Griffin & West, Kin Discrimination and the Benefit of Helping in Cooperatively Breeding Vertebrates

Supplementary information

Materials and Methods

We collected relevant literature by: (1) performing literature searches using the ISI Web of Science, with all papers published up to 31 December 2002 considered; (2) forward and backwards searching through the citations of all the papers on our list and other key references (S*1*); (3) directly contacting researchers working on long-term studies of cooperatively breeding species that were not on our list, to check for the existence of unpublished results. We identified 28 relevant studies 16 on birds and 12 on mammals. Of these, five mammal studies (Belding's ground squirrel (S*2*), cavy (S*3*), Japanese macaque (S*4*), lions (S*5*), long-tailed macaque(S*6*)) and one bird study (white-browed sparrow weaver (S*7*)) were excluded on the basis that they included parent-offspring interactions in their analyses. Of the remaining 22 studies, 18 contained data specifically relating to kin discrimination in offspring care (Table S1). In the majority of cases, data for the calculation of r_{help} from a species was obtained from the same reference that had provided the data for r_{kin} (Table S2). In other cases we searched the literature on a species for the relevant data or contacted researchers directly.

Effects sizes (*r*) were calculated using standard methodology, described in detail elsewhere (S*8, S9*); see Ref (S*10*) for a detailed example. Briefly: (a) in some studies the effect size is given, as the correlation coefficient (*r*), the % of variance explained (r^2) or the spearman rank correlation coefficient (r_s); (b) in other cases the effect size can be calculated from a test statistic (e.g. *t,* F, χ^2 or P value) and the sample size. The formulas for calculating *r* from test statistics are given in standard meta-analyis texts (S*8, S9*), and also implemented in the statistical calculator of the package MetaWin 2.0(S*8*).

Table S1 Studies of measures of kin discrimination from which data for meta-analysis were extracted (mean r_{kin} values and amalgamated n values in bold)

Species	Reference	Helping trait	Test statistic	Effect size (r)	Sample size (n)	Unit of n	n groups	Parameter measured	n
Mammals									
Brown hyaena *Hyaena brunnea*	Owens and Owens 1984(S*11*)	Pup feeding	Calculated from paper	0.185	159	Feeding event	1	Amount	1
Dwarf mongoose *Helogale parvula*	Creel et al. 1991(S*12*)	Allosuckling	F = 15.59, df = 1,179	0.283	181	Dyad	Not given	Probability	
Lion *Panthero leo*	Grinnel et al. 1995(S*13*)	Defence	Calculated from paper	0.224	23	Playback	20	Probability	2
			Calculated from paper	0.215	23	Playback	20	Probability	2
				0.219	**23**				

Meerkat *Suricata suricatta*	Clutton-Brock et al. 1999(S*14*)	Guarding	P = 0.5	0.255	7	Group	7	Amount	
	Clutton-Brock et al. 2001(S*15*)	Pup feeding	χ^2 = 1.78	0.204	43	Litter		Amount	
			P = 0.33	0.346	15	Note 4	<13	Amount	3
			P = 0.39	0.208	17	Note 4	<14	Amount	
			P = 0.39	0.501	6	Note 4	<15	Amount	
				0.244	**43**				
			Mean from pup feeding data only	**0.244**	**43**				
Spotted hyaena *Crocuta crocuta*	Mills 1985(S*16*)	Foraging	P = 0.005	0.173	262	Foraging group	1	Probability	4
Tammar wallaby *Macropus eugenii*	Blumstein et al. 2002(S*17*)	Aggression	Calculated from paper	0.599	12	Expt. pair	1	N/A	5
			Rs = -0.54	0.540	12	Expt. pair	1	N/A	

				0.570	**12**				
Birds									
Arabian babbler *Turdoides squamiceps*	Wright et al. 1999(S*18*)	Chick feeding	P = 0.875	0.018	74	Note 7	18	Amount	6
			P = 0.128	-0.159	92	Note 7	18	Amount	
			P = 0.147	0.152	91	Note 7	18	Amount	
			P = 0.065	-0.192	92	Note 7	18	Amount	
			P = 0.59	-0.056	92	Note 7	18	Amount	
				-0.050	**92**				
Australian bell miner *Manorina melanophyrus*	Clarke 1984(S*19*)	Chick feeding	Calculated from paper	0.540	7	Dyad	2	Amount	7
Australian magpie *Gymnorina tibicen*	Finn and Hughes 2001(S*20*)	Chick feeding	χ^2 = 0.144	0.045	72	Helper	12	Probability	
Florida scrub jay *Aphelocoma c. coerulescens*	Mumme 1992(S*21*)	Chick feeding	Calculated from p = 0.02	0.401	36	Helper	20 groups 1987; 15	Probability	8

