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Journal
International Journal of Comparative Psychology, 30(0)

ISSN
0889-3675

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Publication Date
2017

DOI
10.46867/ijcp.2017.30.00.17

INTERNATIONAL JOURNAL OF COMPARATIVE PSYCHOLOGY

2017, 30
Heather M. Hill
Editor
Peer-reviewed

The Valuation Cost Decreases as a Function of Extended Exposure to a Risky-Choice Procedure

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Studies in pigeons and rats have reported a predictable relationship between latencies during no-choice trials and the ulterior preference in choice trials. The Sequential Choice Model (SCM) was proposed in Shapiro, Siller, and Kacelnik (2008) to account for these results, and, more importantly, to make precise predictions about the correlation between latency and preference. Eight male Wistar rats were exposed to 48 sessions in a risk-sensitive procedure, with each session composed of 10 blocks of trials (2 no-choice and 4 choice trials). We analyzed the latencies of response in order to test the SCM's predictions. Our data partially support the SCM's predictions, but a monotonic decrease to a floor effect in all latencies of response did not allow the confirmation of all predictions. The results are discussed regarding a decrease in the valuation cost as a result of extended exposure, and it is argued that diminishing latencies in this particular procedure contributed to the increased rate of reinforcement.

In choice procedures, an organism (human or animal) is faced with options that can differ in several properties such as amount, delay, rate, magnitude of the reinforcer and other relevant measures. The basic procedure consists of exposing the organism (independent of the alternatives that compose the context of choice) to repeated trials of one single alternative (no-choice trials), and then, after knowing the properties of each alternative, to present the options simultaneously (choice-trials) in order to assess its preference during choice trials. The main variable analyzed is the preference for some of the alternatives; however, the response rate and latency of choice may also be regarded as relevant measures, depending on the specific procedure. Using this general arrangement, many phenomena have been studied; for example state dependent valuation (Aw, Holbrook, de Perera, & Kacelnik, 2009; Schuk-Paim, Pompillo, & Kacelnik, 2004), rationality, transitivity, context dependent decisions (Hurly & Oseen, 1999; Schuck-Paim & Kacelnik, 2002; Schuck-Paim & Kacelnik, 2007), and risk sensitivity (Caraco, Martindale, & Whittam, 1980; Perez & Waddington, 1996).

In the context of choice procedures, it has been suggested that latency of choice can be associated with the preference and the attributed value of a particular alternative (Kacelnik, Vasconcelos, Monteiro, & Aw, 2011; Shapiro, Siller, & Kacelnik, 2008). The basic rationale underlying this relationship is the assumption that when animals respond to a particular stimulus (e.g., a foraging option), that stimulus acquires some value and when that stimulus is presented again, latency of response is a way to "express" the acquired value. Thus, it follows that when an animal prefers one stimulus over another, the latency to choose that stimulus will be shorter than the latency for a non-preferred stimulus. This consideration is based on the assumption that animals are naturally exposed to sequential single encounters of foraging options. Consequently, when two options are presented simultaneously what happens—instead of a comparison process between alternatives—is a "competition process" between acquired latencies, where the shorter latencies (related to higher value) will be associated with the preferred options (for a detailed description see Kacelnik et al., 2011). As a consequence of this process, the Sequential Choice Model (SCM) states the following predictions:

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> a) the valuation process involves learning and reflects the attractiveness of the present option relative to the background opportunities, b) cross-censorship between the processes generating latencies to act leads to observing shorter latencies during simultaneous choices than sequential encounters, particularly for the less preferred option, and c) one should be able to predict partial preferences between options, when faced simultaneously, from behavior (i.e., latencies) during sequential encounters. (Kacelnik et al., 2011, p. 551)

The absence of a comparison process involved during choice is one of the main assumptions of the SCM (see Kacelnik, Vasconcelos, Monteiro, & Aw, 2011). Many choice procedures have reported findings in agreement with one or more predictions of the SCM. For example, Bateson and Kacelnik (1995) found shorter latencies during no-choice trials for options delivering variable delays (the higher valued and preferred option) compared to options delivering fixed delays (the lower valued options). Schuck-Paim and Kacelnik (2002) also found the same effect using a rational choice procedure with variable delays. Shapiro et al. (2008) found shorter latencies during no-choice trials for options delivering higher rates of reinforcement (the preferred option) compared to options with lower rates of reinforcement. They also found that preference during choice trials can be predicted from latencies from no-choice trials.

Other findings suggest that the relationship between choice and latency can differ due to a valuation cost and a comparison process. For example, studies about choice in humans show that even when people tend to prefer larger rather than smaller assortments of options, the former is associated with a cost that not everyone is disposed to pay because of the sacrifice (e.g., time or energy) involved in the valuation process (Dar-Nimrod, Rawn, Lehman, & Schwartz, 2009). Additionally, studies using both animals and humans as participants show that increasing the number of alternatives can provoke less accurate choices (see Hutchinson, 2005 for a review) due to an assumed comparison process. With regards to the above mentioned evidence, predictions a) and b) of the SCM turn out to be debatable and thus deserve further verification.

Different studies with animals and humans in which choice between two stimuli is involved (e.g., transitive inference) have also shown that latency of choice can be affected by previous training and the programmed order of the stimuli (which also suggests a valuation cost). These changes in latencies can be evidenced in the so called symbolic distance effect (SDE), where latency of choice increases for pairs of stimuli in which the organism has not been trained. The SDE has been shown in humans (Hinton, Dymond, von Hecker, & Evans, 2010) and animals (Bond, Kamil, & Balda, 2003; D'amato & Colombo, 1990). Additionally, studies of reaction times in humans suggest that latency can be decreased as a consequence of learning. According to this evidence, the extended exposure to a particular task could systematically reduce reaction times. This trend can be modeled by a *power law* (Logan, 1992) and has been reported in lexical decisions (Logan, 1990) and in humans and animals using a choice reaction time task (Blokland, 1998).

