length of the ITI did not influence subjects' choices of the subsequent combinations. This was demonstrated by the homogeneity of the results in the between-subject comparisons, as well as comparing the individual performance (Figure 2) to average data (Figure 1).

In general, these results can be grouped in the following observed effects: (a) except for subject p1, all the pigeons showed indifference (choices near 50%) between the options in phases I (5:50/3:30), III (5:100/3:30), and IV (3:100/3:30), after 800 forced-choice trials and 380 choice-trials, for a total of 1180 trials of exposure to the contingencies of both components in each phase; and (b) the only phase in which subjects showed a clear preference for one option was phase II (10:100/3:30), which revealed a tendency in almost 80% of the trials in the final test session in favor of the option with greater time of exposure to the feeder and greater duration of the ITI.

Discussion

Considering the procedure applied in this experiment as a valid way to analyze self-control (or delay discounting) behavior under conditions of negative punishment is based on two main points: 1) considering the time of access to the feeder as the delay between response and consequence; and 2) considering the differences in the length of the inter-trial interval (post-reinforcement delay) as a measure of the intensity of the negative punishment applied.

Our results, however, show that the subjects did not distinguish between 5 and 10 seconds of access to the feeder (though they did differentiate between 3 and 10). More importantly, they did not distinguish between 30, 50, or 100 seconds of post-reinforcement delay. It could be argued that the indifference reflected in these choices reflects that the relative value of the reinforcer of each component was equivalent between the two response options available in each phase, but this would contradict our observations. While in phase II, where this "equivalence" existed (10:100 vs. 3:30, a tenfold relation in both cases), a clear preference for the component with greater time of access to the feeder was found, in phase IV (3:100/3:30), where the relation was 1:30 vs. 1:10, the proportion of choices was quite similar in both options.

One of the main problems involved in analyzing the effect of the duration of the reinforcer on choice behavior consists in conceptualizing it in terms of magnitude. The amount of food ingested is not a simple linear function of the time of access to the feeder (Epstein, 1981), so it is erroneous to consider that an increase of that time will correspond to a proportional increase of the magnitude (amount) of the reinforcer. Several studies have focused efforts on demonstrating the sensitivity of subjects to these types of variation, manifested in their preference for options with different times of access to the feeder. Catania (1963), for example, compared the behavior of three pigeons to two 2'-VI programs as a function of their concurrent or simple presentation, while varying at the same time the duration of access to the reinforcer in each option (in seconds: 4.5/4.5, 6/3, 3-6, 4.5-4.5'). Results showed that not only the increase in the duration of the reinforcer affected the amount of food ingested, but that when the programs were presented concurrently the response rate adjusted linearly to that duration and was not influenced when the simple programs were manipulated. This result is similar to the findings reported by Jenkins and Clayton (1949) with durations of 2'' and 5''. Rachlin and Baum (1969) replicated Catania's experiment (1963) with some variations in the procedure. They compared an option of 4 seconds of access to the feeder with others of 1, 4, and 16 seconds, also finding that the results adjusted to a linear function of the duration of the reinforcer. In general, it can be affirmed that when the other variables are held constant, subjects choose the option that offers the greatest duration of the reinforcer (Logan, 1965; Picker & Poling, 1982; Schwartz, 1969; Young, 1981).

If we focus on subjects' performance exclusively as a function of the duration of the reinforcer, the results obtained in the present experiment do not seem to support the differences between 3'' and 6'' found by Catania (1963), while sensitivity was observed only between the durations of 3 vs. 10 seconds. This explains why this combination was used in experiments 3 and 4.

Other studies, however, suggest a certain insensitivity to the duration of the reinforcer when other variables, such as the reinforcement rate, are manipulated (Davison & Hogsden, 1984; Landom, Davison, & Elliffe, 2003; Todorov, 1973; Todorov, Hanna, & Bittencourt de Sá, 1984), since high reinforcement frequencies were found to be more attractive (in relation to subjects' choices) than longer durations of access to the reinforcer. In fact, a study by Keller and Gollub (1977) assumed this low adjustment and proposed increasing sensitivity to changes in the duration of the reinforcer by exposing subjects to continuous changes in it.

