

Supporting information for:

**Aggressiveness as a latent personality trait of
domestic dogs: testing local independence and
measurement invariance**

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Obtaining model predictions for the graphical posterior predictive checks

In Figures 1 and 2, we obtained the predicted probabilities of aggression in each context and sex and/or age group by marginalising over the random effects with the approximation given by Zeger et al. (1988: 1054):

$$\frac{\beta x}{(1 + c^2 + \sigma^2)}$$

where β is the regression coefficient for some explanatory variable x , c is $16\sqrt{3}/(15\pi)$ and σ^2 is the variance of the random effect (e.g. random intercept). Applying this approximation allowed for the model predictions to be comparable to the probabilities of aggression in the raw data. In hierarchical logistic regression models, the estimates conditional on the random effects (i.e. conditional on the random intercepts being at their mean, in this case zero) can be larger in absolute value than the marginal estimates. In our case, the conditional estimates were lower than the marginal estimates (since estimates on the log-odd scale were negative), meaning that the model predicted probabilities in Figures 1 and 2 are slightly higher than their corresponding conditional estimates. The conditional estimates were used for plotting purposes only, and without any loss of information, to provide graphical posterior predictive checks against the raw data. The numerical results reported in text are all conditional estimates.

References

Zeger SL, Liang KY, Albert PS. Models for longitudinal data: a generalized estimating equation approach. *Biometrics*. 1988, Dec 1:1049-60.

Table S1. Counts of aggression per context. The number of dogs who had 0, 1, and > 1 observations of aggression while at the shelter.

Context	0 (n)	1 (n)	> 1 (n)
Handling	0 (n = 4286)	1 (n = 338)	> 1 (n = 103)
In kennel towards people	0 (n = 3990)	1 (n = 340)	> 1 (n = 332)
In kennel towards dogs	0 (n = 4050)	1 (n = 365)	> 1 (n = 219)
Interactions with familiar people	0 (n = 4217)	1 (n = 291)	> 1 (n = 63)
Interactions with unfamiliar people	0 (n = 4104)	1 (n = 421)	> 1 (n = 181)
Out of kennel towards people	0 (n = 4491)	1 (n = 165)	> 1 (n = 29)
Out of kennel towards dogs	0 (n = 3855)	1 (n = 455)	> 1 (n = 375)
Interactions with food	0 (n = 4279)	1 (n = 255)	> 1 (n = 45)
Interactions with toys	0 (n = 4348)	1 (n = 125)	> 1 (n = 18)
Interactions with female dogs	0 (n = 3097)	1 (n = 623)	> 1 (n = 168)
Interactions with male dogs	0 (n = 2923)	1 (n = 753)	> 1 (n = 265)

Table S2. Tetrachoric correlations between aggression contexts. Tetrachoric correlations between aggression contexts on the raw binary data, before the multiple imputation. Abbreviations used: HND (*Handling*); FPL (*Interactions with familiar people*); UPL (*Interactions with unfamiliar people*); KD (*In kennel towards dogs*); KP (*In kennel towards people*); OKD (*Out of kennel towards dogs*); OKP (*Out of kennel towards people*); EAT (*Eating food*); TOY (*Interactions with toys*); DM (*Interactions with male dogs*); DF (*Interactions with female dogs*).