Since the SCM does not make predictions about the possible effect of extended exposure to each option, the above mentioned decrease in latencies could affect the SCM's predictions. This suggestion can be empirically supported by the observation that previous studies with the SCM have employed a relatively small number of trials and sessions, and that these studies do not show a detailed analysis of latencies across sessions. For example, Freidin, Aw, and Kacelnik (2009) used a choice phase composed of approximately 87 choice trials per session (three daily sessions); Vasconcelos, Monteiro, Aw, and Kacelnik (2010) used 30 sessions composed of 144 no-choice trials and 24 choice trials (this arrangement was for four options); Shapiro, Schuck-Paim, and Kacelnik (2012) reported two sessions per day, each one with 20 blocks of 6 trials (four no-choice and two choice trials); Aw, Monteiro, Vasconcelos, and Kacelnik (2012) administered two sessions of 176 trials (no-choice) for training, and 144 trials (no-choice) and 24 choice trials during

testing; while Craft (2016) used five sessions of training (20 trials each, until reaching the stability criterion), and then 5 choice sessions of 28 trials (eight no-choice and 20 choice trials). In the present experiment, we used 48 sessions, with each session composed of 20 no-choice trials and 40 choice trials, so that we presented approximately 960 no-choice trials and 1940 choice-trials.

In light of the aforementioned evidence with respect to latencies of choice and the predictions of the SCM, the aim of the present study was to evaluate the predictions of the SCM in a choice procedure that involved the extended presentation of options differing in variability. In order to assess these predictions, we reanalyzed data about preference previously reported in Camarena and García-Leal (2015). Our aim is not concerned with delineating the contrast between models (e.g., SCM and tug-of-war models), which although important in the study of foraging choices, would be beyond the scope of this paper.

Method

Participants

Eight male Wistar rats (*Rattus norvegicus*) aged 13 weeks were used. Rats were maintained *ad libitum* prior to risk-sensitivity procedure and were confined individually in their cages under laboratory conditions, controlled temperature, and a 12-hour dark-light cycle. Initially, rats were fed with rodent lab chow until week 15. Subsequently, amaranth seeds were always used for feeding (both during housing and experimental sessions) since it has been shown that these seeds function as a reinforcement in operant paradigms (Cabrera, Robayo-Castro, & Covarrubias, 2010).

The employed rats were the same which were selected from the novelty seeking procedure reported in Camarena and García-Leal (2015). Using a modified version of the so-called free-choice procedure previously used by Wooters, Dwoskin and Bardo (2006) we selected four LR rats (LR, by low rate of exploration time) and four HR rats (HR, by high rate of exploration time).

All experimental procedures were approved by the local ethical committee of the Center for Studies and Investigations in Behavior, by the University of Guadalajara committee for animal experiments and met governmental guidelines.

Procedure

As mentioned above, in the choice behavior measures (not latency measures) that were previously reported in Camarena and García-Leal (2015), we found a consistent preference for the variable option regardless of the individual differences in the novelty seeking procedure. Due to this, we evaluated variations in latencies in choice behavior independently of previous classification in novelty seeking differences, taking all the rats together in a single group ($N = 8$).

Magazine training procedure. All rats were exposed to a magazine training procedure in order to obtain basal levels of pressing-lever response. During this procedure, the rats—at 85% of their free-feeding body weight—were exposed to a concurrent schedule of reinforcement with two components: fixed-time 30'' (FT30'') continuos reinforcement (CRF). This procedure finished when each rat completed 100 responses for two consecutive sessions.

Risk-sensitivity procedure. Two operant chambers (MED EVN-007, 25. 4 cm wide × 21 cm high × 31. 8 cm long) were employed for the choice procedure. Each cage had three levers (center, left, right), each one associated with a light. These lights (all of them white, but with variable intensity) signaled each one of the options presented. The rats were exposed to no-choice trials (center lever only), and free-choice trials (left and right levers simultaneously), according to the procedure described in the following paragraphs. The lights that signaled each alternative were not counterbalanced between rats, so that the most intense white-light was used for the option that delivered a constant outcome, and the less intense white-light signaled the option that delivered a variable outcome. The position of the alternatives was counterbalanced between blocks of sessions. See below for a more extensive explanation of this detail.

The experiment consisted of two phases, each composed of 24 sessions (one per day). During the first phase the rats were maintained at 75% of their free-feeding body weight. Subsequently, the level of food deprivation was decreased until they reached 90% of their free-feeding body weight. The weight was controlled by adding food after each experimental session (approximately 8 gr of amaranth). We manipulated food deprivation because this has been a variable widely explored in risk sensitivity procedures

since the work of Stephens (1981). As mentioned in Camarena and García-Leal (2015), the level of food deprivation did not have an effect on preference under this procedure. However, we will differentiate between phases to be consistent with the analysis of preference already published (Camarena & García-Leal, 2015). The position of the levers was counterbalanced in both phases, so that each phase began with the constant option (C) in the left side and the variable option (V) in the right side. This arrangement was reversed after session 12. Therefore, the arrangement C-V becomes V-C after 12 sessions in each phase (see Table 1).

Table 1
Order and Position of Each Option Across Phases

Phenotypic classification	Experimental conditions	
	Phase 1 (75% body weight)	*Phase 2 (90% body weight)*
Novelty-seeking test 8 rats (4 LR and 8 HR)	Risk-sensitive procedure: 24 sessions Lever position counterbalanced after 12 session (C-V to V-C)	

Ten blocks of trials were conducted during each session. Each block was composed of two no-choice trials and four choice trials. For all trials the constant option was associated with a high-intensity white light located over the lever and the variable option was associated with a low-intensity white light over the corresponding lever. Intensity was fixed using a 4-level fader control (control model MED EVN-226A). Thus, the light of the constant option was activated using input # 1 and that of the variable option using input # 3 of the fader control, so that both alternatives were perfectly distinguished. With this stimulus arrangement, the constant option delivered 0.05 gr of amaranth with a constant delay of 22.5 s and the variable option delivered the same 0.05 gr, but with a variable delay of 5, 10, 25, or 50 s. These values were presented randomly with equal probability (using a random sample with replacement). In the long-term, both options delivered the same mean amount of reinforcement but with different variability in delay.

During the no-choice trials one of the two alternatives was randomly presented in the center of the panel; the placement probability was equal to 0.5. Afterwards, during the choice-trials, both alternatives were presented simultaneously, with their position controlled as was previously mentioned above. After the choice, the lever (or the levers in the choice trials) was retracted, the reinforcer was delivered with the corresponding delay, and then an inter-trial interval of 10 s was interposed before the next trial.

The experimental manipulations across the whole study are summarized in Table 2.

