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Dog-Human Coevolution: Cross-Cultural Analysis of Multiple Hypotheses

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Supplementary Materials

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Methods:

Items and descriptions for DUH, HUD, and PD scales

Table S1. *Personhood of dogs* (PD) item descriptions for coding HRAF materials

Personhood of dogs (PD) items	Description
Personhood	dogs classified as a "person" or being "like people"
Kinship	dogs are afforded status as kin by use of kinship terms for dogs, or membership in lineage, clan, sib etc.
Soul	dogs have souls like humans
Family	dogs as family members
Name	naming of individual dogs
Burial	dogs buried upon death
Mourning	dogs are mourned, 'owners' feel sadness upon death of dog
Affection	people show affection toward dogs
Indoors	dogs allowed to be inside people's houses
Shape-shifter	dog in human (or spirit) form or vice versa
Co-sleeping	dog sleeps with humans

Table S2. *Dog's utility for humans* (DUH) item descriptions for coding HRAF materials

Dog's utility for humans (DUH) items	Description
Hunting	dogs used for hunting (includes sub codes)
Herding	dogs used for driving or herding livestock
Hauling/Burden	dog as beast of burden; dog used to move, carry, or transport things, e.g., sled, cart, etc.
Tracking (not just hunting)	dog used to track animals without specific reference to scent
Guarding	guard-dogs, with no mention of alarm, but a mention of guarding, protecting
Alarm	dog barks to alert people, serves as watchdog
Consumption	eating dog meat
Commodity	dogs traded or used in payment, including dowry and bridewealth
Skins and teeth are commodities ('Parts')	dogs' teeth traded/as payment; dog pelt used as clothing, blanket etc.
Scavenging	dogs consume human refuse
Ethnomedicine	Dogs/body parts used in traditional medicine for humans
Spirit medium	dogs communicate with spirits, deities, ghosts
Spirit protector	dogs protect humans from evil spirits
Co-sleeping	dogs sleep with humans

Table S3. *Humans' utility for dogs* (HUD) item descriptions for coding HRAF materials

Humans' utility for dogs items	Description
Feeding	food given to dogs
Care	removing parasites, cleaning, looking after dogs
Ethnoveterinary care	traditional medicine-healing for dogs
Affection	people show affection toward dogs
Indoors	dogs allowed in human houses
Housing	dogs take shelter in outbuildings or have specific houses
Scavenge	dogs consume human refuse
Hunting	dogs used for hunting (includes multiple sub-codes)
Co-sleeping	dogs sleep with humans

Methods: Variable selection and model relevance

We examined five theoretically and analytically important groups of variables for inclusion in regression models. Hypotheses are discussed in the text.

Ecological constraints. First, dogs' heat tolerance may make coevolution unlikely where heat stress is a problem (Lupo 2019). *Ambient temperature* entered the regression models as an 8-point scale from *niche temperature* (SCCS variable 854) (White et al 1986) which was reverse coded by multiplying by -1 so that -1 (very hot) > -8 (very cold) to aid model interpretation. Second, risk of zoonotic infection could diminish dogs' importance to humans. Developments in behavioral immunology

suggest that where pathogen loads are high, humans may avoid potential disease carriers such as dogs and outsiders (Hruschka et al 2014). We used *total pathogen stress* (SCCS variable 1260) (Low 1988) as a proxy for potential zoonotic infections. We constructed a centered *pathogen stress* variable based on the first component of a Principal Components Analysis of SCCS pathogen variables 1253-1259, and this score was nearly perfectly correlated with SCCS variable 1260 ($r = .99$). We included *squared-pathogen stress* as a quadratic term as pathogens have been shown to have a non-linear relationship with human ecology and behavior (Quinlan 2007).

