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Delay Discounting Measured Using a Sequential Patch Depletion Procedure

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ABSTRACT

Running Delay Discounting experiment in Rats

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MATERIALS TEXT

Food (Teklad Laboratory Diet #8604) is continuously available in the home cage.

Animals

1 Rats are housed in same-sex pairs in plastic laboratory cages (42 cm × 22 cm × 20 cm) lined with bedding (Aspen Shavings) and maintained in a reverse light-dark cycle (lights on from 19:00 to 07:00 hours) in a temperature (22 ± 1°C) and humidity (approximately 55 ± 5%) controlled colony.

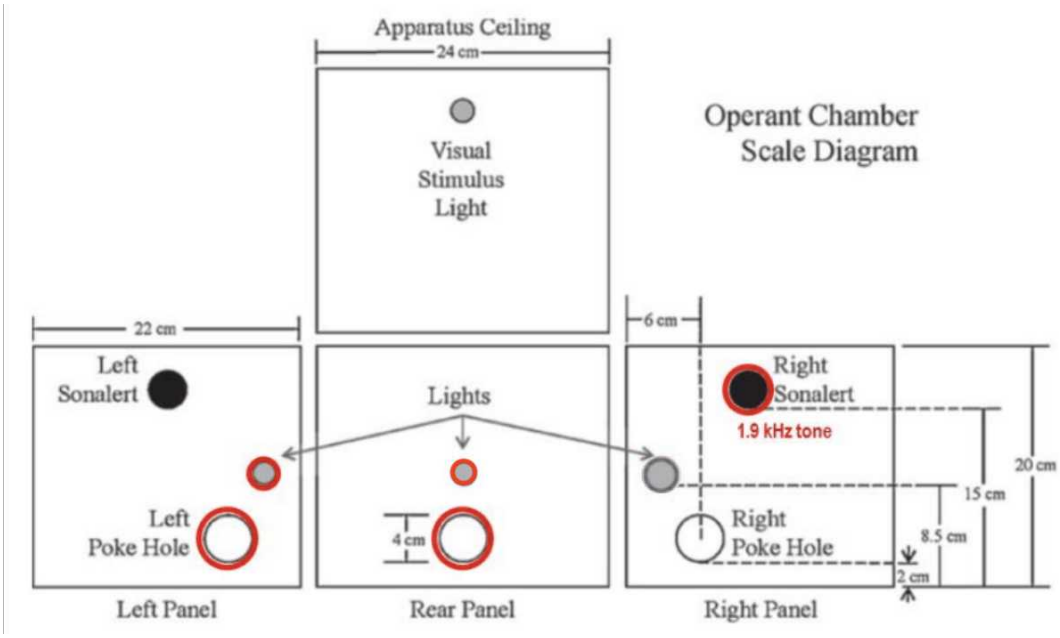
1.1 Animals have *ad libitum* access to food (Teklad Laboratory Diet #8604, Envigo, Indianapolis, IN)) except during experimental testing.

1.2 Rats are maintained on a water restriction regimen for the duration of the experiment. Accordingly, free access to water is restricted to 30 minutes following testing on Monday through Friday. At the end of the testing on Saturday, animals have free access to water until it is removed on Sunday approximately 20 hours prior to testing on Monday.

1.3 Animals are treated in compliance with the Guide for the Care and Use of Laboratory Animals, and the experiments are conducted in accordance with a protocol approved by the Institutional Animal Care and Use Committee (IACUC) at the University at Buffalo, The State University of New York.

Apparatus

2 Behavior is measured in 24 locally constructed operant chambers (see the diagram below).



A schematic diagram of the testing chamber. Elements used in the Delay Discounting experiments are shown in red.

2.1 The back and two side walls of the test chambers are made of aluminum. The

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top and front of the chambers are made of Plexiglas. The flooring is made of parallel stainless steel rods at a distance of 1 cm, below which there is a removable litter pan with an absorbent paper liner (Techboard®, Shepherd Specialty Papers, Watertown, TN).

2.2 Each test chamber has three snout poke holes (4 cm in diameter) located in the left, right, and rear aluminum walls. Stimulus lights are located above the snout poke holes. Infrared photodetectors, placed 1 cm from the snout poke hole entrance, are used to record the frequency and duration of the snout poke.

2.3 Each snout poke hole provides access to an acrylic dish into which precise amounts of water can be pumped. Tygon® tubing (S3 E-3603) connects these acrylic dishes to two 60- ml syringes mounted on two syringe pumps (PHM-100, Med Associates, Fairfax, VT) located externally to the sound-attenuating cooler.

2.4 A tone generator (SC628EJR, Mallory Sonalert, Indianapolis, IN) in the right panel that emits a pulsed 1.9-kHz tone provides an auditory stimulation.

2.5 Each test chamber is housed in a cooler (Model # 3000000187, Coleman, Chicago, IL), which blocks external audiovisual sources of stimulation and contains a fan for air circulation.