In any case, and regardless of the indifference found in certain combinations of duration values, a difference was observed between 3 and 10; durations that not only delayed the appearance of the ITI by distinct degrees but, due to the impossibility of accessing the reinforcers, functioned as the context required for their disappearance to be converted into the posterior consequence as a form of negative punishment.

Therefore, attending to the second question posed at the outset of this discussion, could manipulation of the duration of the ITI modulate the degree of negative punishment? Studies that have analyzed temporal choices involving losses often have employed procedures that implicate a series of choices between hypothetical amounts of money (one immediate, the other delayed; Holt, Green, & Myerson, 2012). And then they usually test their adjustment to Mazur's hyperbolic model (1987). Results have repeatedly shown discount functions that are inverse to those observed in money gains; that is, avoiding higher payments though reception of the losses is delayed (Estle, Green, Myerson, & Holt, 2006; Murphy, Vuchinich, & Simpson, 2001). This model has even been used in studies that analyze risk behavior in populations with addiction disorders (Baker, Johnson, & Bickel, 2003; Ohmura, Takahashi, & Kitamura, 2005).

Given the characteristics of the subjects that participated in the present experiment, it was not possible to apply a loss of money or points paradigm, so we opted for a protocol like the so-called blackout approach (Catania, 1974); that is, applying a time-out when the lights of the experimental camera were turned off for a period of no reinforcement due to the impossibility of emitting the target response. For authors like Baum (1973), the time-out evidences the reciprocal relation between reinforcement and punishment, since it acquires its punitive (or even aversive) functions by limiting access to the reinforcement.

The use of blackout as a form of –presumably negative– punishment has demonstrated its efficacy for reducing the rate of behaviors with which it becomes contingent in rats (Neuringer, 1991). Therefore, the duration of the post-reinforcement delay (ITI, blackout) is, in theoretical terms, a valid way of applying different degrees or intensities of negative punishment. Results, however, revealed complete insensitivity to the values selected, which in some cases were greater than triple between the two options.

In humans, time-out is a technique used very often in clinical and educational psychology. Its effectiveness in suppressing behaviors has been demonstrated in numerous studies (Foxx & Shapiro, 1978; Hackenberg & DeFulio, 2007). Time-out is frequently applied by changing the subject's location to a specific area, but in other approaches the configuration of the stimuli is changed during the time-out using a black screen or blackout, for example (Valero & Luciano, 1997; Reilly & Glenn, 2000). The basic characteristic that the time-out must satisfy to be effective is that the condition posterior to the inadequate response is an environment with fewer reinforcement options (Van Houten, 1983).

Although the results obtained in this experiment were coherent with other studies that have underscored the low importance of post-reinforcement delay as a control variable for choice behavior (Lea, 1979; Logue, Smith, & Rachlin, 1985; Mazur, Snyderman, & Coe, 1985), the clearly demonstrated effectiveness of using blackout with humans led us to elaborate another experiment to test this analogously. For this reason, in experiment 2 we employed a procedure in which the subjects (now humans) were exposed to choice trials in which the components were constructed to offer the same time of access to the reinforcer but distinct blackout values, similar to phase IV of the experiment just described.

EXPERIMENT 2
SENSITIVITY TO POST-REINFORCEMENT DELAY IN THE CHOICES OF ADULT HUMANS

METHOD

Participants

Participants were forty-seven first year (second semester) university psychology students from the Universidad Nacional de Educación a Distancia (UNED Madrid), aged 18-51 years (*M*= 32). There were twenty-nine women and eighteen men, none of whom had participated previously in any experimental task involving operant conditioning. All participants were recruited from the second semester "Psychology of learning" course.

The study was conducted in accordance with the Declaration of Helsinki and was approved by our Institutional Review Board with code number 23268. Informed consent was obtained from all the participants involved in the experiment.

Instruments

We used five soundproofed cabins for the experiments with humans, each one equipped with a Pentium IV computer with a 15" LED screen and earphones for presenting the sound stimuli. The procedure was programmed in Action Script 2.0© in the Flash CS4© graphic environment. The program, compiled as an executable file, was designed to display all contingencies and record all responses. Two different-colored buttons were used as the discriminative stimuli (grey and brown) and presented on the screen. The function of the colors was assigned randomly for each subject.