							groups 1988		
Galapagos mockingbird *Nesomimus parvulus*	Curry 1988(S*22*)	Chick feeding	Calculated from paper	0.124	292	Helper season	Max. 122	Probability	9
Green woodhoope *Phoeniculus purpureus*	Du Plessis 1993(S*23*)	Chick feeding	Calculated from paper	0.245	4	Expt. group		Amount	1
Grey-capped social weaver Pseudonigrita arnaudi	Bennun 1989(S*24*)	Chick feeding	p = 0.031	0.660	8	Helper	Max. 50	Probability	1
	Bennun 1994(S*25*)	Chick feeding	t = 1.2	0.279	19		Max. 50	Amount	
				0.386	**27**				
Kookaburra *Dacelo novaeguineae*	Legge 2000(S*26*)	Chick feeding	$\chi^2 = 2.28$	-0.156	94	Helper	20	Amount	
Long-tailed tit *Aegithalos caudatus*	Russell and Hatchwell 2001(S*27*)	Chick feeding	Calculated from paper	0.882	17	Helper		Probability	1
Pied kingfisher *Ceryle rudis*	Reyer 1984(S*28*)	Guarding	Calculated from paper	0.229	17	Nest	Max. 37	Amount	1

		Risk taking	Calculated from paper	0.920	10	Helper	Max. 37	N/A	1
		Chick feeding	Calculated from paper	0.868	15	Nest		Amount	1
			Calculated from paper	0.452	16	Nest		Amount	1
			Calculated from paper	0.894	13			Amount	1
				0.756	**17**				
			Mean from chick feeding data only	**0.790**	**16**				
Red-cockaded woodpecker *Picoides borealis*	Khan and Walters 2000(S*29*)	Reciprocal exchange of help	χ^2 = 8.31	0.062	1184	Dyad	Max 350	Probability	1
Seychelles warbler	Komdeur 1994(S*30*)	Chick feeding	P = 0.0001	0.580	45	Helper	Max. 123	Probability	

Acrocephalus sechellensis									
			P = 0.00003	0.551	57	Helper	Max. 123	Probability	
			P = 0.002	0.977	10	Helper		Probability	
			T = 4.206	0.903	6	Helper		Amount	
			T = 2.496	0.870	4	Helper		Amount	
			T = 2.795	0.813	6	Helper		Amount	
			T = 2.425	0.864	4	Helper		Amount	
			T = 6.190	0.952	6	Helper		Amount	
			T = 3.714	0.935	4	Helper		Amount	
				0.815	**112**				
Stripe-backed wren *Campylorhynchus nuchalis*	Rabenold 1985(S*31*)	Chick feeding	Calculated from paper	-0.208	97	Helper	Max. 30	Amount	1
Superb fairy-wren *Malurus cyaenus*	Dunn et al. 1995(S*32*)	Chick feeding	F = 1.9, df = 1, 21	-0.288	23	Helper – brood dyad	13	Amount	
			$r^2 = 0.03$	0.173	7	Dyad		Amount	
Western bluebird *Sialia*	Dickinson et al.	Chick feeding	Calculated from	0.326	321	Helper	363	Probability	1

mexicana	1996(S*33*)		paper						
White-fronted bee eater	Emlen and Wrege	Chick feeding	G = 70	0.664	159	Dyad	Not given	Probability	
Merops bulockoides	1988(S*34*)								
			G = 46	0.567	143	Dyad	Not given	Probability	
			G = 55.1	0.521	203	Dyad	Not given	Probability	
			G = 41.3	0.627	105	Dyad	Not given	Probability	
			Calculated from	0.200	59	Dyad	Not given	Amount	1
			paper						
				0.545	**367**				

