

# **ELECTRONIC APPENDIX**

This is the Electronic Appendix to the article

**The ecology and evolution of patience in two New World monkeys**

by

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Electronic appendices are refereed with the text; however, no attempt is made to impose a uniform editorial style on the electronic appendices.

## Supporting Online Material

### Material and Methods

#### *Subjects*

We used six adult cotton-top tamarins (three males and three females) and five adult common marmosets (three males and two females) as subjects in this experiment (See Table S.1 for more information). All subjects participated in other behavioural experiments. One month before this experiment, we tested four of the six tamarin subjects (DW, JK, SP, and UB) in a pilot experiment in which they chose between an immediate two pellets or six pellets delayed 15, 20, 25, or 30 sec. There were no statistically significant differences in indifference points for naïve or experienced subjects ( $F_{1,4} = 0.28, p = 0.63$ ), although the sample size is admittedly small. Nevertheless, the two naïve tamarins showed indifference at levels within the range of the experienced individuals (Table S.1). All marmosets were naïve to the experiment to the self-control paradigm.

The subjects received their daily food allotments after the experiments were completed at the end of the day. Both tamarins and marmosets were maintained at body weights which provided the most reliable performance in food-motivated tasks.

#### *Apparatus*

We placed subjects in a metal cage (30×30×30 cm) adjacent to the discounting apparatus. There were four holes in the clear Plexiglas front panel of the cage. By reaching through the lower two holes in the wall, subjects could grasp one of two tool handles to bring the food reward within reach through the upper two holes (Figure 1). Transparent covers prevented subjects from accessing the food until the end of a delay. Two solenoids operated the movement of the covers to reveal and cover the food rewards. An experimenter flipped a

switch, starting the electronic timer and, after a specified delay, activated the solenoids to open the covers. A buzzer sounded during the delay period.

### *Trial procedures*

A trial started with the presentation of two L-shaped tools to the subject through the lower holes in the front barrier. The tools consisted of a straight handle and a crossbar trough containing food pellets (Research Diet 45 mg banana-flavoured purified diet primate pellets). A green tool was always associated with the delivery of six pellets, whereas an orange tool always delivered two pellets. Within a session the tools remained on the same side of the apparatus, but they alternated sides between sessions. To choose one of the reward options, the subject had five seconds to touch one of the tools and 30 seconds to pull the tool until the trough contacted the front of the Plexiglas barrier of the transport cage. Minimal effort was required to pull both of the tools. Once the subjects touched one of the tools, the other was immediately removed, preventing them from switching between tools. As soon as the trough was pulled forward enough to contact the barrier, the experimenter started the delay by activating the timer. At the end of the delay, the solenoids moved the covers, allowing the subject to reach their reward. After retrieving the last pellets from the trough, the experimenter started a 30 second inter-trial interval.

Each session consisted of 14 trials and lasted approximately 15 minutes. Four of the 14 trials were forced trials; the other 10 were free choice trials. In forced trials we only presented one tool to the subject, with the other tool remaining in sight but out of reach. A session always started with two forced trials: one forced the larger reward and one forced the smaller. We alternated the order of this presentation between sessions. We randomly interspersed the remaining two forced trials (one of each choice) throughout the session. The other ten trials

were free choice trials which allowed subjects to choose between rewards by pulling one of the two tools.

### *Experimental design*

Throughout the experiment, subjects received access to the small reward immediately (standard option). The delay for the large reward (adjusting option) was constant within a session but varied between sessions. In the first session, it started at zero and increased by one second for the next session if the subject chose the larger of the rewards seven or more times. Similarly, if the subject picked the smaller reward seven or more times, the adjusting delay decreased by one second in the following session. If the subject chose neither tool seven or more times, the delay remained the same for the next session. By adjusting the delay, we were able to find the point at which the subjects were indifferent between the smaller, immediate option and the larger, delayed option. We calculated this indifference point by comparing the mean delay to large for the last five completed sessions with the mean of the previous five sessions. Subjects reached indifference when the mean delay of the last five sessions did not differ from the mean delay of the preceding five sessions by more than 10% or one second, whichever was larger. We used the mean delay of the last five sessions as our estimate for the indifference point.

### *Calculating delays, handling times, and indifference points*

Standard delay time ( $t_s$ ) was the estimated time between toggling switch and food becoming available (0.1 sec). Handling times ( $h_s$  and  $h_a$ ) were estimated from measurements of the time between the first and last reach for pellets in six forced short-delay trials and six forced long-delay trials for each subject. Each species' predicted indifference points ( $t_a$ ) are a mean

of individual subject predicted indifference points. That is, we applied the rate maximization equation to each subject rather than to the overall species means. If predicted indifference points were negative for a subject, we used a time of zero sec. This accounts for the discrepancy between the stated predicted indifference point for tamarins ( $t_a=8.6$  sec) and that calculated using the overall species means.