The interaction of the subject with the events presented consisted in selecting the buttons using the computer's mouse. The reinforcing stimuli took the form of obtaining points, which were announced immediately (shown on the screen) and accumulated on a scoreboard situated permanently in the upper right area of the screen. During the inter-trial intervals (or post-reinforcement delay) the screen went black, regardless of the duration of the ITI.

Design

The design applied between-subject comparison under one sole experimental condition. All subjects could choose by pressing the grey or brown button. After the 4'' of access to the task (during which they could obtain points), the post-reinforcement delay was 10'' or 20''.

As the dependent variable, we measured the number of choices of the response option that included the shorter post-reinforcement delay.

Procedure

Each subject participated in one session that lasted no longer than 60 minutes. The duration of the sessions depended on subjects' choices and the time they took to make each one. Before beginning, they were instructed to fill out a brief form to identify their sex and age. After that, general instructions on how to interact with the contingencies were presented (mainly how to use the mouse). To induce the ideas that both optimizing time and the differences between the short and long ITIs were important for subjects, the instructions given emphasized the following:

“OBJECTIVE: FROM THIS MOMENT YOU HAVE 20 MINUTES TO OBTAIN THE MAXIMUM NUMBER OF POINTS BY CLICKING ON THE GIFT BOXES SHOWN ON THE SCREEN”.

The task began with a block that presented subjects the components of the future choice situation. This block consisted of 12 “forced choice” trials: 6 interspersed trials presented randomly to each one of the components (A and B) alone. Once they passed this block, subjects were exposed to 20 choice trials in which they could select one component or the other by clicking on the button that appeared on the screen (grey or brown).

The task on which they could obtain points (analogous to the time of access to the feeder in the previous experiment) asked them to select, using the mouse, a series of “gift boxes” that appeared in random positions on the screen against a white background before disappearing quickly (mean 0.7’’). Once the time of access to this task ended (4’’), the ITI (or post-reinforcement delay) applied was the one that corresponded to the component that had been chosen at the beginning of the trial. When this interval ended, the ensuing trial commenced.

Figure 3 shows a summary of the sequence in the short ITI component.

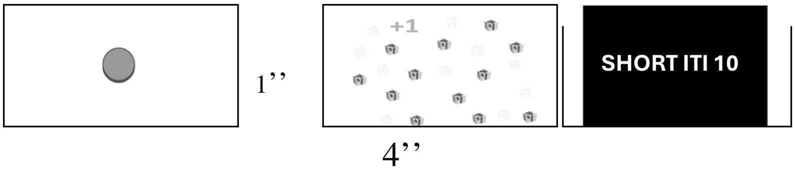

Figure 3. Trial example. The initial button could be either gray or brown. When pressed, one second passed, and the task was presented for four seconds. The gift boxes were white with red ribbons. Points earned were green. After the task, the ITI could be either short (10”) or long (20”).

Results

Considering all the choice trials (20), most subjects showed indifference between the two options. The option with the short ITI was selected between 8 and 12 times (a range that represents clear indifference) by 61.4% of the subjects. The percentages of subjects who demonstrated choosing one of the components consistently throughout the 20 trials (i.e., above 80% of choices of the same option) was 3.8% for the component with the long ITI and 1.9% for the component with the short ITI.

If we focus on only the last five trials (that is, after greater exposure to the differences between the components), we find a similar indifference, as 57.7% of subjects chose the component with the short ITI 2 or 3 times (half of the five trials), while 15.4% always selected the option with the long ITI, and 13.5% always chose the one with the short ITI (Figure 5 presents these results graphically. Please, see the results of the Experiment 3).