Subsistence system. Most hypotheses for dog-human coevolution include subsistence as an important driver. We examined *percent of dependence on hunting for subsistence* (SCCS variable 204) *dependence on agriculture* (SCCS 207), *dependence on animal husbandry* (SCCS 206), and *population density* (SCCS 64) to characterize relevant subsistence systems. We include *population density* because Coppinger and Coppinger (2001, 2015) indicate that domestication occurred as would-be-dogs scavenged around agricultural settlements at increased population densities with more human refuse. Variables 204 (*hunting*), 207 (*agriculture*) and 64 (*population density*) were highly correlated, and would cause multicollinearity in regression analyses. We created a bipolar scale of *hunting, agriculture* and *population density* using Principal Components Analysis. We reversed the poles of the scale by multiplying by −1 so that positive values indicated more *dependence on hunting* at low *population density*, while negative values indicated more *dependence on agriculture* at higher *population densities* (see table 6, results).

Resource defense. Human-dog coevolution may have proceeded from a combination of cooperative hunting and resource defense (Shipman 2016). We included three predictor variables for *resource defense*: (1) *Intergroup violence* (SCCS variable 1648 *overall warfare*); (2) a *theft-assault-homicide* scale including three substantially correlated items from the SCCS (variables 1665 *homicide*, 1666 *assault*, 1667 *theft*) (see table 6.); and (3) *trespassing* (SCCS variable 1668). All of the resource defense variables demonstrate reliability (Ember and Ember 1992).

Gendered coevolution. Women might have had a particularly important role in dog-human coevolution (Cummins 2013). We used two binary indicator variables from our original coded eHRAF data to indicate gendered coevolution: (1) *dog affiliation with men*; and (2) *dog affiliation with women*. These variables were dichotomous, rather than counts, to more easily compare regression coefficients for men and women. We assume that dog affiliation with human adults is an important component of coevolution, and we are not particularly interested in the significance of their effects *per se*, but rather the difference in the effect of women and men on the three outcome variables is theoretically important. Hence, we include these variables in regression models to evaluate whether *affiliation with women* has *greater* influence than does *affiliation with men*.

Nuisance parameters. Finally, we included two control variables that are not of theoretical interest: (1) *Length of the text* (i.e. number of paragraphs), as some observations may be more likely given a longer and more detailed ethnographic account. (2) *Years since the SCCS observation* is important because the pre-coded SCCS data used as predictors refer to a focal time period (Ember and Ember 2007). Subsequent observations may have followed the focal SCCS period by as much as 200 years (observation date differences were Winsorized to 200 years, i.e. "ancient"). Hence, *years since observation* controls for potential "decay" of cultural-ecological systems over time.

Results and Discussion:

Table S4. Description and associations among coevolutionary outcome variables with shared items removed.

	Correlations			Descriptive	Statistics	
Outcome variables revised	DUHr	PSr	HUDr	Mean (SD)	n of items	Cronbach's Alpha
Dog's utility revised (DUHr)	1			1.29 (1.6)	12	0.64
Person scale revised (PSr)	0.63	1		0.59 (1.2)	10	0.66
Human's utility revised (HUDr)	0.63	0.56	1	0.64 (1.1)	5	0.68

Table S5. Hunting to Agriculture-population-density scale properties

Variable	Hunting	Agriculture	Comp 1	Comp 2
Contribution of hunting to subsistence (SCCS 204)	1.00		−0.57	0.75
Contribution of agriculture to subsistence (SCCS 207)	−0.67	1.00	0.57	0.66
Population density (SCCS 64)	−0.71	0.72	0.59	0.08
Eigenvalue *(Comp1/Comp2=7.27)*			2.4	0.33
Variance explained			80%	11%
Cronbach's alpha for ***Hunting-Agriculture Scale***=	0.85			

Table S6. Theft-assault-homicide scale properties

Variable	Homicide	Assault	Comp 1	Comp 2
Homicide (SCCS variable 1665)	1.00		0.54	0.82
Assault (SCCS variable 1666)	0.59	1.00	0.60	−0.22
Theft (SCCS variable 1667)	0.52	0.70	0.58	−0.53
Eigenvalue *(Comp1/Comp2=4.4)*			2.2	0.5
Variance explained			74%	17%
Cronbach's alpha for ***Theft-Assault-Homicide Scale*** =	0.82			

Table S7. Bivariate correlations among predictor variables to asses multicollinearity for regression in table 6. Even with the addition of a quadratic term for pathogens, maximum VIF was < 4 indicating acceptable multi-collinearity for regression models.