	HND	FPL	UPL	KD	KP	OKD	OKP	EAT	TOY	DM	DF
HND	1	0.585	0.446	0.046	0.396	0.108	0.346	0.499	0.448	0.134	0.179
FPL	0.585	1	0.568	0.051	0.526	0.007	0.413	0.471	0.39	0.136	0.121
UPL	0.446	0.568	1	0.089	0.746	0.134	0.607	0.387	0.242	0.093	0.12
KD	0.046	0.051	0.089	1	0.153	0.337	0.135	0.008	-0.002	0.422	0.447
KP	0.396	0.526	0.746	0.153	1	0.136	0.531	0.403	0.139	0.131	0.154
OKD	0.108	0.007	0.134	0.337	0.136	1	0.176	0.095	0.143	0.315	0.285
OKP	0.346	0.413	0.607	0.135	0.531	0.176	1	0.272	0.244	0.122	0.192
EAT	0.499	0.471	0.387	0.008	0.403	0.095	0.272	1	0.59	0.116	0.130
TOY	0.448	0.39	0.242	-0.002	0.139	0.143	0.244	0.590	1	0.12	0.058
DM	0.134	0.136	0.093	0.422	0.131	0.315	0.122	0.116	0.120	1	0.540
DF	0.179	0.121	0.120	0.447	0.154	0.285	0.192	0.130	0.058	0.540	1

Table S3. Bayesian hierarchical model parameter estimates for aggression towards people in different contexts. Mean and 95% highest density interval (HDI) estimates for all parameters from the Bayesian hierarchical logistic model assessing measurement invariance for contexts reflecting aggressiveness towards people. Differences between levels of categorical variables are indicated by ‘.v.’ in the parameter name; interactions are denoted with ‘*’ in the parameter name. The decision rule for each parameter is given except for those variables not interpreted inferentially: YES = 95% HDI falls completely outside the region of practical equivalence (ROPE); NULL = 95% HDI falls completely inside the ROPE; ROPE = 95% HDI partly covers the ROPE.

Parameter	Mean	HDI low	HDI high	Decision
Weight	0.928	0.863	0.987	Not interpreted
Total days	1.863	1.745	1.99	Not interpreted
London centre .v. Brands Hatch centre	1.7	1.525	1.895	Not interpreted
London centre .v. Old Windsor centre	2.026	1.849	2.204	Not interpreted
Brands Hatch centre.v. Old Windsor centre	0.841	0.74	0.947	Not interpreted
Not neutered .v. neutered on site	2.418	2.205	2.631	Not interpreted
Not neutered .v. neutered	1.649	1.506	1.793	Not interpreted
Neutered .v. neutered on site	1.468	1.35	1.6	Not interpreted
Gift.v.Return	0.707	0.608	0.808	Not interpreted
Gift.v.Stray	2.471	2.273	2.678	Not interpreted
Stray.v.return	0.286	0.242	0.328	Not interpreted
Females.v.males	0.719	0.668	0.77	YES
Handling.v.In kennel towards people	0.535	0.494	0.576	YES
Handling.v.Out of kennel towards people	2.821	2.536	3.078	YES
Handling.v.Eating food	1.51	1.379	1.644	YES
Handling.v.Interactions with toys	3.45	3.089	3.806	YES
Handling.V.Interactions with familiar people	1.314	1.203	1.432	ROPE
Handling.V.Interactions with unfamiliar people	0.622	0.58	0.675	YES
In kennel towards people.V.Out of kennel towards people	5.273	4.786	5.771	YES
In kennel towards people.V.Eating food	1.51	1.379	1.644	YES
In kennel towards people.V.Interactions with toys	6.45	5.823	7.122	YES
In kennel towards people.V.Interactions with familiar people	2.456	2.261	2.656	YES
In kennel towards people.V.Interactions with unfamiliar people	1.163	1.078	1.243	NULL
Out of kennel towards people.V.Eating food	0.536	0.484	0.592	YES
Out of kennel towards people.V.Interactions with toys	1.225	1.086	1.366	ROPE
Out of kennel towards people.V.Interactions with familiar people	0.466	0.42	0.512	YES
Out of kennel towards people.V.Interactions with unfamiliar people	0.221	0.201	0.241	YES
Eating food.V.Interactions with toys	2.287	2.038	2.532	YES
Eating food.V.Interactions with familiar people	0.871	0.789	0.948	ROPE