Discussion

The results obtained replicated those observed with the pigeons in the previous experiment; that is, over 98% of subjects did not choose consistently the component with the short ITI over the long one in the entire session, and over 86% did not do so during the final five trials. Observations of the low importance demonstrated for the length of the ITI with respect to the choice behavior of the subjects (both humans and pigeons) invalidates its conceptualization as a way to modulate the intensity of negative punishment, at least under the parameters used in these two experiments. This finding triggered a re-orientation of our interests -in terms of both analyzing the data obtained and planning the ensuing experiments- towards a concept that we began to denominate "insensitivity to post-reinforcement delay".

There is, in fact, a great deal of empirical evidence that is coherent with these results, suggesting that the length of the extinction periods, time-out, inter-trial interval, or post-reinforcement delays, all have a low degree of control over subjects' behavior or, at least, that achieving some degree of influence requires much more significant differences, or maintaining all the other relevant variables constant.

De Villiers (1977), for example, showed that under certain circumstances subjects are sensitive to post-reinforcement delay only when all the components offer the same pre-reinforcement delay, but not even that sensitivity was symmetrical. In fact, studies have found that in situations with different pre- and post-reinforcement delays, subjects choose the shorter pre-reinforcement delay even though this entails a lower reinforcement rate (Lea, 1979; Logue *et alii*, 1985). Procedures designed to identify the point of indifference in choices have observed a certain sensitivity to the post-reinforcement delay, but one that is much lower than that shown in relation to pre-reinforcement delay (Mazur *et alii*, 1985). Although a certain sensitivity has been seen in human subjects, this has been shown to be much lower than that observed when the magnitude or pre-reinforcement delay is manipulated (Flora & Pavlik, 1992).

This predisposition is coherent with a selection in the phylogeny of the species. In situations with high survival pressures, this is much more adaptive when the events preceding the appearance of the reinforcer are relevant, in detriment to those that follow once this has disappeared. Likewise, it is also more adaptive to ensure the appearance of the reinforcer (whether the presence of an appetitive event or escape from an aversive one) than having to wait for that to occur, though its value may be greater.

This logic is supported empirically by the generalized tendency to act impulsively (i.e., select the option of the reinforcer that is more immediate but has lower magnitude) that has been observed in numerous studies with both pigeons and rats (Ainslie, 1974; 1975), as well as humans, mainly children (Logue, Forzano, & Tobin, 1992). This is also a tendency that has demonstrated great robustness (Rachlin, Logue, Gibbon, & Frankel, 1986; Sonuga-Barke, Lea, & Webley, 1989).

However, even though this behavioral predisposition may have been selected due to its adaptive value in a natural environment, humans (and other species) interact with a social environment in which it may be highly advantageous to have our decisions determined, as well, by the length of the post-reinforcement delay. This is true in many cases.

In situations of positive reinforcement, studies have demonstrated that certain factors can favor self-controlled decision-making in subjects, overcoming that initial inclination towards impulsive choices. For example, impulsive choices can be reduced by omitting the pre-reinforcement delay at the beginning of training and later progressively increasing it (Mazur & Logue, 1978), and by training with delayed reinforcement (Renda & Madden, 2016; Smith, Marshall, & Kirkpatrick, 2015). Other studies have shown that using intermittent reinforcement programs generates less impulsive subjects than those trained with programs of continuous reinforcement (Eisenberg, Weier, Masterson, & Theis, 1989). Or, finally, that introducing the possibility of performing commitment responses also increased the proportion of self-controlled choices (Rachlin & Green, 1972). This possibility was explored in experiment 4 of the present study.

Pursuing this line of thinking, in experiments 3 and 4 we abandoned the initial idea of validating the procedure utilized as a self-control situation with negative punishment to focus attention on, first, replicating the insensitivity found and, second, seeking to reduce it. Hence, for experiment 3 we decided to add a differential context during the post-reinforcement delay to test its effect on subjects' choices; while experiment 4 introduced the requirement of a commitment response, both in isolation and combined with the differential context. In both cases, pigeons and humans participated as experimental subjects.

