

Learned use of an innate sound-meaning association in birds

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Supplementary methods and results

Superb fairy-wren and white-browed scrubwren model presentation experiments

Across avian lineages, responses towards distress vocalizations are related to the receiver's and signaler's closeness in body size across avian lineages, as a threat to the signaler is likely also a threat to the receiver[1]. As brood parasites target similarly-sized hosts[2], body size may too help explain the distribution of species that respond to whining vocalizations, as most hosts (93%) are passerines and therefore similar in body size[3]. Our model presentation experiments support this idea: passerines that attended trials where whining vocalizations were more size-matched (26.5 ± 5.9 g, range: 6.7–118 g) to our focal species (10.3 g for superb fairy-wrens and 13.2 g for white-browed scrubwrens) than those that did not attend (96.4 ± 25.8 g, range: 9–508 g) and non-passerines (321.4 ± 170.9 g, range: 29.5–2333.1 g).

Purple-crowned fairy-wren playback experiments

Purple-crowned fairy-wrens (*Malurus coronatus*) produced more whining vocalizations towards a model cuckoo (mean = 8.6 ± 5.83 , range = 0 – 141 with whining vocalisations in 3/30 trials) than a nest predator (Merten's water monitor, *Varanus mertensi* [mean = 0.57 ± 0.57 , range = 0 – 17 with whining vocalizations in 1/30 trials]) or a predator of adults and nestlings (brown goshawk, *Accipiter fasciatus* [mean = 1.72 ± 1.7 , range = 0 – 50 with whining vocalizations in 1/29 trials], and no whining vocalizations recorded to a non-threatening control (peaceful dove, *Geopelia placida*). Interestingly, the low number of whining vocalizations produced towards cuckoos occurred in years where parasitism rates were very low (3% in 2016, $N = 33$ nests and 0% in 2017, $N = 115$ nests). In superb fairy-wrens, similar low rates of whining occur when parasitism rates are low[4] which is explained by social learning[5], suggesting that the production of whining vocalizations is likely also socially learned in purple-crowned fairy-wrens.

Macroecological correlates of whining vocalization evolution

While no significant association was identified between species which are cooperatively breeding and species which produce whining-type vocalizations, we note that 47% (7 of 15 species) of cooperatively breeding species produce whining calls compared to 7% (2 of 25 species) of non-cooperatively breeding species. The observed proportions suggest that there may be a relationship between cooperative breeding status and whining call production; however, when accounting for shared ancestry we do not identify a significant association between the two traits. Hence, the observed proportions may reflect clades within our sample of species which produce whining vocalizations and adopt cooperative breeding strategies sharing a common ancestry. The production of whining vocalizations being phylogenetically conserved (Pagel's $\lambda = 0.91$) further supports the notion that their evolution occurred independently of a species' social breeding system. Expanding the dataset to include more species may help to clarify this relationship.

Supplementary Tables

Supplementary Table 1. Responses by superb fairy-wrens (*Malurus cyaneus*) and white-browed scrubwrens (*Sericornis frontalis*) during 5 min model presentation experiments ($N = 17$ per treatment) (mean $\pm$ standard error).

	superb fairy-wren	white-browed scrubwren
	Number of whining vocalizations	
Cuckoo	459.24 $\pm$ 92.90	213.76 $\pm$ 34.63
Control	34.94 $\pm$ 29.44	3.35 $\pm$ 2.30
Currawong	9.41 $\pm$ 9.41	8.35 $\pm$ 6.11
Raptor	51.24 $\pm$ 31.28	2.06 $\pm$ 20.6
Snake	0.53 $\pm$ 0.42	1.53 $\pm$ 1.10
	Time mobbing (sec)	
Cuckoo	237.88 $\pm$ 23.89	248.35 $\pm$ 20.61
Control	59.18 $\pm$ 22.62	25.24 $\pm$ 11.85
Currawong	14.71 $\pm$ 13.06	4.82 $\pm$ 3.58
Raptor	45.94 $\pm$ 22.81	1.00 $\pm$ 1.00
Snake	32.82 $\pm$ 14.30	5.47 $\pm$ 2.88
	Number of heterospecifics	
Cuckoo	3.71 $\pm$ 0.97	9.71 $\pm$ 1.72
Control	0.71 $\pm$ 0.27	0.12 $\pm$ 0.08
Currawong	0.18 $\pm$ 0.18	0.53 $\pm$ 0.23
Raptor	0.82 $\pm$ 0.44	1.24 $\pm$ 0.44
Snake	0.06 $\pm$ 0.06	0.82 $\pm$ 0.38