Eating food.V.Interactions with unfamiliar people	0.412	0.378	0.447	YES
Interactions with toys.V.Interactions with familiar people	0.382	0.344	0.426	YES
Interactions with toys.V.Interactions with unfamiliar people	0.181	0.163	0.2	YES
Interactions with familiar people.V.Interactions with unfamiliar people	0.474	0.435	0.512	YES
4 to 10 months.v.10 months to 3 years	0.638	0.565	0.705	YES
4 to 10 months.v.3 to 6 years	0.744	0.654	0.828	ROPE
4 to 10 months.v.Over 6 years	0.842	0.736	0.952	ROPE
10 months to 3 years.v.3 to 6 years	1.166	1.069	1.271	ROPE
10 months to 3 years.v.Over 6 years	1.32	1.188	1.453	ROPE
3 to 6 years.v.Over 6 years	1.133	1.013	1.261	ROPE
Handling.V.In kennel towards people*female.v.male	0.779	0.67	0.895	ROPE
Handling.V.Out of kennel towards people*female.v.male	0.578	0.481	0.682	YES
Handling.V.Eating food*female.v.male	1.042	0.88	1.222	NULL
Handling.V.Interactions with toys*female.v.male	0.787	0.636	0.933	ROPE
Handling.V.Interactions with familiar people*female.v.male	1.033	0.87	1.193	NULL
Handling.V.Interactions with unfamiliar people*female.v.male	0.616	0.53	0.702	YES
In kennel towards people.V.Out of kennel towards people*female.v.male	0.743	0.623	0.867	ROPE
In kennel towards people.V.Eating food*female.v.male	1.339	1.145	1.559	ROPE
In kennel towards people.V.Interactions with toys*female.v.male	1.012	0.83	1.197	NULL
In kennel towards people.V.Interactions with familiar people*female.v.male	1.329	1.136	1.522	ROPE
In kennel towards people.V.Interactions with unfamiliar people*female.v.male	0.792	0.701	0.902	ROPE
Out of kennel towards people.V.Eating food*female.v.male	1.812	1.495	2.152	YES
Out of kennel towards people.V.Interactions with toys*female.v.male	1.369	1.066	1.652	ROPE
Out of kennel towards people.V.Interactions with familiar people*female.v.male	1.798	1.488	2.126	YES
Out of kennel towards people.V.Interactions with unfamiliar people*female.v.male	1.072	0.891	1.243	NULL
Eating food.V.Interactions with toys*female.v.male	0.759	0.609	0.904	ROPE
Eating food.V.Interactions with familiar people*female.v.male	0.996	0.836	1.174	NULL
Eating food.V.Interactions with unfamiliar people*female.v.male	0.594	0.506	0.686	YES
Interactions with toys.V.Interactions with familiar people*female.v.male	1.321	1.088	1.595	ROPE
Interactions with toys.V.Interactions with unfamiliar people*female.v.male	0.788	0.651	0.929	ROPE
Interactions with familiar people.V.Interactions with unfamiliar people*female.v.male	0.598	0.513	0.687	YES
Handling.V.In kennel towards people*4 to 10 months.v.10 months to 3 years	1.353	1.071	1.651	ROPE
Handling.V.Out of kennel towards people*4 to 10 months.v.10 months to 3 years	0.958	0.722	1.228	ROPE
Handling.V.Eating food*4 to 10 months.v.10 months to 3 years	0.706	0.533	0.884	ROPE
Handling.V.Interactions with toys*4 to 10 months.v.10 months to 3	0.882	0.622	1.147	ROPE