Experiment 3

Including differential contexts as a function of the duration of post-reinforcement delay: Effects on choice by humans and pigeons

Method

Participants

In this experiment, four experimentally naïve pigeons (Columbia Livia) were maintained at 80-85% of their weight ad libitum. All the pigeons were females, aged 4-5 months. They were called p7, p8, p9, and p10. These pigeons were different from the ones used in experiment 1. The human participants were fifty-one first-year university (second semester) psychology students from the UNED (Madrid), aged 18-56 years (M= 31), twenty-nine women and twenty-two men. None had participated previously in any experimental task involving operant conditioning, and all gave their informed consent to participate voluntarily in the study. They were recruited from the second semester "Psychology of learning" course.

The experiment was conducted in accordance with the Declaration of Helsinki and was approved by our institutional review board with code number 23.268. Applicable legal considerations concerning animal health and welfare were strictly followed, and informed consent was obtained from all the human participants involved in the study.

Instruments

The instruments were the same as those used in experiments 1 and 2.

Design

The design called for between-subject comparisons under one sole experimental condition. During the choice trials, the pigeons could opt for components with ITI of 100'' or 30'' (both with 3'' of access to the feeder), while the humans could select an ITI of 20'' or 10'' (both with 4'' of access to the task). Once again, the dependent variable for the pigeons was the number of choices of each response option in the final phase of evaluation. For the humans, we counted the number of choices of the response option that entailed a shorter post-reinforcement delay.

Procedure

The procedure used with the pigeons was identical to the one applied in Phase IV of experiment 1 (see Table 1), except that during the ITI the touchscreen coupled to the experimental box was illuminated completely in the same button color as the active component that the subject chose at trial onset. For the human subjects, we applied the same procedure as in experiment 2 under the same conditions. Hence, with both the pigeons and humans, the post-reinforcement delays were "signaled" by the same color of the discriminative stimulus associated with each component. The function of the colors (blue and red for pigeons, grey and brown for humans) was assigned randomly for each subject.

Results

In the case of the pigeons, though we observed a higher number of choices of the component with the short ITI in this experiment than in experiment 1 (which could function as its control with respect to the presence of the differential context), results still showed indifference with respect to both components since choices ranged from 45-55%. Figure 4 shows both the individual data of the subjects of this experiment, and the comparison of the means with the subjects from experiment 1.

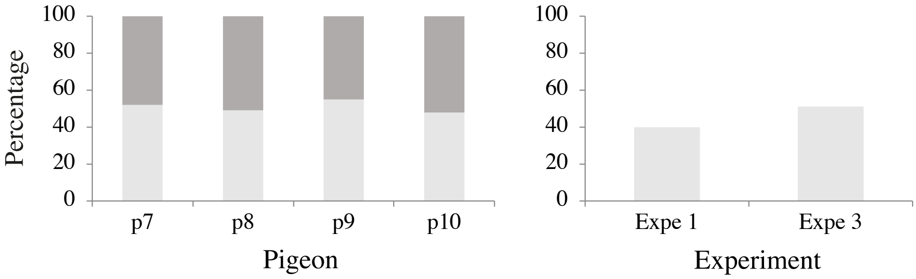

Figure 4. Individual data from this experiment and average data from experiments 1 and 3. The graph from the left shows the individual percentage of choices of the component with the short ITI (light gray) and the long ITI (dark gray) during the last test session. The graph from the right shows the average percentage of choices of the component with the shortest ITI by the subjects from experiments 1 and 3, also during the last test session.

In this experiment, 33.3% of the human participants showed clear indifference between the two options, selecting the option with the short ITI between 8 and 12 times during all the choice trials (20). The percentages of subjects that chose one option consistently (over 80% of choices of the same option) were 1.9% for the component with the long ITI and 5.6% for the one with the short ITI. Figure 5 shows the complete distribution of these percentages.

Focusing on the last five trials shows that 44.5% of subjects showed indifference between the two components (choosing the component with the short ITI 2 or 3 times). Of the subjects that followed one of the criteria strictly (five choices of the same component), 22.2% selected the short ITI and 11.1% the long ITI.

