Article

Partner-specific reinforcement of human door opening by intermittent feline passage

Published online: 20 November 2026

Open access

Mara Ellis-Veyrin[1]

capstract:2611.00044v1 [q-bio.NC] 20 Nov 2026

A cat that requests an opening and remains on the sill has elicited the human response without supplying its usual consequence. How often must the animal go through to maintain that response? We modeled a household in which a resident's willingness to open the door depends on how many of their recent openings went unused. For one resident, evenly spaced passages minimize the number of calls per opening at fixed passage frequency. A second resident reverses the ordering of some schedules. When two people alternate, crossing at every fourth household opening reinforces only one person and yields 29.6 openings per 100 calls in the reference model. Crossing less often, at every fifth opening, reaches both people and raises the rate to 44.4. Counting every fourth opening separately for each resident yields 50.0 openings per 100 calls at the original passage budget. This can be achieved by going through the door and immediately coming back on the other person's turn. The model predicts which resident should see the cat cross after an interruption to the usual order of door opening.

In Thorndike's puzzle boxes the cat worked the latch. The observer timed the interval between confinement and escape[1]. In a house with a lever handle the division of labor is often different. The cat calls at a closed door, a person opens it, and the cat sometimes remains where it was. The elapsed time to escape is then censored. The elapsed time to a human response is perfectly observable.

The two latencies answer different questions. A cat seeking the other room has failed to use an opportunity when it stays on the sill. A cat seeking continued access to a person who will open the door has spent nothing on that occasion. Occasional passage may be enough to maintain the person's response. There is experimental evidence that a cat's solicitation changes human judgments of urgency[2]. Whether the person subsequently sees the cat make use of the service is a second, separable event.

We examine the maintenance problem for an already responsive person. We count the cat's passages as a limited resource and ask how many openings it can obtain for a given number of calls. Instrumental conditioning experiments separate delivery of an outcome from performance of the action that earns it[3]. Here the action is pressing the handle and the outcome is seeing the animal go through. In a household with two residents there is a further choice of denominator. An outcome delivered to the household can occur while one of its members is upstairs.

Spacing passages at one door

A bout begins with the door closed. The cat can call repeatedly until the designated resident opens it. The cat then crosses or stays. The door closes in either case. Calls within the bout count separately, so a resident who answers on the third call contributes one opening and three requests. The two rooms have equal value, and a cat that crosses starts its next bout on the far side. There is no cost for being in either room. The constraint is on the fraction of openings at which the animal changes rooms.

Let j be the number of consecutive times a particular resident has opened the door and seen the cat stay. The mean number of calls needed for that resident's next opening is $c(j)$. A passage in their presence resets j to zero. For an interval of k openings between passages the expected call count is

$$C(k) = \sum_{j=0}^{k-1} c(j). \tag{1}$$

The extra cost of lengthening the interval by one opening is $c(k)$. If opening the door to a stationary cat makes the next opening harder to obtain, this marginal cost increases. Shifting one opening from a long interval to a short one therefore weakly reduces the total number of calls. Repeating the exchange gives equal intervals, up to one opening when the mean is noninteger. This argument requires only that c be nondecreasing. It does not require the animal to predict the number of calls the person will ignore.

At one passage per four openings, a regular schedule produced 50.0 openings per 100 calls. Crossing independently with probability one quarter produced 38.5 (Methods). The number of passages per opening was the same in the long run. The extra calls were spent after runs of empty openings. A record that started only when the handle moved would omit all of them.

Alternate residents receive different schedules

Suppose two residents take turns. If the cat crosses on openings 4, 8 and 12, the second resident sees a passage on alternate turns. The first resident has opened the door six times without seeing the cat use it. Once the response cost reaches its ceiling, that resident needs 5.25 calls per opening. The second needs 1.50 on average. Pooling calls gives 29.6 openings per 100. Averaging the two residents' individual opening probabilities would give the slower resident too little weight.

Even and odd intervals gave different results (Fig. 1). Reducing passage from every fourth opening to every fifth increased the opening rate from 29.6 to 44.4 per 100 calls. Both residents now saw a passage on every fifth personal turn. With three residents the minima moved to multiples of

[1]Laboratory for Comparative Learning, Fen Alder Institute, Exeter, UK.

three. The number who ever see the animal cross is n/d, where n is the number of residents and d the greatest common divisor of n and k. A change in who answers first merely changes which person receives the crossings.