2.6 Two computers connected to a Med Associates interface control sets of 16 and 8 chambers, respectively. The MED-PC IV software package (Med Associates, Fairfax, VT) is used to program and control experimental contingencies as well as collect data. The complete system operates at a temporal resolution of 0.01 s.

Behavioral testing procedure

3 Delay Discounting is measured using a sequential patch depletion procedure, which simulates naturally occurring choice problems confronting animals while foraging for food resources (see the figure below). Patches refer to concentrations of resources, and patch depletion refers to the fact that staying in a patch longer while consuming a resource depletes the patch and decreases the rate of immediate resource consumption. However, leaving the depleting patch for a new patch requires enduring a delay associated with traveling from the depleted patch to the new patch, during which resources are not available. Foraging theory predicts that, when confronted with long delays, the animal will deplete patches to lower levels before leaving.

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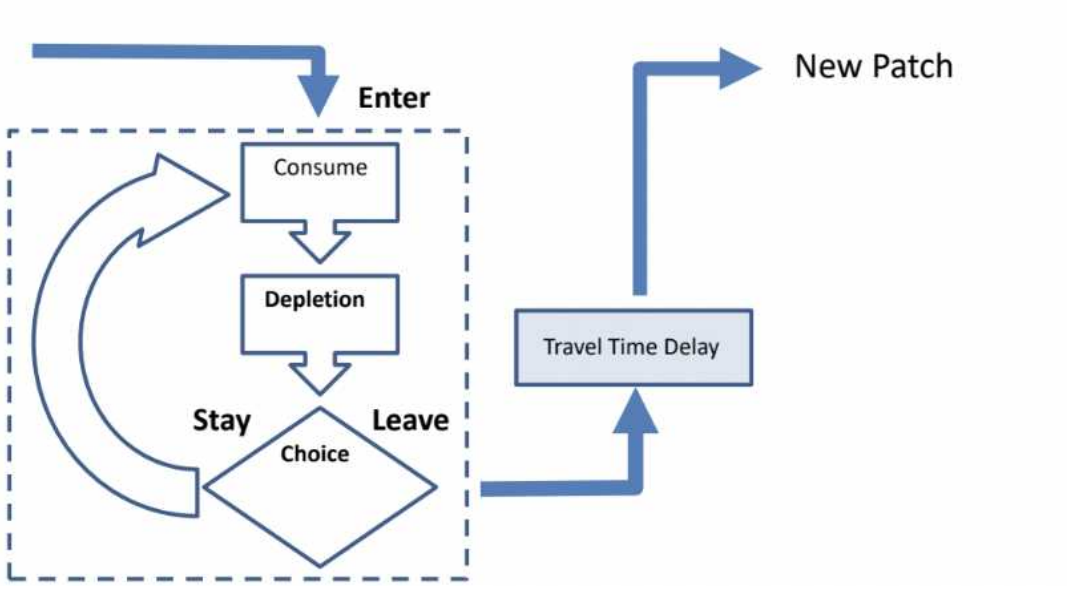

A schematic diagram of sequential patch foraging. The animal chooses between staying in the depleting patch and leaving and moving to a new patch, which requires enduring a travel time delay, during which the rate of immediate resource consumption is zero.

3.1 In the laboratory patch depletion procedure, water-restricted rats alternate drinking water at the left and center (rear) water feeders ("patches") in the testing chamber. The third (right) feeder is not used for this experiment. The left and center feeders are used to minimize the physical distance the rat must travel to switch patches.

3.2 Rats are water-restricted prior to the start of the experiment (see 1.2). Water is removed from the home cage on the day before the start of the experiment, approximately 20 hours before the first experimental session.

3.3 Behavioral testing is conducted 6 days a week (Monday through Saturday) for four weeks between 08:30 and 12:30 hours during the dark phase of the light-dark cycle.

3.4 To initiate a session, place the rat in the testing chamber and insert a finger in the center poke hole in the rear panel. The stimulus light above the left poke hole is immediately illuminated to signal the availability of water in that hole.

3.5 The rat receives successively smaller amounts of water every 4 s when it remains at the same feeder. The amount of water delivered is initially 150 µL and then decreased by 20 % after each delivery from the same feeder. Thus, when the animal remains at the same feeder, it will receive 150 µL at 0 s, 120 µL at 4 s, 96 µL at 8 s, 77 µL at 12 s, 61 µL at 16 s, etc. The stimulus light above the active

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feeder is turned on during the availability of water at that feeder.

3.6 The rat can reset the amount of water to the initial maximum of150 µL by switching to the alternative water feeder. However, switching to a new feeder results in a delay (0, 6, 12, 18, or 24 s) in the activation of the new feeder, simulating a travel time delay in patch foraging. During the delay, water is not available at either feeder regardless of responding, and the 1.9-kHz tone is turned on. At the termination of the delay, the stimulus light above the new feeder turns on to signal the availability of water at the feeder.