Predictor variable	1	2	3	4	5	6	7	8	9	10	11
1. Temperature	1.00										
2. Pathogen scale ***(max VIF=3.9)***	**0.65**	1.00									
3. Squared pathogens	−0.17	**0.35**	1.00								
4. Hunting+ − Agriculture- scale	**−0.50**	**−0.51**	**0.20**	1.00							
5. Animal husbandry	−0.04	0.05	−0.14	**−0.21**	1.00						
6. Intergroup violence	0.09	0.01	0.01	0.04	−0.02	1.00					
7. Theft-assault-homicide	0.04	−0.01	−0.06	−0.06	−0.01	**0.26**	1.00				
8. Trespassing	0.18	0.09	0.05	0.04	0.04	**0.22**	**0.35**	1.00			
9. Affiliation with women	−0.06	0.07	0.10	0.05	−0.03	0.01	−0.04	0.02	1.00		
10. Affiliation with men	−0.03	0.06	0.07	0.06	−0.03	−0.03	−0.02	−0.01	**0.29**	1.00	
11. Years since SCCS observation	−0.08	−0.14	0.03	0.18	−0.11	0.08	0.10	0.08	−0.06	−0.07	1.00
12. Text length (paragraphs)	0.01	−0.02	−0.01	−0.05	−0.01	−0.07	−0.01	0.06	0.07	0.14	−0.07

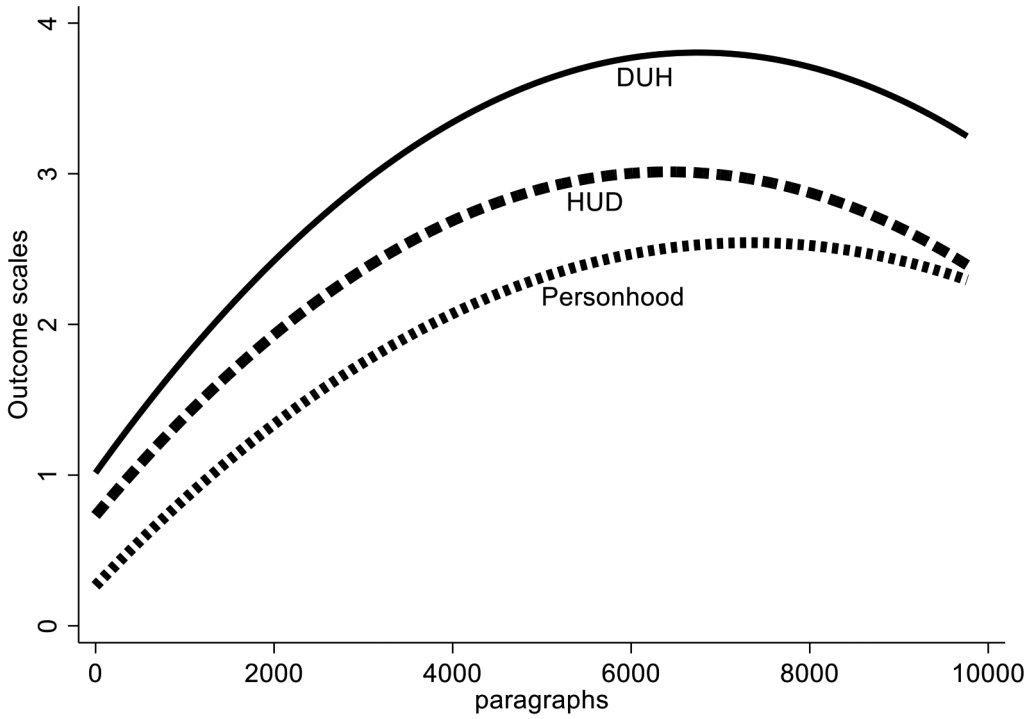

Figure S1. Quadratic relationship between text length and outcome scales (see results table 3).