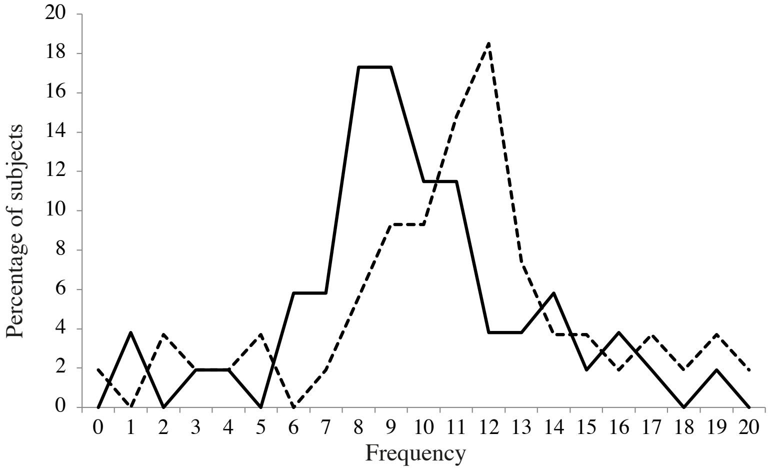

Figure 5. Frequency of short ITI choices by subjects from experiments 2 and 3. Percentage of subjects (vertical axis) from experiments 2 (solid line) and 3 (dashed line) that chose the short ITI component with the frequency signaled in the horizontal axis.

Discussion

The hypothesis under which this experiment was conducted (and, to a certain degree, the following one, as well) posited that including a distinct context during the short ITI with respect to the long ITI and using the same color of the response button that corresponded to that component, would increase subjects' sensitivity to the difference of duration, measured as the degree of preference for the shorter ITI.

This hypothesis was supported by two, non-exclusive, "facilitator" effects: That adding distinct elements between one ITI and the other could facilitate their discrimination and, therefore, the adjustment of subjects' choices to them (greater sensitivity), like what is observed in operant discriminations (White, Pipe, & McLean, 1985); and, that the color of the context of each ITI could be conditioned by their negative contingency with the food/points and so be converted into inhibitory appetitive conditioned stimuli with distinct eliciting capacities as a function of duration. This could affect the degree of preference between a button with one color or the other during the choice situation.

The results with both pigeons and humans indicate a certain increase in the proportion that chose the option with the shorter ITI when compared to experiments 1 and 2 (Figures 4 and 5). However, that difference was not sufficient to affirm that indifference was no longer shown between the two options in most cases.

The behavior showed by the subjects that participated in this experiment strengthens the results on the low importance of the duration of post-reinforcement delay for choices found in the two earlier experiments. However, since we cannot affirm that the results are identical, we opted to test its effect in an approach that combined a requirement of a commitment response in the fourth (and final) experiment.

Experiment 4
Including a commitment response and a differential context: Effects on sensitivity to post-reinforcement delay in pigeons and humans

Method

Participants

In this experiment, twelve experimentally naïve pigeons (Columbia Livia) were maintained at 80-85% of their weight ad libitum. All pigeons were females, aged 4-5 months. They were called p11-p22.

The human participants were one hundred ninety-seven first-year university (second semester) psychology students from the UNED (Madrid), aged 18-54 years (M= 29), one hundred twelve women and eighty-five men. None had participated previously in any experimental task involving operant conditioning, and all gave their informed consent to participate voluntarily in the study. They were recruited from the second semester "Psychology of learning" course.

The experiment was conducted in accordance with the Declaration of Helsinki and was approved by our institutional review board with code number 23.268. Applicable legal considerations concerning animal health and welfare were strictly followed, and informed consent was obtained from all the human participants involved in the study.

Instruments

The instruments were the same as those used in experiments 1 and 2.

Design

This procedure applied a 2x2 between-group comparison design with four experimental conditions as a function of whether a differential context was presented during the ITI, and the duration of the extra time after emission of the "commitment response". Assignment of subjects to conditions (A, B, C, D) was random. Table 2 shows the number of subjects by condition. The same dependent variables were considered as in the previous experiments.

Table 2. Experimental conditions and number of subjects randomly assigned to each condition.