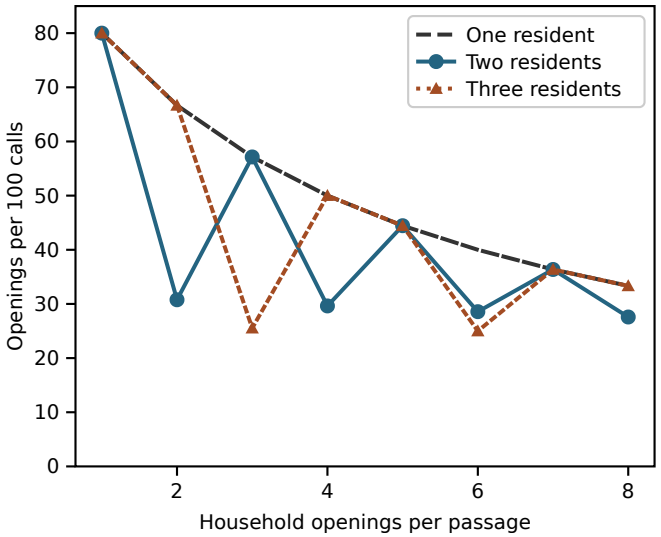


Fig. 1 | Opening rate on a fixed rotation. The cat crosses at every kth household opening. Points are exact long-run rates for equally responsive residents who observe only their own turns. Lines connect integer schedules.

A cat that distinguishes residents can distribute the same number of passages differently. At a budget of one in four, it can cross for A and then immediately cross back for B, followed by six openings at which it stays put. Each person receives one passage per four personal openings. This restores the single-resident rate of 50.0 (Table 1). The two consecutive passages return the cat to its original room. They complete a separate reinforcement cycle for each person.

Table 1 | Two residents alternating at one door. Rates are per 100 calls. Passage is conditional on an opening. Both residents have identical response parameters.

Passage schedule	Passages per 100 openings	Openings per 100 calls
Every opening	100	80.0
Every fourth per person	25	50.0
Random, one in four	25	38.5
Every fourth overall	25	29.6
Stay at every opening	0	19.0

Interrupting the rotation

A fixed roster is an unusually strong assumption for a domestic door. We relaxed it by allowing the same person to answer the next bout with probability s. Under the household count, an occasional second turn by one resident changed the identity of the person due to see a crossing. At $s = 0.10$ the rate rose to 36.7 openings per 100 calls. Independent assignment of residents ($s = 0.50$) raised it to 42.8. Neither change required the cat to move more often (Fig. 2). With separate counts the rate remained 50.0, since every resident's sequence still contained exactly three omissions between passages.

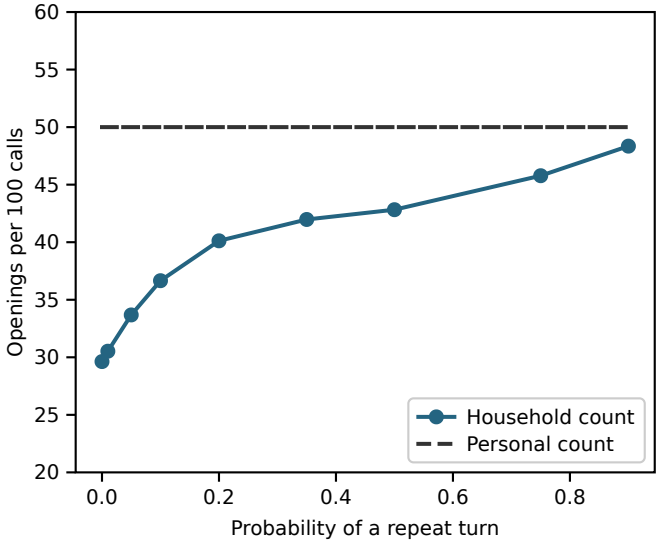


Fig. 2 | Departures from alternation. The horizontal axis gives the probability that the same resident takes the next bout. Each policy spends one passage per four openings in the long run. Points on the household curve come from the finite phase calculation in Methods.

The magnitude depends on how long empty openings continue to matter. When the response cost stopped increasing after four omissions instead of eight, the rate under strict alternation rose from 29.6 to 42.1. With a ceiling of two omissions the household and personal schedules tied at 53.3. One person still saw every passage. At that ceiling there was no additional call cost for allowing their partner to go indefinitely without one.

We repeated the fourth-versus-fifth comparison with a resident who gradually revises an expectation after each opening (Methods). At a learning rate of 0.25, passing every fifth time still produced more openings than passing every fourth time, 30.5 versus 27.4 per 100 calls. This difference was smaller than the 14.8 openings gained under the omission count. A single passage no longer erased the history of the preceding turns.

Discussion

Two people can give conflicting accounts of the same cat. One has repeatedly opened the door for an animal that then walked through it. The other has never seen the point of opening the door. Such a difference ordinarily invites an explanation in terms of attachment or temperament. In the fixed rotation it occurs with identical residents and a cat whose decision rule makes no reference to identity. An individual difference in the return from opening the door can arise entirely from the order in which people get up.