This experiment was conducted in compliance with the Harvard University Animal Care protocols 92-16 and 22-07.

## **Results**

### *Sex differences*

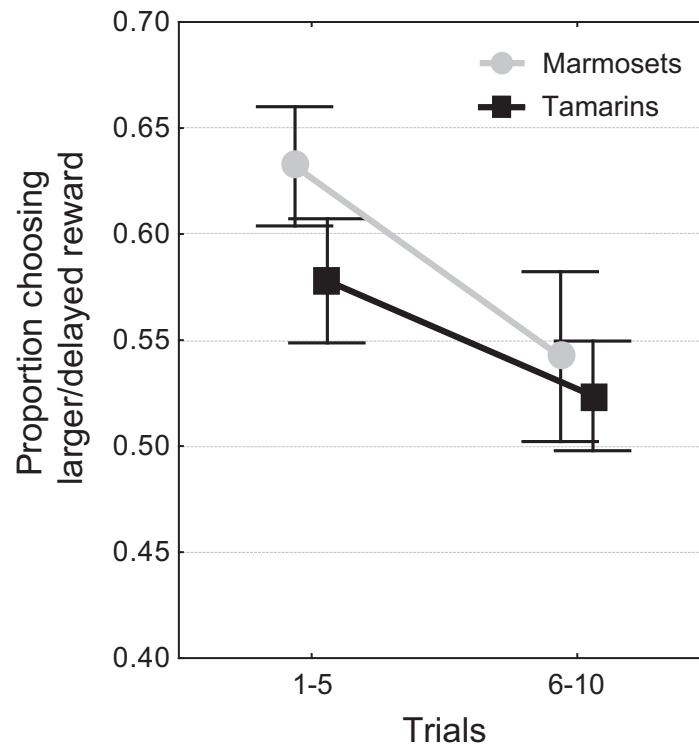
Although sample sizes are small, there are no sex differences in indifference point ( $F_{1,7} = 0.06, p = 0.81$ ) and there is no interaction between species and sex ( $F_{1,7} = 0.01, p = 0.91$ ).

### *Motivation*

To further assess the role of motivation in this experiment, we examined the subjects' performance in trials within a session. We measured the proportion of choices for the larger/delayed reward (arc-sine, square-root transformed) in the last 10 sessions for each subject (the sessions used to assess the indifference point). We then divided the trials into those which occurred in the first half of the session (trials 1-5) or the second half (trials 6-10). There was a strong effect of trial ( $F_{1,97} = 6.49, p = 0.01$ )—subjects chose the larger/delayed reward more in the first five trials. Significantly, there was no species effect or species by trial interaction (Figure S.1). Therefore, motivation changed within a session but was the same for both species, suggesting that their general motivational levels were roughly equal.

**Table S.1: Subject data for weights, handling times, and indifference points**

<b>Subject</b>	<b>Species</b>	<b>Sex</b>	<b>Weight (g)</b>	<b>Standard handling time (sec)</b>	<b>Adjusted handling time (sec)</b>	<b>Observed indifference point (sec)</b>
AG	Tamarin	M	413	18.3	16.5	7.6
DW	Tamarin	M	322	6.7	23.8	8.4
JG	Tamarin	F	431	11.2	21.2	9.2
JK	Tamarin	F	376	4.8	15.8	5.6
SP	Tamarin	M	435	9	39	6.7
UB	Tamarin	F	404	14.2	46	9.8
<b>Mean</b>	<b>Tamarin</b>		<b>397</b>	<b>10.7</b>	<b>27.1</b>	<b>7.9</b>
Ant	Marmoset	M	254	8.7	18	10
Des	Marmoset	F	340	10	21.8	16.2
Jul	Marmoset	F	394	6.2	13.8	12.8
Oth	Marmoset	M	294	8.8	20.3	13.8
Rom	Marmoset	M	335	7.7	18.5	19
<b>Mean</b>	<b>Marmoset</b>		<b>324</b>	<b>8.3</b>	<b>18.5</b>	<b>14.4</b>



**Figure S.1:** Species and trial effects on choices. Both species chose the larger/delayed option more often in the first five trials of a session than in the last five trials. There is no species by trial interaction, suggesting that both species faced similar changes in motivation within a session.