Table 2
Summary of Handling and Experimental Manipulations Across the Experiment

Period (weeks)	Handling/Conditions	Feeding regime
0 – 13	Individual housing	Lab chows *ad libitum*
13 - 15	Novelty-seeking test	
15 - 16	Magazine training	Amaranth seeds
16 - 18	Food deprivation	
18 - 23	Phase 1 (75% body weight)	
23 - 25	Feeding until reach 90 % body weight	
25 - 30	Phase 2 (90% body weight)	

Data Analysis

In order to assess the SCM's predictions, we included in our data analysis latencies during the no-choice and choice trials across sessions, and across blocks, depending on each prediction. Due to the fact that latencies for both options showed a decrease as sessions progressed (see Figures 1 and 2) we only analyzed the first three sessions (referred to as initial latencies) and the last three sessions (referred to as final latencies) in order to make the comparisons for each alternative during each phase. Additionally, we averaged the median of the latencies for all rats and sessions in order to illustrate descriptive trends with respect to the latencies across sessions.

Due to the clear limitations imposed by the number of subjects and the characteristics of the distribution of the latencies, for predictions a) and b) we applied non-parametric tests in order to perform the required comparisons. In the case of the choice trials, because of the strong preference for the variable option (which implies more latencies for V than for C), we randomly selected a sample of the choice trails in which the V option was selected, in order to have a comparable sample size between C and V choice trials. In the case of prediction c), we employed a binary logistic regression assuming that the outcomes to be predicted were associated with only two options. Other studies have employed Pearson correlations but with a set of options greater than two (Craft, 2016; Shapiro et al., 2008).

Results

The first notable results concern the trend in latencies during no-choice and choice trials across sessions. For both types of trials, latencies increase through the first sessions, and then decrease monotonically to an asymptotic level. This asymptotic level is reached during Phase 1 and continues across to Phase 2. See Figures 1 and 2.

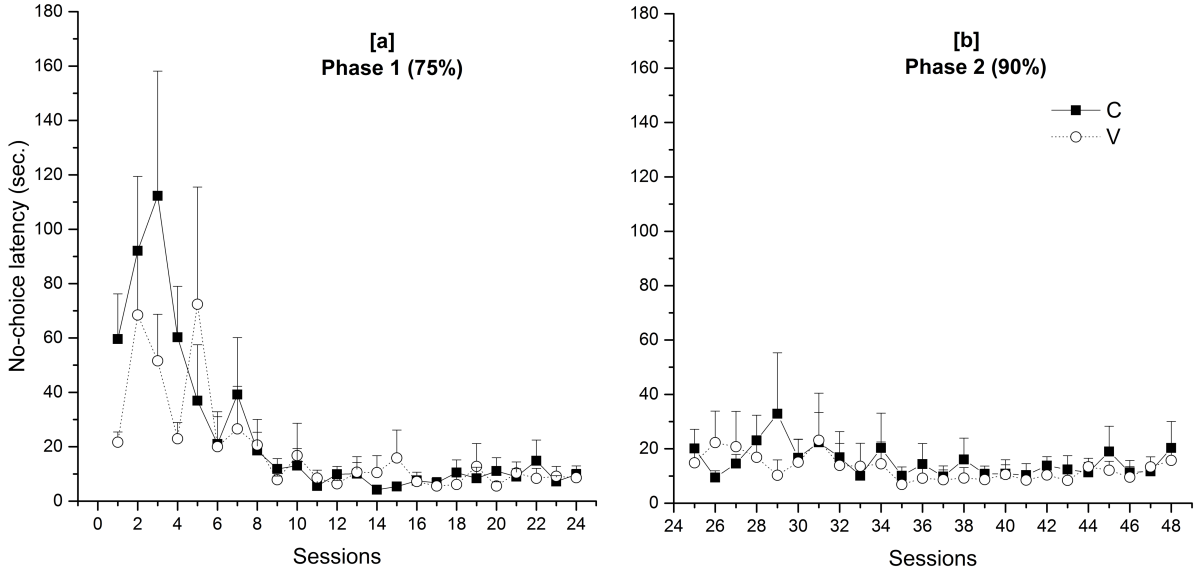

Figure 1. **Mean (±SEM) median latencies.** Means include all rats across sessions during no-choice trials for each option; (a) Phase 1 and (b) Phase 2.

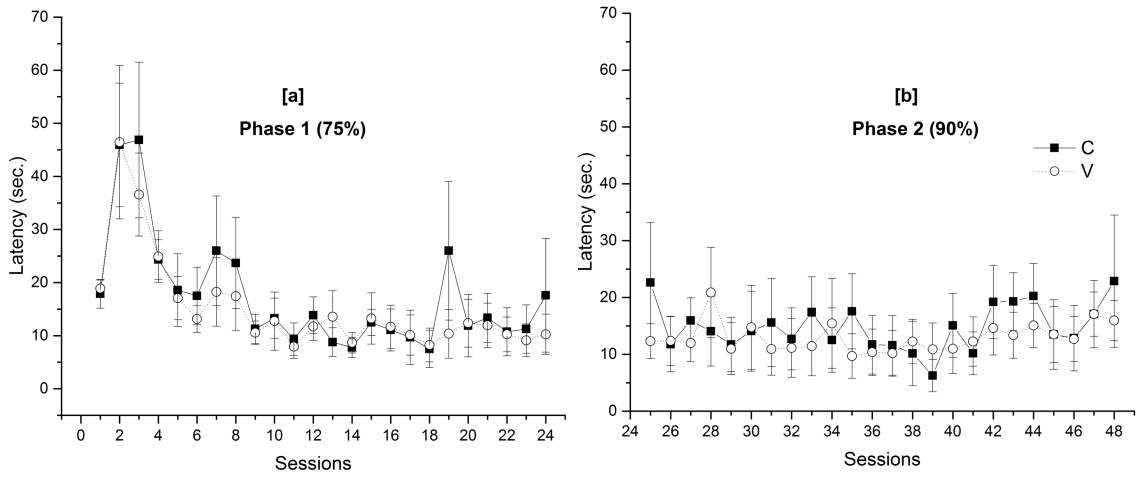

Figure 2. **Mean (±SEM) median latencies**. Means include all rats across sessions during choice trials for each option; (a) Phase 1 and (b) Phase 2.

SCM's predictions will be presented and assessed in the same order they were introduced.

Prediction A: The valuation process involves learning and reflects the attractiveness of the present option relative to the background opportunities.

A strong preference for the V alternative was found. Regarding this preference, shorter latencies for V than for C would be expected during no-choice trials. In order to test this prediction, we compared initial and final latencies for both options during each phase for the no-choice trials.