A household record could distinguish a personal schedule from a household count. Consider a bout at which the arriving resident has already seen three omissions but the household's last opening ended in a crossing. A personal count of four predicts passage at this opening. A household count of four predicts that the cat stays. Swapping the order of two residents creates these disagreements without changing the room or the direction of travel. Voice discrimination in domestic cats makes identity a plausible cue[4], although it supplies no evidence that cats keep an opening count. A separate prediction concerns the person. On the next bout, their own last few openings should predict the number of calls required even after conditioning on the recent history of the door. Testing the human response requires recording the calls that nobody answers.

The calculation treats successful passage as the event of value to a resident. A person who values a minute of quiet may instead learn from the cessation of calling, which follows every opening here. In that case the predicted parity effect disappears if crossing carries no additional value. The same loss of parity occurs when both residents witness every opening

and update a common history. Exposure duration during extinction affects conditioned responding in rats[5]. Long absences could restore responsiveness independently of what the cat last did. Clock time and bout order must then be recorded separately. Weather on the far side of an exterior door gives a cat an independent reason to turn back. An interior door with a resident substitution is the cleaner test.

Methods

Response law and schedules

All results concern model households. At each call a resident with omission count j opens independently with probability $1/c(j)$, where $c(j) = a + b\min(j, L)$. We used $a = 1.25$ calls per opening, $b = 0.50$ additional calls per opening per omission and $L = 8$ omissions. These illustrative values set the scale of the rates. A refusal leaves the state and the assigned resident unchanged. Only the person who opens sees the outcome. A resident's state is retained until their next turn. Bout duration and number of calls are distinct quantities; the analysis uses the latter.

For one person on a regular schedule the mean calls per opening are $C(k)/k$ from equation (1). Under independent passage with probability $1/k$, the probability of at least t successive omissions at an opening epoch is $(1 - 1/k)^t$. Summing this tail over $t = 1, \dots, L$ gives the expected capped count. We multiplied it by b, added a and took the reciprocal to obtain openings per call. For a cyclic roster, successive passages advance k places modulo n. Each visited resident receives a passage once per k/d personal openings. The mean cost is the weighted average of $C(k/d)/(k/d)$ for the fraction $1/d$ visited and $c(L)$ for the rest. We inverted after averaging because the roster changes on openings.

For the gradual update, each resident retained a value v between zero and one. They opened with probability $0.19 + 0.61v$ per call. After an opening they updated v by $\alpha(r - v)$, with $r = 1$ for passage and zero for an omission. On a personal schedule of period h the steady value just after a passage is $\alpha/[1 - (1 - \alpha)^h]$. We decayed this value by a factor $1 - \alpha$ at each intervening omission and averaged reciprocal opening probabilities across phases and residents as above. The advantage of the fifth over the fourth household opening was 3.6, 3.1 and 1.1 openings per 100 calls at $\alpha = 0.10$, 0.25 and 0.50.

Irregular assignment and numerical check

The two-resident roster has equal stationary opening shares. At any one resident's turns the gap D since that person's previous turn, measured in household openings, has probability s at $D = 1$ and $(1 - s)^2 s^{D-2}$ at $D \geq 2$. These gaps are independent at successive returns. To count recent omissions we started with uniform mass on the k possible phases of the most recent personal opening. We removed mass on phase zero (passage), recorded the surviving mass, and moved each survivor back D phases modulo k using the gap probabilities. After L removals the sum of the recorded masses gives the mean capped count. Grouping the geometric tail by residue modulo k evaluates the transition without truncation.

We checked this calculation by drawing individual responses for 32 rosters at each of $s = 0$, 0.10 and 0.50. We used Python's MT19937 generator, seeds 0 through 31 in each condition, both counts initially zero, and a passage at each fourth household opening. After discarding 200 openings we counted calls to the next 40,000. Mean openings per 100 calls (Monte Carlo standard errors across rosters) were 29.66 (0.025), 36.70 (0.027) and 42.86 (0.032), respectively. The plotted curves and table use the exact calculation.

References

1. Thorndike, E.L. *Animal Intelligence: Experimental Studies* (Macmillan, 1911).
2. McComb, K., Taylor, A.M., Wilson, C. & Charlton, B.D. The cry embedded within the purr. *Current Biology* **19**, R507–R508 (2009).
3. Hammond, L.J. The effect of contingency upon the appetitive conditioning of free-operant behavior. *Journal of the Experimental Analysis of Behavior* **34**, 297–304 (1980).
4. Saito, A. & Shinozuka, K. Vocal recognition of owners by domestic cats (Felis catus). *Animal Cognition* **16**, 685–690 (2013).
5. Drew, M.R., Walsh, C. & Balsam, P.D. Rescaling of temporal expectations during extinction. *Journal of Experimental Psychology: Animal Learning and Cognition* **43**, 1–14 (2017).