		Extra time after commitment response	
		Long (6'', 10'')	Short (3'', 5'')
Differential context during	Yes	A. 55 humans, 4 pigeons	B. 44 humans, 4 pigeons
the Inter-Trial Interval	No	C. 47 humans, 4 pigeons	D. 51 humans

Procedure

The procedures followed were the same as those described in experiment 3, except for the inclusion of the requirement of a commitment response. In this experiment, at the beginning of each choice trial the selection of one component or the other was followed by a pre-reinforcement delay that could be of two lengths (depending on the experimental condition). The long delay (shown in Table 2) was 10'' for the pigeons and 6'' for the humans; the short delay was half of those times in both cases (that is, 5'' and 3'', respectively).

Results

Figure 6 shows the percentage of choices of the component with the lowest post-reinforcement delay during the final evaluation session for each pigeon that participated both in this experiment and experiments 1 and 3, as well as the mean of those choices in each experiment. These means (right side of the graph) indicate a progression in the percentage (39.75, 51, 47, 53.75, and 58.25%) of choices of the component with the shortest ITI.

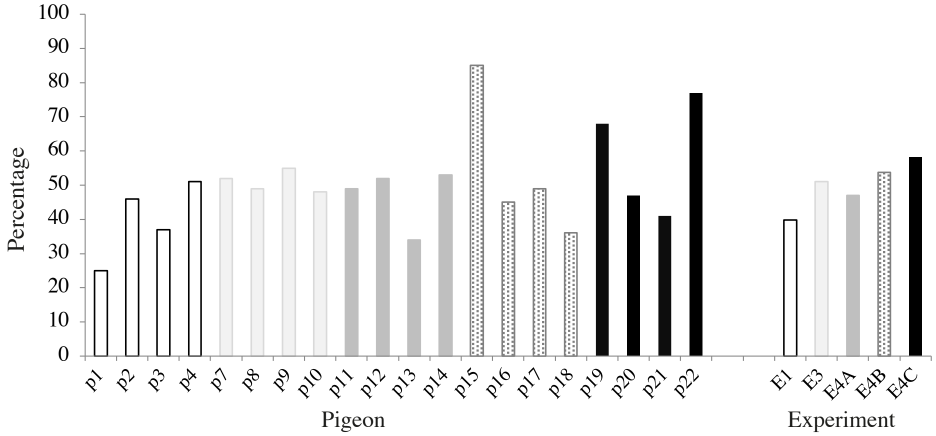

Figure 6. Percentage of the shortest ITI choices by subjects from experiments 1, 3 and 4. Percentage of choices of the component with the shortest ITI by the subjects from experiment 1 (p1-p4), experiment 3 (p7-p10) and the three conditions of experiment 4 (p11-p14; p15-p18; p19-p22) during the last test session (individual subject data); The graph from the right shows the average data for these five groups.

Figure 7 shows the percentage of human participants that chose the component with the shortest post-reinforcement delay 4 or 5 times in both experiments 2 and 3 and the four conditions of experiment 4.

In condition C, 43.63% of participants chose the option with the short post-reinforcement delay over 80% of times in the final five trials. This should be compared to 18.36% in experiment 2, which could serve as its simple control.

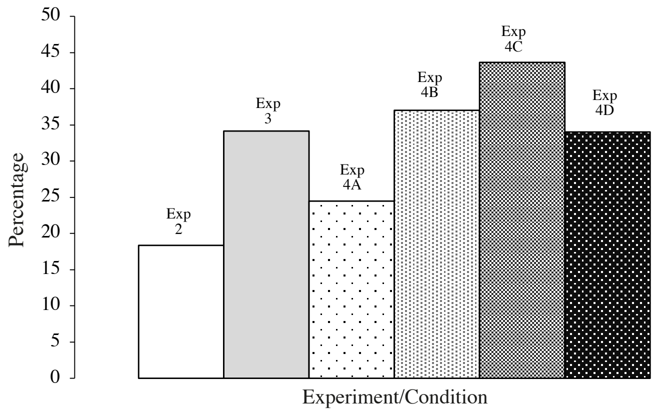

Figure 7. Percentage of subjects that chose the shortest ITI more than 80% of times in the last 5 trials. Data from experiments 2, 3 and 4.