As can be seen in Figure 3, in Phase 1 the initial no-choice trials C's latencies ($\bar{X}$ = 88.13 s) and the initial no-choice trials V's latencies ($\bar{X}$ = 66.03 s), did not differ, Wilcoxon Z = -1.14, p = 0.15, but a statistically significant difference was found when comparing final latencies between C ($\bar{X}$ = 11.41 s), and V ($\bar{X}$ = 10.44 s), Wilcoxon Z = -2.32, p = 0.02. During Phase 2 there were no statistically significant differences between the initial latencies for C ($\bar{X}$ = 27.83 s) and V ($\bar{X}$ = 32.38 s), Wilcoxon Z = -1.51, p = 0.13, nor between the final latencies for C ($\bar{X}$ = 16.9 s) and V ($\bar{X}$ = 15.19 s), Wilcoxon Z = -0.55, p = 0.59.

When comparing latencies for the same option (initial vs final) during the same phase, a significant difference was found between the initial and final latencies for both options, with the exception of the V alternative in Phase 2. That is to say, latencies decreased from the beginning to the end of Phase 1. This difference was significant for the initial C´s latencies ($\bar{X}$ = 88.13 s), and final C's latencies ($\bar{X}$ = 10.44 s), Wilcoxon Z = -8.19, p < 0. 01, and likewise for the initial V's latencies ($\bar{X}$ = 66.03 s) and final V's latencies, ($\bar{X}$ = 10.05 s), Wilcoxon Z = -7.74, p < 0.01. During Phase 2, the same comparison revealed statistical differences for the initial C's latencies ($\bar{X}$ = 27.83 s) and final C's latencies ($\bar{X}$ = 16.89 s), Wilcoxon Z =

-2.506, p = 0.01, but not for the initial V's latencies ($\bar{X}$ = 32.38 s) and final V's latencies ($\bar{X}$ = 15.13 s), Wilcoxon Z = -1.26, p = 0.21.

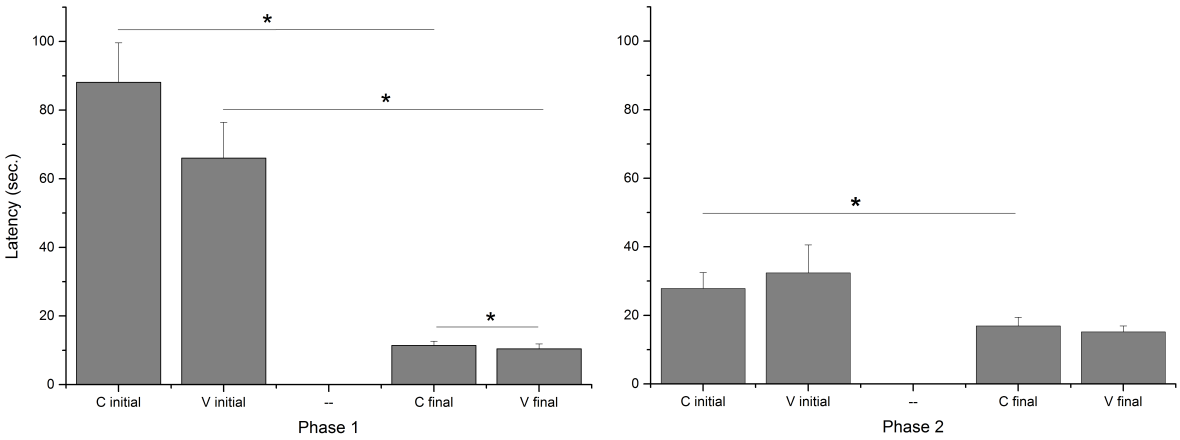

Figure 3. **Comparison of the initial and final latencies for C and V (mean ± SEM) for no-choice trials during each phase.**

As Figure 3 shows, there was a decrement of latency of choice across both phases. This decrement was statistically significant for the following comparisons: 1) initial latencies for C were shorter during Phase 2 ($\bar{X}$ = 27.17 s) than during Phase 1 ($\bar{X}$ = 80.13 s), Wilcoxon Z = -5.98, $p < 0.01$; 2) Initial latencies for V were shorter during Phase 2 ($\bar{X}$ = 30.44 s), than during phase 1 ($\bar{X}$ = 66.03 s), Wilcoxon Z = -6.78, $p < 0.01$; 3) final latencies for C were shorter during Phase 1 ($\bar{X}$ = 11.45 s), than during Phase 2, ($\bar{X}$ = 16.9 s), Wilcoxon Z = -1.97, p = 0.05; and 4) final latencies for V were shorter during Phase 1 ($\bar{X}$ = 10.48 s), than during Phase 2 ($\bar{X}$ = 15.19 s), Wilcoxon Z = -3.27, p = 0.01.

Our data support prediction A, assuming that the V alternative is the preferred option. Final latencies in both phases were shorter for alternative V than for alternative C (reaching statistical significance only during Phase 1). This is not the case for the initial latencies where this difference did not reach statistical significance. We observed the effect predicted in Phase 1, but a reverse effect within Phase 2. This could be explained by the assumption that because we reversed the order in which the alternatives were presented, the first sessions accounted for the animals' adaptation to the new configuration, with the result that their latencies did not display the value expected to be seen in each alternative. Additionally, comparisons between the same options across phases show a clear decrement in all latencies similar to a floor effect.

Prediction B: Cross-censorship between the processes generating latencies to act leads to observing shorter latencies during simultaneous choices than sequential encounters, particularly for the less preferred option.

According to prediction B, latencies during no-choice trials (sequential encounters) should be larger than latencies during choice trials (simultaneous encounters), particularly for option C, as the less preferred

alternative option. To test this prediction, we compared latencies during no-choice trials with latencies during choice trials. We introduced in the analysis all individual latencies. Secondly, we compared initial and final latencies for the preferred and non-preferred option during choice trials.

Regardless of the preferred option (see Figure 4), there was a statistically significant difference between the no-choice trials ($\bar{X}$ = 20.27 s) and choice trials ($\bar{X}$ = 15.29 s) during Phase 1, Wilcoxon Z = -4.93, $p < 0.01$. During Phase 2, that difference continued, but did not reach statistical significance ($\bar{X}_{\text{no-choice}}$ = 18.96 s; $\bar{X}_{\text{choice}}$ = 13.77 s), Wilcoxon Z = -1.54, $p = 0.12$ (see Figure 4).