Controling for time since SCCS observation may be especially important (Ember and Ember 2007); hence, we conducted a second analysis including all variables in table 6 (see main text), but restricted to observations <50 years from the SCCS date (see supplement table S5). This reduced sample had 623 of our original 844 observations, and showed the same pattern of results as in table 6 (supplemental table S5). In some cases, p-values were lower in the reduced sample, possibly indicating stronger effects; however, *time since the focal SCCS observations* was not significant for DUH, HUD or PS.

Table S8. Negative-binomial regression models restricted to <50 years from SCCS focal observation as assess effects of time since SCCS observation. N = 633, Regions = 6, SCCS = 138

Variable	Dog's utility for humans				Human's utility for dogs				Personhood			
	Coef	*P*	95%	*CI*	*Coef*	*P*	95%	*CI*	*Coef*	*P*	95%	*CI*
Temperature	0.234	0.000	0.116	0.353	0.213	0.001	0.085	0.341	0.327	0.000	0.168	0.487
Pathogens scale	0.267	0.003	0.089	0.445	0.238	0.017	0.042	0.433	0.416	0.001	0.174	0.659
Squared Pathogens scale	−0.112	0.002	−0.184	−0.040	−0.107	0.007	−0.184	−0.029	−0.139	0.003	−0.231	−0.047
Animal husbandry	−0.082	0.039	−0.160	−0.004	−0.119	0.010	−0.209	−0.028	−0.149	0.007	−0.257	−0.041
Hunting-Agriculture scale	0.158	0.007	0.043	0.274	0.178	0.006	0.050	0.305	0.116	0.115	−0.028	0.261
Intergroup violence	0.008	0.124	−0.002	0.018	0.009	0.090	−0.001	0.020	0.014	0.011	0.003	0.026
Theft-assault-homicide	0.002	0.963	−0.099	0.103	0.021	0.705	−0.089	0.131	−0.072	0.283	−0.202	0.059
Trespassing	−0.002	0.187	−0.006	0.001	−0.002	0.242	−0.006	0.002	−0.004	0.123	−0.008	0.001
Affiliation with men	0.482	0.000	0.244	0.720	0.230	0.131	−0.069	0.529	0.479	0.018	0.083	0.876
Affiliation with women	0.556	0.000	0.345	0.767	0.931	0.000	0.685	1.178	1.250	0.000	0.928	1.572
Text length (paragraphs)	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.001	0.000	0.001	0.001
Text length-squared	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Yrs between SCCS & Observation	−0.004	0.155	−0.009	0.001	0.004	0.225	−0.002	0.010	−0.002	0.613	−0.011	0.007
Constant	−0.271	0.310	−0.793	0.252	−0.738	0.009	−1.290	−0.186	−1.797	0.000	−2.425	−1.170
Log Overdispersion for Negative-Binomial Regression	−2.827		−4.283	−1.372	−1.996		−2.941	−1.052	−1.269		−2.193	−0.346
Culture within Region variance	0.217		0.050	0.938	0.211		0.044	1.016	0.225		0.053	0.958
Author within Culture variance	0.329		0.201	0.538	0.354		0.200	0.627	0.274		0.115	0.651

Three coevolutionary scales share several items: e.g. hunting, co-sleeping, scavenging, affection, indoors. Scales with shared items removed still show useful reliability (table S1). We repeated the analysis with truncated scales reported in table S4. Results show a nearly identical pattern of associations. Note that hunting is now marginally significant for the revised HUD scale as *hunting with dogs* is limited to DUH here.

Table S9. Negative-binomial regression models repeated with truncated dependent variables from table S1.