3.7 A change in the patch is indicated by a snout poke into the alternative non-active feeder. The obtained patch change time is measured as the time from the last head detection in the previously active patch to the head poke into the currently active patch.

3.8 When a patch change occurs with a 0-s delay, the light above the abandoned feeder turns off, and the light above the new feeder is illuminated simultaneously with the delivery of 150 µl of water. Under this condition, the patch change time is measured as the time from the last snout detection in the abandoned feeder to the snout poke into the newly-poked hole.

3.9 For non-zero delays (6, 12, 18, or 24 s), the light above the abandoned feeder is turned off, and the pulsed 1.9 kHz tone is presented during the delay. At the end of the delay, the tone is turned off, and the light above the newly-poked feeder is illuminated indicating that water is available in the new feeder. The first head detection in the new feeder after onset of the stimulus light results in the delivery of 150 µL of water.

3.10 Test sessions last for 10 minutes or until the rats have consumed a cumulative total of 5,000 µL of water, whichever occurs first. Short 10-minute sessions are used to prevent rats from switching to grooming.

3.11 The first patch change of the test session is not included in the data analysis. Similarly, only data up until the last patch change of the test session are included in the data analysis (see the figure below).

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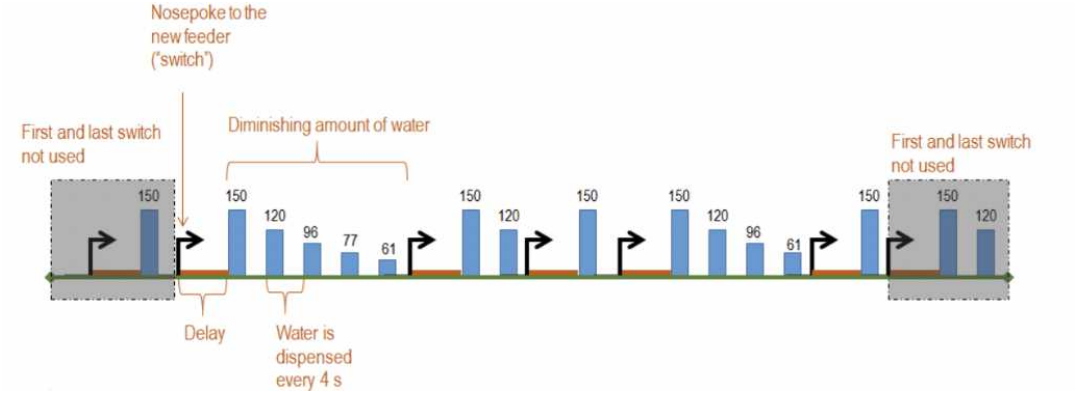

Example of an 10-minute session. Data from the first and last patch changes are not used in metrics calculation (patch change, total time, total water, etc.). The stimulus light is "on" only during the availability of water in the corresponding hole. The sound is "on" during delay periods.

3.12 Delays of 0, 6, 12, 18, and 24 seconds are tested. The delay is constant within a session but varied between sessions in the following sequence (Monday through Saturday); 0, 0, 6, 12, 18, and 24 s. This 6-day cycle is repeated four times for a total of 24 test sessions. Data from the last two cycles are combined and used for the data analysis. However, the first session of the week (Mondays) with the 0-s delay is excluded from analysis.

Dependent Measures

4 There are four primary behavioral dependent measures.

4.1 The first dependent measure is the indifference point for each delay, which indexes the point of subjective equality between 150 uL of water in the delayed new patch and the water available in the depleting patch. The indifference point indicates how much the animal values the delayed new patch, and it is defined as the amount of water available (in µL) at the depleting feeder right before the animal chooses to leave.

4.2 The indifference point decreases as the delay to the activation of the new patch increases. The rate of the decrease in the indifference points as a function of delay indicates the discount rate (i.e., how much the subjective value of a delayed reward is depreciated as delay to its receipt is increased). This discount rate is summarized by the second dependent measure, the normalized area under the discount curve (AUC), which is given by the indifference points obtained for the five delays tested. Smaller AUC values indicate steeper discounting. The AUC measure provides a simple measure of discounting that is not tied to a particular discount function (Myerson, 2001).

4.3 The third dependent measure is the discount factor *k*, which is another measure

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of the discount rate and is obtained by fitting the obtained discount curve with the hyperbolic discounting function:

$V = A / (1 + kD)$,

where V is the subjective value of a reward of size A when it is delayed by D units of time. Higher values of k indicate steeper discounting.

4.4 The fourth dependent measure is the rate of reward consumption for each delay. This is given by the water consumption rate (in µL/min), which is the total amount of water obtained at each snout-poke location divided by the session duration for each delay.

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