Comparing the no-choice and choice trials across phases there was an effect of phase: the no-choice trials did not differ between phases 1 and 2 ($\bar{X}_{\text{phase 1}}$ = 20.27 s vs $\bar{X}_{\text{phase 2}}$ = 18.96 s, respectively), Wilcoxon Z = 0.94, $p = 0.35$, but the choice trials showed a decrement from phase 1 to phase 2 ($\bar{X}_{\text{phase 1}}$ = 15.29 s vs $\bar{X}_{\text{phase 2}}$ = 13.77 s, respectively), Wilcoxon Z = -4.51, $p < 0.01$ (differences not marked in Figure 4).

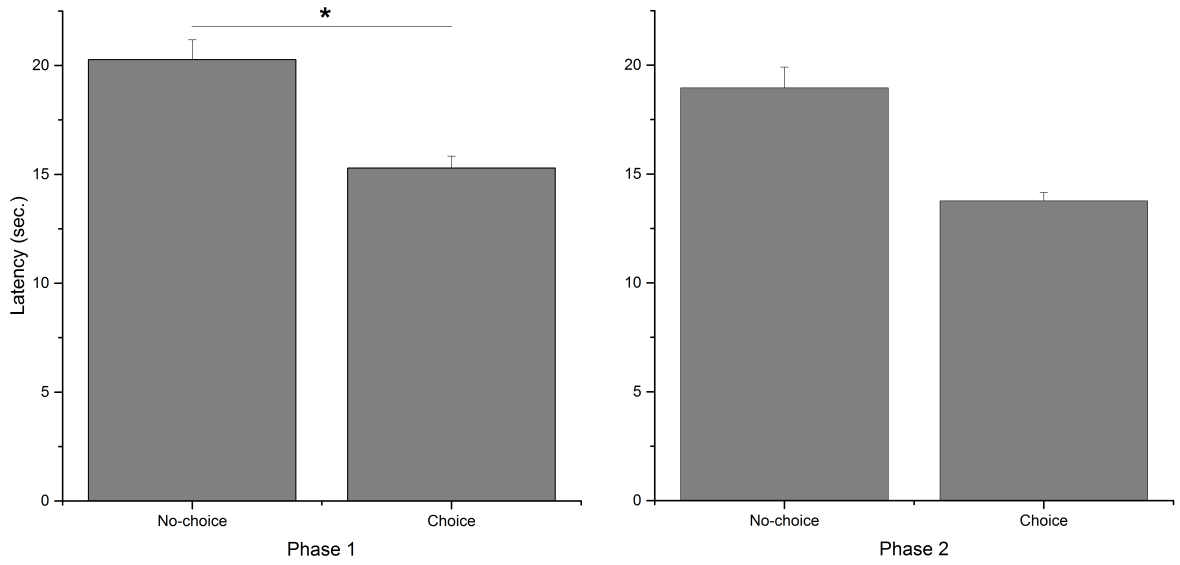

Figure 4. **Comparison of latencies during all no-choice trials and all choice trials (mean ± SEM) for each phase.**

When comparing the initial and final latencies during choice trials, a trend was observed in which the V's latencies were shorter than C's latencies. This difference reached statistical significance at the beginning. Thus, the initial latencies between C ($\bar{X}$ = 44.59 s) and V ($\bar{X}$ = 37.49 s), differed during Phase 1, Wilcoxon Z = 0.92, $p = 0.03$, but not during Phase 2 ($\bar{X}_{\text{C}}$ = 18.76 s vs $\bar{X}_{\text{V}}$ = 16.66 s), Wilcoxon Z = -0.3, $p = 0.76$. The same was observed for the final latencies between C ($\bar{X}$ = 13.46 s) and V ($\bar{X}$ = 11.67 s), during Phase 1, Wilcoxon Z = -1.1, $p = 0.27$. In the case of Phase 2, the initial latencies between C ($\bar{X}$ = 18.76 s) and V ($\bar{X}$ = 16.18 s) did not differ significantly, Wilcoxon Z = -1.1, $p = 0.65$, nor did the final latencies ($\bar{X}_{\text{C}}$ = 19.5 s vs $\bar{X}_{\text{V}}$ = 15.05 s), Wilcoxon Z = -0.61, $p = 0.54$. When, comparing latencies for the same option during the same phase, there was a difference between initial the C's latencies ($\bar{X}$ = 44.59 s), and final C's latencies ($\bar{X}$ = 13.46 s), Wilcoxon Z = -4.69, $p < 0.01$, likewise for the initial V's latencies ($\bar{X}$ = 37.49 s), and final V's latencies ($\bar{X}$ = 11.67 s), Wilcoxon Z = -8.07, $p < 0.01$, during Phase 1. During phase 2, the initial C's latencies ($\bar{X}$ = 18.76 s) did not differ from the final C's latencies ($\bar{X}$ = 19.5 s), Wilcoxon Z = -1.13, $p = 0.25$,

but the initial V's latencies ($\bar{X}$ = 16.18 s) differed from the final V's latencies ($\bar{X}$ = 15.05 s), Wilcoxon Z = -2.54, p = 0.01 (see Figure 5).

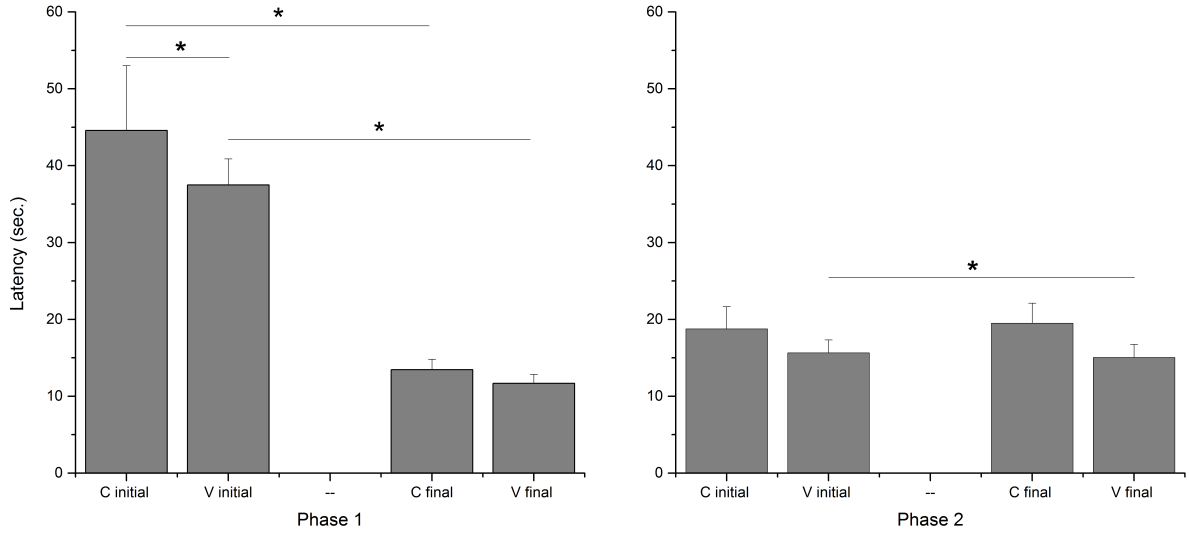

Figure 5. **Comparison between initial and final latencies for C and V (mean ± SEM) for choice trials during each phase.**