Variable	Dog's utility for humans				Human's utility for dogs				Personhood			
	β	***P***	***95%***	***CI***	***β***	***P***	95%	***CI***	***β***	***P***	***95%***	***CI***
Temperature	0.277	0.000	0.165	0.389	0.241	0.000	0.110	0.371	0.342	0.000	0.191	0.493
Pathogens scale	0.295	0.000	0.134	0.456	0.246	0.016	0.046	0.445	0.400	0.000	0.182	0.618
Squared Pathogens scale	−0.110	0.002	-0.178	-0.042	−0.133	0.001	−0.215	−0.051	−0.148	0.001	−0.235	−0.062
Animal husbandry	−0.079	0.034	-0.153	-0.006	−0.084	0.078	−0.178	0.009	−0.156	0.004	−0.261	−0.050
Hunting-Agriculture scale	0.173	0.002	0.065	0.282	0.128	0.058	−0.005	0.260	0.097	0.164	−0.040	0.234
Intergroup violence	0.007	0.110	-0.002	0.016	0.005	0.336	−0.006	0.016	0.012	0.023	0.002	0.023
Theft-assault-homicide	−0.012	0.799	-0.105	0.080	0.037	0.522	−0.076	0.149	0.004	0.945	−0.113	0.121
Trespassing	−0.002	0.371	-0.005	0.002	−0.002	0.282	−0.006	0.002	−0.003	0.135	−0.008	0.001
Affiliation with men	0.455	0.000	0.253	0.657	0.358	0.040	0.017	0.700	0.464	0.010	0.109	0.819
Affiliation with women	0.377	0.000	0.194	0.560	0.907	0.000	0.622	1.192	1.118	0.000	0.821	1.414
Text length (paragraphs)	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.001	0.000	0.001	0.001
Text length-squared	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Years between SCCS & Observation	−0.002	0.052	-0.004	0.000	−0.002	0.170	-0.006	0.001	−0.003	0.158	−0.006	0.001
Constant	−0.572	0.043	-1.127	-0.018	−1.359	0.000	−1.864	−0.854	−1.786	0.000	−2.406	−1.165
Log Overdispersion for Negative-Binomial	−14.957		-1649	1619	−1.281		−2.089	−0.474	−1.267		−2.064	−0.469
Culture within Region variance	0.297		0.077	1.139	0.106		0.015	0.767	0.254		0.062	1.031
Author within Culture variance	0.337		0.216	0.525	0.339		0.169	0.678	0.327		0.164	0.652

Table S10. Overdispersion and group-level variance for multi-level negative-binomial regression models in Table 3.

	DUH			HUD			PD		
Parameter	**Estimate**	**95%**	**CI**	**Estimate**	**95%**	**CI**	**Estimate**	**95%**	**CI**
Log Overdispersion for Negative-Binomial	−2.94	−4.26	−1.26	−1.76	−2.42	−1.09	−1.05	−1.70	−0.39
Culture within Region variance	0.33	0.09	1.27	0.30	0.07	1.26	0.26	0.06	1.07
Author within Culture variance	0.39	0.25	0.60	0.41	0.25	0.68	0.34	0.17	0.68

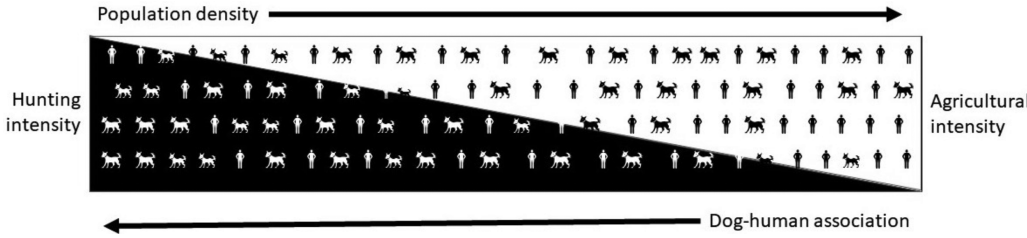

Figure S2. Conceptual representation of association between *hunting-agriculture scale* and dog-human mutual-utility.