years

Handling.V.Interactions with familiar people*4 to 10 months.v.10 months to 3 years	1.048	0.798	1.292	ROPE
Handling.V.Interactions with unfamiliar people*4 to 10 months.v.10 months to 3 years	1.204	0.992	1.413	ROPE
In kennel towards people.V.Out of kennel towards people*4 to 10 months.v.10 months to 3 years	0.712	0.527	0.883	ROPE
In kennel towards people.V.Eating food*4 to 10 months.v.10 months to 3 years	0.524	0.4	0.642	YES
In kennel towards people.V.Interactions with toys*4 to 10 months.v.10 months to 3 years	0.655	0.483	0.851	ROPE
In kennel towards people.V.Interactions with familiar people*4 to 10 months.v.10 months to 3 years	0.779	0.613	0.951	ROPE
In kennel towards people.V.Interactions with unfamiliar people*4 to 10 months.v.10 months to 3 years	0.895	0.754	1.037	ROPE
Out of kennel towards people.V.Eating food*4 to 10 months.v.10 months to 3 years	0.744	0.553	0.964	ROPE
Out of kennel towards people.V.Interactions with toys*4 to 10 months.v.10 months to 3 years	0.93	0.641	1.227	ROPE
Out of kennel towards people.V.Interactions with familiar people*4 to 10 months.v.10 months to 3 years	1.105	0.823	1.416	ROPE
Out of kennel towards people.V.Interactions with unfamiliar people*4 to 10 months.v.10 months to 3 years	1.27	1.025	1.547	ROPE
Eating food.V.Interactions with toys*4 to 10 months.v.10 months to 3 years	1.26	0.864	1.643	ROPE
Eating food.V.Interactions with familiar people*4 to 10 months.v.10 months to 3 years	1.498	1.153	1.928	ROPE
Eating food.V.Interactions with unfamiliar people*4 to 10 months.v.10 months to 3 years	1.721	1.403	2.059	YES
Interactions with toys.V.Interactions with familiar people*4 to 10 months.v.10 months to 3 years	1.208	0.87	1.594	ROPE
Interactions with toys.V.Interactions with unfamiliar people*4 to 10 months.v.10 months to 3 years	1.387	1.035	1.72	ROPE
Interactions with familiar people.V.Interactions with unfamiliar people*4 to 10 months.v.10 months to 3 years	1.158	0.951	1.364	ROPE
Handling.V.In kennel towards people*4 to 10 months.v.3 to 6 years	1.074	0.841	1.325	ROPE
Handling.V.Out of kennel towards people*4 to 10 months.v.3 to 6 years	0.501	0.365	0.645	YES
Handling.V.Eating food*4 to 10 months.v.3 to 6 years	0.861	0.657	1.084	ROPE
Handling.V.Interactions with toys*4 to 10 months.v.3 to 6 years	0.598	0.428	0.799	YES
Handling.V.Interactions with familiar people*4 to 10 months.v.3 to 6 years	0.733	0.555	0.914	ROPE
Handling.V.Interactions with unfamiliar people*4 to 10 months.v.3 to 6 years	1.015	0.825	1.201	NULL
In kennel towards people.V.Out of kennel towards people*4 to 10 months.v.3 to 6 years	0.47	0.355	0.606	YES
In kennel towards people.V.Eating food*4 to 10 months.v.3 to 6 years	0.806	0.636	1.021	ROPE
In kennel towards people.V.Interactions with toys*4 to 10 months.v.3 to 6 years	0.56	0.405	0.731	YES
In kennel towards people.V.Interactions with familiar people*4 to 10 months.v.3 to 6 years	0.686	0.533	0.852	ROPE
In kennel towards people.V.Interactions with unfamiliar people*4 to 10 months.v.3 to 6 years	0.951	0.788	1.104	ROPE
Out of kennel towards people.V.Eating food*4 to 10 months.v.3 to 6 years	1.74	1.233	2.234	ROPE
Out of kennel towards people.V.Interactions with toys*4 to 10 months.v.3 to 6 years	1.208	0.839	1.624	ROPE