When comparing latencies during choice trials for the same option it is possible to see a significant decrement between phases: The initial latencies for C decreased from Phase 1 ($\bar{X}$ = 44.33 s) to Phase 2 ($\bar{X}$ = 21.59 s), Wilcoxon Z = -4.3, $p < 0.01$. The initial latencies for V also decreased from Phase 1 ($\bar{X}$ = 38.01 s), to Phase 2 ($\bar{X}$ = 16.65 s), Wilcoxon Z = -7.81, $p < 0.01$. In the case of the final latencies, the opposite trend was found; final latencies for C increased from Phase 1 ($\bar{X}$ = 14.56 s) to Phase 2 ($\bar{X}$ = 19.5 s), which was without statistical significance, Wilcoxon Z = -1.16, p = 0.25. The final latencies for V increased from Phase 1 ($\bar{X}$ = 10.54 s) to Phase 2 ($\bar{X}$ = 16.18 s), Wilcoxon Z = -8.6, $p < 0.01$ (difference not marked in Figure 5).

In sum, our data are compatible with prediction B, but only in Phase 1, where the latencies for choice trials (simultaneous encounters) were shorter than the latencies for no-choice trials (sequential encounters). Additionally, latencies for the preferred option were shorter, although this difference did not reach statistical significance in all cases.

Prediction C: One should be able to predict partial preferences between options, when faced simultaneously, from behavior (i.e., latencies) during sequential encounters.

According to prediction C, latencies during no-choice trials should allow the prediction of preference during choice trials. In order to test this prediction, we took the averaged latencies from no-choice trials for each option (using the first and last six sessions of each phase), and ran a binary logistic regression taking preference for V as the dependent variable. In order to dichotomize all variables, we calculated the cases where the mean latency to V was shorter than the latency for C during the no-choice trials (V < C = 1 and V > C = 0) across blocks, and selected these as predictors of the mean preference for V during the choice trials across blocks (preference for V > 50% = 1 and preference for V < 50% = 0). The results of the logistic regressions are presented in Table 3.

Table 3

Results of Binary Logistic Regression Taking the First and Last Sessions of Each Phase

Phases	*Coefficient*	*SD error*	*Wald chi-square*	*p-value*
Phase 1: first 6 sessions	-2.303	1.11	4.299	0.038
Phase 1: last 6 sessions	-	-	-	-
Phase 2: first 6 sessions	1.003	0.55	3.333	0.068
Phase 2: last 6 sessions	-17.592	6607.684	0	0.998

Note. The last six sessions of phase 1 do not allow the running of this regression as there were no cases of preference for V < 50%.

The correlation between the average latencies during choice trials and the preference during choice trials was significant only during the first sessions of Phase 1.

A more detailed analysis of the proportion of V's latencies shorter than C's latencies during no-choice trials across all sessions revealed that during Phase 1 this proportion was 55% differing from chance, binomial test, $p < 0.01$; likewise for Phase 2, binomial test, $p < 0.01$. Additionally, the accumulated distribution of the differences between C and V's latencies for no-choice trials overlapped for both phases, especially for the last sessions, when it is supposed that the preference is steady. Finally, the differences in latencies during no-choice trials show a leptokurtic distribution, such that the main proportion of the scores were distributed around the mean difference with low variability.

In sum, the distribution of latencies within no-choice trials allowed the confirmation of prediction C only during the first six sessions.

Discussion

The aim of the present experiment was to test the predictions of the SCM in a risk sensitive procedure. Our data support some of the SCM's predictions: Prediction A was not completely confirmed when analyzing no-choice and choice trials; Prediction B was confirmed regarding all no-choice and choice trials, but not regarding the initial and final latencies; and Prediction C was confirmed only for the first six sessions of the experiment, because the obtained distribution of latencies for both alternatives during no-choice trials tended to overlapped each other.

The following explanations support the effect of extended exposure on the SCM's predictions and valuation cost.

Since the SCM does not make predictions based on the possible effects of the learning rate (understood here as the extended exposure to the value of each option) on latency of choice, and due to the fact that there is no agreement about the quantity of trials necessary to observe steady preference, variations in the number of trials can affect the latencies for each option (e.g., decreasing all latencies) as a consequence of learning. Assuming this effect of learning, our data suggest that the extended exposure to the options provoked a general decrement in latencies (see Figures 1 and 2), as has been previously reported in humans (Logan, 1990, 1992) and rats (Blokland, 1998). Therefore, the trend found when testing prediction A, may be a consequence of a floor effect in which the latency for both options in no-choice trails differs only during the last three sessions of Phase 1; subsequently, the difference between the latencies is without statistical

significance. Thus, due to the floor effect, when a set of alternatives has been extensively learned, the difference between the latencies seems to disappear, possibly due to a *reduced valuation cost* (see Figure 1). Mazur (2010) found a similar trend in latencies when employing three phases of 64 trials each (divided in blocks of two no-choice and two choice trials), such that in his experiment, pigeons tended to respond faster for any option, demonstrating a similar overlap in latencies during no-choice trials as to the one we found in our experiment. Other studies have shown shorter latencies for the preferred option during no-choice trials (Aw et al., 2012; Craft, 2016; Schuck-Paim & Kacelnik, 2002; Vasconcelos et al., 2010), but without an analysis across sessions. With respect to this observed trend, it is important to point out that from Phase 1 to Phase 2 the level of food deprivation was decreased, so the effect of extended exposition to each alternative cannot be differentiated from the possible effect of decreasing food deprivation. Nevertheless, other studies have found that increasing food deprivation provokes shorter latencies (Stephens & Dunlap, 2011), which would be contrary to our findings, where there was a general decrement from 75% to 90% of food deprivation. Due to the fact that food deprivation did not affected preference in our procedure (Camarena & García-Leal, 2015), we regard the decrement in latency as a consequence of the extended exposure to the options.

