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Supporting Online Material for

Food-Caching Western Scrub-Jays Keep Track of Who was Watching When

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Supporting Online Material

Materials and Methods.

The jays were housed in 2m x 1m x 1m steel cages. During caching and recovery trials the cages were divided by a transparent barrier such that a storer was housed in one section (1m3) and an observer in the other. Caching trays were constructed from plastic ice-cube trays, each containing a 2 x 8 array of moulds, attached to a wooden board (*7*). A configuration of Lego Duplo® bricks along one of the long sides of the tray made each tray unique. Birds were deprived of food overnight. Caching trials started at 10am the following day. In Experiment 1 & 2, the birds' recovery behavior was recorded using a digital handycam positioned 30cm from of the storer's cage. In Experiment 3, cache recovery was recorded using a multicam surveillance system.

Experiment 1.

6 females and 8 males were tested. Five birds (2 females and 3 males) acted as only as observers, and 9 birds (4 females, 5 males), were both observers and storers. Storers cached in each of 4 conditions; watched by (1) their partner, (2) a dominant, (3) a subordinate, and (4) with an opaque divider ($1m^2$) between the storer and observer's cage sections ('In Private'). The 4 trial types were conducted in a pseudo-randomized order, as were the trials on which any bird acted as either storer or observer. No two birds cached in the same condition on any given day.

Partnerships and dominance indices were determined just prior to the onset of Experiment 1 when groups of 7 birds were housed together in aviaries (*18*). Partnerships

were identified by the propensity of the female bird to spend a large proportion of time in close proximity to, and share food exclusively with 1 male bird, behaviors which are clear indicators of affiliation in corvids (*S1, S2*). The dominance indices were based on the outcome of aggressive interactions between the jays. The most dominant bird won the greatest proportion of the aggressive interactions in which they were involved, and the most subordinate bird the least.

During a 15-min caching trial, a tray was placed on both the left and right hand sides of the cage, so one was 'far' and one 'near' to the observer's cage. A bowl containing 50 wax-worms was placed equidistant to the 2 caching trays. Surplus wax-worms were left in the food bowl at the end of every trial.

After caching, the trays and food bowl were removed from the storer's cage along with any caches made around the home-cage. We recorded the number and location of the food items cached in the trays nearest to ('near' tray), and farthest from ('far' tray) the observer. Opaque dividers were then put up to block the observer's view. After 3-hr, the trays were returned to their original location in the storer's cage and the birds allowed to recover their caches 'In Private'. We recorded the number of caches that were re-cached by the storer. Note, however, that on each trial a few items were often cached and not recovered (as in Experiment 2 & 3).

Experiment Two.

3 females and 5 males acted as both storers and observers. As a storer, each bird was given the opportunity to cache in 'Tray A' in the presence of 'Individual A', and then in 'Tray B' in the presence of 'Individual B' (or vice versa). At the start of a trial, two trays were placed in the storer's cage section, both equidistant to the observer, along with a bowl containing 25 wax-worms. One tray ('Tray B') was covered with Perspex strips such that cache sites were inaccessible to the storer. The birds cached in the uncovered tray ('Tray A') for 7-min 30-sec. The trays and food bowl were then removed from the storer's cage (along with any caches made around the home cage). The observers were subsequently moved (such that a bird who had previously cached in the presence of 'Individual A' now cached in the presence of 'Individual B'), and the Perspex strips taken from 'Tray B', and placed over 'Tray A'. The two trays were then returned to their original location in the storer's cage, along with a bowl of 25 wax-worms, and the storer given the opportunity to cache in 'Tray B' for 7-min 30-sec.

After caching, we recorded the number and location of cached items in both trays. This procedure was repeated on a further 7 days, such that each storer received 8 caching trials in which they had the opportunity to cache successively in two trays, each in-view of a different conspecific. Trials were counterbalanced so that on four occasions each bird was watched by 'Individual A' then 'B' ('AB' trial), and on the other four by 'Individual B' then 'A' ('BA' trial). The birds' roles were then reversed such that the observers became storers, and vice versa.

After 3-hr, the storer's caching trays were replaced in the home cage, and the storers given a 5-min recovery period under one of 4 conditions; watched by 'Individual A', watched by 'Individual B', 'In Private, or watched by a control bird that had not witnessed either caching event. Each recovery condition was administered once after an 'AB' and a 'BA' trial. We recorded the number of caches that the storer re-cached, the number of times re-cached items were moved from one site and immediately re-cached elsewhere (moved items were visibly identifiable as they were either held in the bird's bill, or could be seen in their pouch), and whether re-cached items were placed in previously used (old) or un-used (new) sites. Re-caches were scored by J.M.D. and confirmed by an observer naïve to the experimental hypotheses (A.S. or D.A.). There was a 100% rate of agreement in the scores.

Experiment Three.

The subjects were 2 females and 6 males, all of whom acted as both storers and observers. The experimental procedure was identical to that described for Experiment 2, the only difference being that after the storer had cached in both 'Tray A' and 'Tray B', a control bird witnessed a different storer caching in one of these two trays. This additional caching phase was identical to those described for 'Observer A' and 'Observer B' in Experiment 2. In this way, both the observers and the control birds witnessed a storer caching in one of the two trays. The observers and the control birds differed in whether the bird they saw caching was, or was not, the same storer as the one present at recovery. Each storer received 4 caching trials, which were counter-balanced as described in Experiment 2.