Legend for Table S1

(1) Re-analysis of data in Table 1 with an ordered heterogeneity test gave P = 0.01 (one-tailed), from 159 observations on 24 individuals. (2a) T-test performed on data given in figure 4b on proportion of each approach walked in parallel; t=1.051. (2b) T-test performed on data given in figure 4a on number of glances made during an approach; t = 1.01. (3) n= number of comparisons made within sex/age categories, pooled across groups. (4) Analaysis of Kousant group only: we make conservative assumption of p=0.05; P-value given as <0.05. We were unable to analyse Kaspersaii group because of

inconsistency between D-values given and corresponding P-values. (5) Sign test on 10/12 gives P = 0.019 (one-tailed). (6) Some birds appear twice in the data set where they were observed to feed two broods in the same nest-site. (7) Correlation on data presented in Table 3 re-done, excluding interactions between direct dscendents. (8) Data presented in Figure 7 re-analysed with ordered heterogeneity test gave P = 0.0025. (9a) Ordered regression (df = 1) performed on data on male helpers in Table 4, G = 2.56; (9b) on female helpers, G = 5.64; (9c) on all helpers, G = 4.46. (10) Two-tailed Wilcoxin signed rank test performed on data presented in Figure 1a, p = 0.625. (11) Sign test performed on data provided by Bennun gave P = 0.031, n = 8. (12) G-test performed on data presented in Figure 4b, G =26.47. (13a) Chi-square test performed on data presented in Figure 2a, T = 0.91; (13b) r calculated from data described in second paragraph of section "Contribution of breeders and helpers to brood care", p1166, χ^2 = 8.46; (13c) T-test performed on data presented in Figure 2b, T = 6.29; (13d) T-test performed on data presented in Figure 2c, T = 1.90; (13e) T-test performed on data presented in Figure 2d, T =6.61. (14) Data presented in Table 3 re-analysed with ordered heterogeneity test gave P = 0.016 (one-tailed). (15) Re-analysis of data presented in Figure 4 with an ordered heterogeneity test gave P = 0.02 (one-tailed). (16) Re-analysis of raw data in Table 4 gave $\chi^2_{(1)}$ = 334.15. (17) *r* calculated from statement on p311 "Genetic relatedness explained only 4% of the total variance in helper feeding rate…"

Table S2 Studies of measures of the effect of helpers, from which data for meta-analysis were extracted.

Species	Reference	Benefit	Test statistic	Effect size (*r*)	Sample size (*n*)	Note
Mammals						
Dwarf mongoose *Helogale parvula*	Creel et al. 1991(S*12*)	Litter size	t = 3.58	0.656	19	
Meerkat *Suricata suricatta*	Russell pers.comm.; Clutton-Brock et al. 2001(S*35*)	Survival to 1 year	F = 15.91; df = 1, 137	0.323	139	
Birds						
Arabian babbler *Turdoides squamiceps*	Wright et al. 1998(S*36*)	Fledgling surviving to independence	r^2 = 0.24	0.490	27	

Australian magpie *Gymnorina tibicen*	P. Finn pers. Comm..	Number of fledglings	Calculated from raw data	0.241	8	
Florida scrub jay *Aphelocoma c. coerulescens*	Mumme 1992(S*21*)	Survivorship of young	Calculated from p = 0.008 (one-tailed)	0.396	37	
Green woodhoopoe *Phooeniculus pupureus*	Du Plessis 1993(S*23*)	Number of fledglings	Calculated from paper	0.1018	144	1
Kookaburra *Dacelo novaeguineae*	Legge 2000(S*37*)	Fledgling success	Calculated from p = 0.18 (one-tailed)	-0.187	24	
Pied kingfisher *Ceryle rudis*	Reyer 1984(S*28*)	Number of fledglings	Calculated from paper	0.822	25	2
Seychelles warbler *Acrocephalus sechellensis*	Komdeur 1994(S*38*)	Number of yearlings	t = 3.182	0.662	15	
Stripe-backed wren *Campylorynchus nuchalis*	Rabenold 1984(S*39*)	Nunmber of juveniles	Calculated from paper	0.584	104	3
Superb fairy-wren *Malarus cyaenus*	Dunn et al. 1995(S*32*)	Young surviving to 4 weeks	Calculated from p = 0.63	-0.035	92	
Western bluebird Sialia	Dickinson et al. 1996(S*33*)	Chance of raising at least one	χ^2 = 7.14	0.1079	613	

mexicana		offspring		
White-fronted bee eater *Merops bulockoides*	Emlen and Wrege 1988(S*34*)	Number of fledglings	$r^2 = 0.35$	0.592

Legend for Table S2.

(1) Data presented in Table 3 analysed to give t = 1.22. (2) Data presented in Table 6 analysed to give t = 6.94. (3) Regression performed on data presented in Figure 5.

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Materials and Methods
Tables S1, S2