The findings regarding prediction B also support the effect of the extended exposure to the options. As plotted in Figure 4, latencies during all choice trials were shorter than during all no-choice trials during Phase 1. We obtained a similar result on Phase 2, but in this case the difference in latencies did not reach statistical significance. The evidence confirming this prediction is scarce, but the effect has been shown by Shapiro et al. (2008), who included all latencies across all sessions, as in the present experiment. Mazur (2010) also found the same trend, though not to the level of reaching statistical significance. However, in a risk sensitive procedure where latencies were longer during the choice phase, the contrary has been shown (Roche, Timberlake, & McCloud, 1997). Our data suggest that the extended exposure to the options causes an overlap in latencies from Phase 1 to Phase 2. As noted above in the discussion of prediction A, it seems improbable that the level of food deprivation was the cause of this trend.

Studies in reaction times in rats have also shown shorter latencies for two options compared with latencies for a single one, along with a decrement in latencies between sessions (Blokland, 1998). Additionally, Roche et al. (1997) found no difference in latencies between baseline (two options with the same value) and choice (two options differing in value) in a risk sensitive procedure, which also places into question prediction B.

When comparing the initial and final latencies for the preferred and non-preferred option in choice trails, the possible effect of extended exposure can also be confirmed. As can be seen in Figure 5, the initial latencies for V were shorter than latencies for C during Phase 1. Subsequently, differences in latencies for the preferred and less preferred options disappeared. Nevertheless, latencies for both options decreased during Phase 1, and this decrease becomes a floor effect during Phase 2, where only the initial latencies for V differed from final latencies for V. Thus, the effect observed when testing prediction B supports the idea of a *reduced valuation cost* during simultaneous encounters due to the learning of the value of the alternatives, which is also consistent with the assumption about the effects of extended exposure to the options. In humans, this effect of flat response times across sessions has also been found in perceptual choice procedures, and has been explained as an effect of practice (Ratcliff & Rouder, 1998).

The decrement in reaction times as a function of training has been previously reported. Since the majority of this evidence comes from studies with humans, we searched for a model capable of explaining

the observed decrement in latencies across sessions. Logan (1992) proposed an exponential decrement, according to the following equation:

$$RT = a + bN^{-c}$$

Where RT is the reaction time; *a* is the asymptote, reflecting an irreducible limit on performance; *b* is the difference between initial and asymptotic performance; *N* is the amount of practice, measured in sessions or trials per item; and the exponent *c* is the learning rate. Both parameters *a* and *b* are scaling parameters that move the function with regard to data, but the shape of the function is completely determined by parameter *c*.

The Logan equation fit our data, when taking the averaged medians across sesions (see Table 2), but this was so only during Phase 1. In the case of Phase 2, because of the floor effect, our data were better described by a linear equation (see Table 2).

The distribution of latencies during Phase 1 (exponential shape) and Phase 2 (linear shape) supports the idea of the general decrement in latency of choice as a consequence of learning, which in turn did not allow the visualization of the predicted differences between C and V. This decrement in latency of choice has also been found in other procedures with animals such as rats (Blokland, 1998; Döbrössy & Dunnet, 1997) and monkeys (Albantakis & Deco, 2009).

Table 4
Logan Equation Fitting for Phase 1 for Each Option During No-Choice and Choice Trials

	a	**b**	**c**	**R^2**
Phase 1 (Logan equation)				
No-choice: C	0	0	0. 64	0.52**
No-choice: V	0	0	0. 47	0.29**
Choice: C	0	0	0. 34	0. 29**
Choice: V	0	0	0. 38	0.44**
Phase 2 (Linear equation)				
No-choice: C	-0.28	25.52		0.08
No-choice: V	-0.32	24.52		0.22*
Choice: C	0.08	11.8		-0.02
Choice: V	0.06	10.65		-0.01

Note. Linear equation fitting for Phase 2 for each option during no-choice and choice trials.
* $p < 0.05$. ** $p < 0.01$.

Although we found a decrement in latencies from no-choice to choice trials, our data do not support the prediction of a reduction in the latencies during choice trials for the less preferred option (second statement of prediction B). The above cited previous studies also failed to prove a decreased latency for the less preferred option during choice trials, so this statement of the SCM as of yet remains unsolved.

It is probable that the most important result of our experiment, with respect to the SCM, is that we did not find a consistent relationship between latencies during no-choice trials and preference during choice trials (prediction C reached significance only for initial sessions). Other studies have shown a clear support for this prediction (Aw et al., 2012; Craft, 2016; Freidin et al., 2009; Shapiro et al., 2008; Vasconcelos et al., 2010). However, these studies do not analyze the possible effect of extended exposure to the value of the options, since the number of trials was less than the quantity employed in the present experiment, and their analyses are usually based on the final sessions or steady preferences. Mazur (2010) also found a lack correlation between latencies during no-choice trials and preference during choice-trials, but this was observed when taking only the last two sessions.

The observed correlation between latencies in no-choice trials and preference in choice trials only during the first six sessions of Phase 1, along with the general decrement for all latencies, suggest not only learning, but also the effect of a maximization process. Under this consideration, shorter latencies for any option during any trial would maximize the rate of reinforcement per session, as both options had the same mean of reinforcement and sessions always lasted one hour, or ended when all blocks of trials were completed. In our experiment, the number of trials completed increased across sessions quickly reaching a ceiling effect. This was especially notable during Phase 2 (see Figure 6). This would explain the noticeable decrement in latencies during no-choice and choice trials, supporting the idea of a maximization processes.