Supplementary Table 2. Responses by superb fairy-wrens and white-browed scrubwrens during 30 s audio playback experiments ($N = 17$ per treatment) (mean $\pm$ standard error).

	superb fairy-wren		white-browed scrubwren	
	Number of conspecifics	Number of heterospecifics	Number of conspecifics	Number of heterospecifics
Whining	2.59 ± 0.21	1.53 ± 0.24	2.29 ± 0.14	2.88 ± 0.28
Alarm	1.94 ± 0.16	0.65 ± 0.17	1.24 ± 0.16	1.00 ± 0.15
Control	0.59 ± 0.15	0.18 ± 0.10	0.65 ± 0.12	0.29 ± 0.11

Supplementary Table 3. Contingency table summarising the number of species recorded during point counts conducted at study nests and cuckoo (**a–c**) and control (**d–e**) model presentation trials. For cuckoo model presentation trials, data are shown for **a**, the number of host and non-host species; **b**, the number of passerine and non-passerine species; and **c**, the number of passerine host and passerine non-host species. For control model presentation trials data are shown for **d**, the number of host and non-host species; and **e**, the number of passerine and non-passerine species. Species which attended model presentation trials are denoted ‘yes’, and species not recorded at model presentation trials are denoted ‘no’. Totals represent the sum of species recorded for each category within each trial type.

Group	Category	Yes	No	Total
Cuckoo model presentation				
a. Host vs. non-host	Host	23	22	45
	Non-host	2	13	15
	Total	25	35	60
b. Passerine vs. non-passerine	Passerine	25	22	47
	Non-passerine	0	13	13
	Total	25	35	60
c. Passerine host vs. passerine non-host	Passerine host	23	21	44
	Passerine non-host	2	1	3
	Total	25	22	47
Control model presentation				
d. Host vs. non-host	Host	0	15	15
	Non-host	6	39	45
	Total	6	54	60
e. Passerine vs. non-passerine	Passerine	6	41	47
	Non-passerine	0	13	13
	Total	6	54	60

Supplementary Table 4. Responses by rufescent prinias (*Prinia rufescens*), superb fairy-wrens, common tailorbirds (*Orthotomus sutorius*) and white-browed scrubwrens during 30 s audio playback experiments ($N = 17$ per treatment) (mean $\pm$ standard error).

	rufescent prinia		superb fairy-wren		common tailorbird		White-browed scrubwren	
	Number of conspecifics	Number of heterospecifics	Number of conspecifics	Number of heterospecifics	Number of conspecifics	Number of heterospecifics	Number of conspecifics	Number of heterospecifics
Conspecific	1.82 $\pm$ 0.10	1.59 $\pm$ 0.38	1.71 $\pm$ 0.17	1.24 $\pm$ 0.30	1.65 $\pm$ 0.15	1.76 $\pm$ 0.52	1.82 $\pm$ 0.15	2.59 $\pm$ 0.30
Control	1.24 $\pm$ 0.11	0.35 $\pm$ 0.24	0.82 $\pm$ 0.13	0.12 $\pm$ 0.12	0.76 $\pm$ 0.11	0.18 $\pm$ 0.10	1.00 $\pm$ 0.12	0.29 $\pm$ 0.11
Allopatric heterospecific	1.88 $\pm$ 0.12	1.88 $\pm$ 0.52	2.00 $\pm$ 0.12	1.76 $\pm$ 0.37	1.47 $\pm$ 0.19	1.65 $\pm$ 0.63	1.76 $\pm$ 0.16	3.06 $\pm$ 0.25
Sympatric heterospecific	2.00 $\pm$ 0.15	1.76 $\pm$ 0.42	2.00 $\pm$ 0.23	1.71 $\pm$ 0.34	1.82 $\pm$ 0.25	1.59 $\pm$ 0.45	1.65 $\pm$ 0.15	2.41 $\pm$ 0.34

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