In addition to the data described in Experiment 2, we recorded the proportion of time the observer spent in each quadrant of its cage during cache recovery, and whether the observer was oriented towards, or away from, the 'observed' or 'other' tray. Orientation towards a specific tray was defined by the bird being in the quadrant of the cage adjacent to that tray, with its tail being positioned within the 180° radius which resulted in a bodily orientation towards that tray. The time spent in each quadrant in both orientations was analyzed as a proportion of the total time spent in all 4 quadrants (Table S3). The analysis identified significant differences in the observers' behaviour in both the 'Observed' (Friedman's ANOVA, χ^2_3= 12.8, P = 0.001) and 'Observer Control' conditions (Friedman's ANOVA, χ^2_3= 14.4, P = 0.001). In both conditions, these differences were attributable to a significant preference to orient towards the trays ('Observed', Scheffé Test, z^2 = 11.8, P = 0.01; 'Observer Control', Scheffé Test, z^2 = 12.2, P = 0.01), but there was no significant difference in the proportion of time the observers spent in the quadrants of the cage nearest to either the 'observed' or 'other' tray ('Observed', Scheffé Test, z^2 = 0.5, P > 0.05; 'Observer Control', Scheffé Test, z^2 = 0.8, P > 0.05).

Videos were scored by J.M.D. and by two raters who were naïve to the experimental hypotheses but experienced in observing scrub-jays (D.A. & C.T.), there was a 96% rate of agreement between scores. Raters were also asked to indicate which of the two trays they thought was the 'observed' tray, and whether or not the storer at recovery was or was not the bird that the observer had witnessed caching in that tray. In both cases, the raters failed to discriminate between the trays (binomial test, k = 14, P = 0.43), and were

unable to determine whether the storer had or had not cached in-view of the observer present at recovery (binomial test, $k = 17$, $P = 0.70$).

Statistical Analysis.

As the data were not normally distributed, they were analyzed using non-parametric statistics. Alpha was set at 0.05 and P values were calculated for each test. We analyzed the number of caches that were re-cached upon recovery as a proportion of those items that were cached, because the number of items available to be re-cached depends on the number cached. Sign tests were used to investigate the presence of a directional preference for re-caching from either the 'near' and 'far' trays in Experiment 1, or from the 'observed' and 'other' trays in Experiments 2 & 3. In Experiment 2, the two-way structure of each condition (Trial x Tray) initially implies the need to take out the effect of individual birds. However, the data is so uniformly distributed that this is technically impossible. The simplest method has therefore been used, which is to sum over all the rows. As is customary for sign tests, tied data is omitted from the analysis. Two birds were removed from the analyses in Experiment 1, and one bird in Experiment 3, as they never cached on any of the trials.

References.

S1. N. Emery, N. Clayton, in *Comparative Vertebrate Cognition: Are primates superior to non-primates?* L. Rogers, G. Kaplan, Eds. (Kluwer Academic Press: The Hague), pp. 3-55.

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Supplementary Table 1.

Caching and recovery behavior in each condition of Experiment 1.

	Dominant Condition		Subordinate Condition		Partner Condition		In Private Condition	
	Near	Far	Near	Far	Near	Far	Near	Far
Number Cached in Either Tray	Median = 2, IQR = 4	Median = 7, IQR = 12	Median = 1, IQR = 2	Median = 3, IQR = 2	Median = 0, IQR = 3	Median = 2, IQR = 13	Median = 6, IQR = 9	Median = 6, IQR = 9

Supplementary Table 2.

Caching & recovery behavior in each condition of Experiment 2.

		Observed Condition	Control Condition	In Private Condition
Caching	Number Cached	Median = 7.1 IQR = 7.1	Median = 6.0 IQR = 6.0	Median = 4.2 IQR = 5.6
Recovery[1]	Proportion Re-cached	Median = 0.4 IQR = 0.1	Median = 0.2 IQR = 0.3	Median = 0.05 IQR = 0.2
	Proportion Re-cached in 'Same' Tray.	Median = 0.6 IQR = 0.5 (observed tray only)	Median = 0 IQR = 0	Median = 0 IQR = 0.5

[1] As in the previous experiment, the number of items available at recovery depends on the number of items the storers cached. We therefore calculated the number of items that were re-cached at recovery as a proportion of the total number of items that had been cached.

Supplementary Table 3.

Caching & Recovery Behavior in Experiment 3.

		Observed Condition		Observer Control Condition	
		'Observed' Tray	'Other' Tray	'Observed' Tray	'Other' Tray
Caching	Number Cached	Median = 4.5 IQR = 5.0	Median = 5.0 IQR = 6.5	Median = 4.0 IQR = 8.0	Median = 6.0 IQR = 3.8
Recovery[2]	Proportion Re-cached in 'Same Tray'.	Median = 0.5 IQR = 0.6	Median = 0 IQR = 0	Median = 0 IQR = 0.7	Median = 0.5 IQR = 0.5
	Proportion of Time Spent Oriented Towards Trays.	Median = 0.2 IQR = 0.2	Median = 0.2 IQR = 0.2	Median = 0.3 IQR = 0.3	Median = 0.2 IQR = 0.4

[2] As in the previous experiments, the number of items available at recovery depends on the number of items the storers cached. We therefore calculated the number of items that were re-cached at recovery as a proportion of the total number of items that had been cached.

Supplementary Table 4.

Caching behaviour of young birds[1].

Bird No.	Observed Condition	
	Near Tray	Far Tray
1	0	10
2	2	6
3	0	1
4	26	8
5	1	7
6	6	18
7	0	4
8	17	0

[1] Note that, unlike the birds in the current study, these birds have not experienced stealing others' caches.