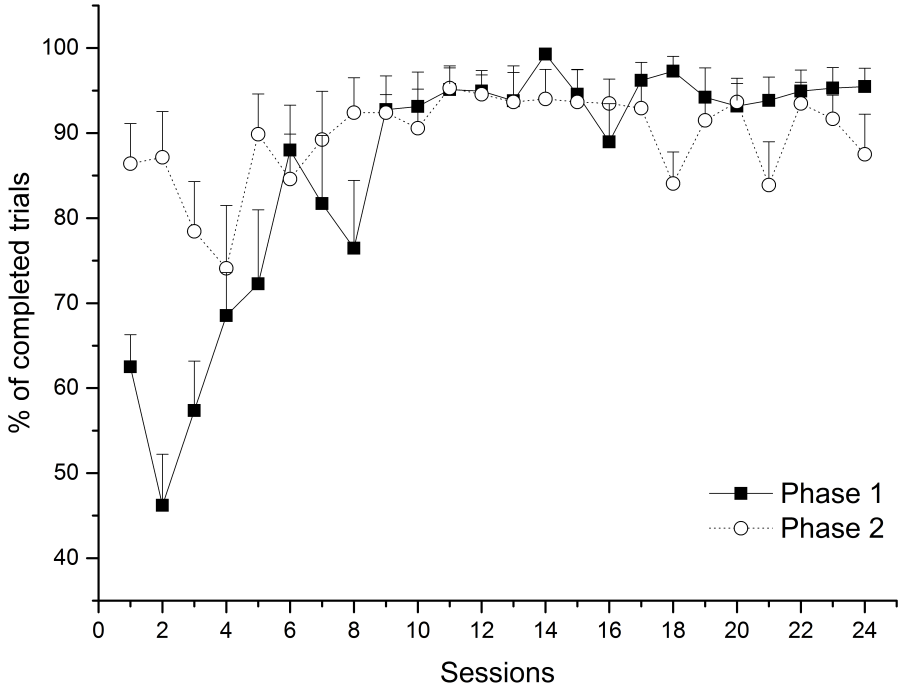

Figure 6. **Mean percentage of trials completed (mean ± SEM) for each Phase.**

In the context of other procedures, the question of the association of shorter latencies with the preferred option remains debatable. For example, shorter latencies have been widely taken as a measure of

preference in marketing research (Aaker, Bagozzi, Carman, & MacLachlan, 1980; Tyebjee, 1979), but Reimann, Castaño, Zaichkowsky, and Bechara (2012) have shown larger latencies for the preferred option in a brand choice procedure (contrary to prediction A). In animals, Roche et al. (1997) found longer latencies during choice trials, even when there was no preference for the variable or the fixed option (contrary to prediction B). Regarding the above relationship between latency and the valuation of alternatives might differ from the SCM's predictions.

The assumption that latency of choice is an "expression" of preference, as the SCM supposes, requires further clarification. For example, studies in reaction times in humans have taken shorter latencies as cases of cognitive processes like memory, learning, automaticity and intelligence (Birren & Fisher, 1995; Logan, 1992). All those processes might well be involved during a choice procedure (e.g., temporal cost of valuation). Therefore, the specific relationship between latency, valuation of alternatives and preference needs to be explored in the context of the afore mentioned evidence.

More evidence supporting a comparison process comes from studies in transitive inference.I n a transitive inference procedure, organisms are exposed to pairs of stimuli where only one is reinforced (e.g., A+ B-) and during training the chain of stimuli is enlarged (e.g., A+ B-, C+ D-, E+ F-). Finally, during testing, subjects have to choose between pairs of stimuli which have not been paired before (e.g., A C, B D, C E, D F). What is observed is an increased latency for pairs of stimuli (called here non-adjacent pairs) that were never paired during training. This is referred to as the symbolic distance effect, and it has been reported in monkeys (D'Amato & Colombo, 1990), humans (Hinton, Dymond, von Hecker, & Evans, 2010) and other species (see Vasconcelos, 2008 for a review). Since choice during testing involves a comparison of untrained pairs, and since latency for these pairs is greater, this evidence suggests a comparison process (contrary to prediction B). Unfortunately, transitive choice procedures do not analyze latencies across all training and test trials, which cannot permit the confirmation of the the afore mentioned effect of the reduction of latencies as a consequence of learning.

Other evidence supporting a comparison process comes from studies and context-dependent preference. Hutchinson (2005) described several procedures in sexual selection and commodities selection where the simple addition of more alternatives affects the preference in a way that is contrary to a maximization assumption. Experiments with monkeys, have shown an exponential decrease in reaction times, but in correlation with the amount of stimuli presented (the more alternatives, the less steep the decrement in reaction times) (Albantakis & Deco, 2009) This also suggests a comparison process. Additionally, studies where subjects are exposed to a set of two alternatives, and then a set which is changed to three alternatives, also show changes in preference, which in this case suggests a context dependent comparison process (Bateson, 2002; Hurly & Oseen, 1999). Other procedures show that the simple addition of a decoy can change the preference for a particular set of alternatives (Bateson, Healy, & Hurly, 2003). Although these effects have not been analyzed in relation to latency of choice, the simple change in preference when an alternative is added suggests a possible comparison process.

In sum, with regard to the three above mentioned SCM predictions, our data partially support the model, due to the observed decrement in latencies. Consequently, our data shown an effect of extended exposure on each prediction, such that due to the progressive reduction in all latencies prediction A cannot be confirmed except for the final sessions of Phase 1. Prediction B was confirmed when comparing all no-choice and all choice trials, but the predicted reduction in latency for the less preferred option during choice trials could not be confirmed. Prediction C was confirmed only for the first sessions.

According to our data, we assume that there is a valuation process which becomes unrelated to latencies as the exposure to the options proceeds. This means that even when the organisms assign a value for each alternative, eventually measured by latency of choice, the differences between latencies for each alternative tend to disappear as training progress (the time or the cost for the valuation process is reduced). Thus, across choice trials, the organism employs a comparison process which involves the rapid valuation of each learned alternative (a detailed explanation of that process is beyond the scope of this paper). Subsequently, with extended exposure to the same alternatives, latency of choice will tend to decrease in a manner similar to the decrease in reaction times previously reported. This trend in latency of choice could be adaptive to choice procedures where reduced deliberation times increases the reinforcement rate, and to procedures where the rate of reinforcement increases as a function of trials completed. Under more natural contexts of choice, lower latencies of choice for the preferred option can also be regarded as adaptive since these could maximize the rate of resources per unit of time.

Due to the fact that the predicted relationship between latency and preference can be significantly affected as a consequence of the learning of the alternatives' values, future studies about the SCM should incorporate analysis about how the learned value of each alternative affects the predicted latency-preference relationship, including the possible role of maximization of reinforcement over latencies. Of course, a contrast with other models that predict foraging choices (e.g., tug-of-war model) also would be helpful in testing the SCM's predictions, but has been mentioned, it would go beyond the scope of this paper. The incorporation of longitudinal studies can also contribute to more accurate and conclusive explanations about latencies and foraging choices. These analyses would allow the determination of how the valuation process involved in no-choice trials and the comparison process involved during choice trials operate and affect choice behavior.

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Financial conflict of interest: No stated conflicts.
Conflict of interest: No stated conflicts.

Submitted: *June 3rd, 2016*
Resubmitted: *December 15th, 2016*
Accepted: *January 9th 2017*