Discussion

Various studies have demonstrated that the frequency of so-called impulsive behavior can be reduced by adding an initial delay in two options and, moreover, that this effect on preference becomes more notable the greater the common delay (Ainslie & Herrnstein, 1981; Rachlin & Green, 1972). This extra time has also been shown to have direct effects on the sensitivity of subjects to the differences in the duration of the reinforcers (Navarick & Fantino, 1976; Snyderman, 1983; White & Pipe, 1987).

Including a "commitment response" in a concurrent program chained to positive reinforcement, like the ones used in the studies cited on self-control, extends the pre-reinforcement delay to the same degree in all components, but does not affect the preference for each one in the same way. If, for example, component A presents a delay-access ratio to the feeder of 10:5 while in component B it is 20:10, then in a simplified manner we could predict the distribution of the responses in each component as follows: (RA/RA+RB) = [(rA/DA)/(rA/DA)+(rB/DB)], where R is the number of responses, r the magnitude of the reinforcer (i.e., time of access to the feeder), and D the response-consequence delay. The relative response rate predicted for component A would then be (5/10)/(5/10)+(10/20)= 0.5, the same as for component B. If we add an extra time of 3 seconds after a commitment response, however, the result would be (5/10+3)/(5/10+3)+ (10/20+3)= 0.47. This can be explained mathematically as follows: with the increase in the duration of that extra time, the option with the lower delay and magnitude of the reinforcer (impulsive choice) progressively decreases its attractiveness compared to the self-controlled option in a way that is coherent with the empirical data.

Including the requirement of a commitment response in this experiment did not, however, adjust completely to this explanatory framework. In theoretical terms, under a punishment procedure (positive or negative), the choice of the component in which the appearance of the consequence is delayed longer would be considered impulsive, even though it is of greater magnitude. The results of this experiment, in contrast, suggest that including the commitment response (with extra delay after the response) increased the proportion of choices of the self-controlled option.

In the case of the pigeons, it is true that the comparison of the means indicates a progression in that percentage (39.75, 51, 47, 53.75, and 58.25%), but these results still come very close to absolute indifference. However, upon examining the individual data, the only three subjects (out of 20) that showed a clear preference for one of the two components -concretely, the one that offered a lower ITI- belonged to conditions B (p15, 85%) and C (p19, 68%; and p22, 77%) of this experiment, while the mean for the rest of the subjects was 45.23%, while the fourth had a higher proportion for subject p9 at 55%.

With the human participants, we also observed the best results in condition C, where 43.63% of participants chose the option with the short post-reinforcement delay over 80% of times in the final five trials, compared to 18.36% in experiment 2, which could serve as its simple control.

For future research, to extend the generalizability of these results, it could be interesting to run the experiments with human participants from different social groups (our participants were all students).

Overall, sensitivity to post-reinforcement delay has only been found under procedures with commitment response, in both pigeons and humans, and with greater magnitudes when presented in isolation (condition C compared to A and B), and if the length of the extra time is greater (condition C compared to B and D). But, as mentioned above, the effect found cannot be explained simply by applying said equation. The extra time, and what we have denominated "delay of negative punishment" (time of access to the reinforcer), cannot be summed, since the nature of the two periods is completely distinct.

We cannot, therefore, offer a clear explanation of the effect found, but can posit a hypothesis whose evaluation would require additional research. In global terms, including the extra time in experiment 4 (with respect to the previous ones) increases the time during which subjects do not have access to the reinforcers in the session. It is possible that reducing the relative time of access to the reinforcer will increase its value (Allison, 1989; Timberlake & Allison, 1974) and, hence, accentuate the differences in the loss of this value as a function of the component chosen.

Conclusion

In any case, what the data do reveal robustly throughout all four experiments, with a total of twenty pigeons and two hundred ninety-five humans, is that subjects' choices are affected very little by the duration of the blackout, at least under these experimental conditions (30 vs. 100 seconds in pigeons, 10 vs. 20 seconds in humans). Moreover, we believe that these results are especially relevant for considering blackout (negative punishment) as a behavior modification technique since, while its effectiveness rests on strong empirical support, it seems that modulating its intensity according to the length of this "time-out", may not function in a direct manner.

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