months.v.3 to 6 years

Out of kennel towards people.V.Interactions with familiar people*4 to 10 months.v.3 to 6 years	1.48	1.079	1.915	ROPE
Out of kennel towards people.V.Interactions with unfamiliar people*4 to 10 months.v.3 to 6 years	2.051	1.608	2.543	YES
Eating food.V.Interactions with toys*4 to 10 months.v.3 to 6 years	0.701	0.487	0.926	ROPE
Eating food.V.Interactions with familiar people*4 to 10 months.v.3 to 6 years	0.859	0.637	1.085	ROPE
Eating food.V.Interactions with unfamiliar people*4 to 10 months.v.3 to 6 years	1.19	0.969	1.429	ROPE
Interactions with toys.V.Interactions with familiar people*4 to 10 months.v.3 to 6 years	1.247	0.85	1.645	ROPE
Interactions with toys.V.Interactions with unfamiliar people*4 to 10 months.v.3 to 6 years	1.726	1.302	2.159	YES
Interactions with familiar people.V.Interactions with unfamiliar people*4 to 10 months.v.3 to 6 years	1.398	1.135	1.673	ROPE
Handling.V.In kennel towards people*4 to 10 months.v.Over 6 years	0.382	0.292	0.485	YES
Handling.V.Out of kennel towards people*4 to 10 months.v.Over 6 years	0.278	0.198	0.373	YES
Handling.V.Eating food*4 to 10 months.v.Over 6 years	0.777	0.576	1	ROPE
Handling.V.Interactions with toys*4 to 10 months.v.Over 6 years	0.822	0.578	1.111	ROPE
Handling.V.Interactions with familiar people*4 to 10 months.v.Over 6 years	0.435	0.323	0.554	YES
Handling.V.Interactions with unfamiliar people*4 to 10 months.v.Over 6 years	0.367	0.297	0.447	YES
In kennel towards people.V.Out of kennel towards people*4 to 10 months.v.Over 6 years	0.733	0.502	0.96	ROPE
In kennel towards people.V.Eating food*4 to 10 months.v.Over 6 years	2.048	1.539	2.606	YES
In kennel towards people.V.Interactions with toys*4 to 10 months.v.Over 6 years	2.164	1.516	2.83	YES
In kennel towards people.V.Interactions with familiar people*4 to 10 months.v.Over 6 years	1.147	0.858	1.46	ROPE
In kennel towards people.V.Interactions with unfamiliar people*4 to 10 months.v.Over 6 years	0.966	0.786	1.164	ROPE
Out of kennel towards people.V.Eating food*4 to 10 months.v.Over 6 years	2.847	1.92	3.777	YES
Out of kennel towards people.V.Interactions with toys*4 to 10 months.v.Over 6 years	3.01	1.908	4.113	YES
Out of kennel towards people.V.Interactions with familiar people*4 to 10 months.v.Over 6 years	1.594	1.117	2.148	ROPE
Out of kennel towards people.V.Interactions with unfamiliar people*4 to 10 months.v.Over 6 years	1.342	0.99	1.705	ROPE
Eating food.V.Interactions with toys*4 to 10 months.v.Over 6 years	1.068	0.729	1.421	ROPE
Eating food.V.Interactions with familiar people*4 to 10 months.v.Over 6 years	0.566	0.408	0.731	YES
Eating food.V.Interactions with unfamiliar people*4 to 10 months.v.Over 6 years	0.476	0.381	0.585	YES
Interactions with toys.V.Interactions with familiar people*4 to 10 months.v.Over 6 years	0.54	0.377	0.727	YES
Interactions with toys.V.Interactions with unfamiliar people*4 to 10 months.v.Over 6 years	0.454	0.34	0.581	YES
Interactions with familiar people.V.Interactions with unfamiliar people*4 to 10 months.v.Over 6 years	0.851	0.668	1.035	ROPE
Handling.V.In kennel towards people*10 months to 3 years.v.3 to 6 years	0.796	0.672	0.928	ROPE

Handling.V.Out of kennel towards people*10 months to 3 years.v.3 to 6 years	0.526	0.409	0.631	YES
Handling.V.Eating food*10 months to 3 years.v.3 to 6 years	1.225	1.001	1.468	ROPE
Handling.V.Interactions with toys*10 months to 3 years.v.3 to 6 years	0.683	0.525	0.841	ROPE
Handling.V.Interactions with familiar people*10 months to 3 years.v.3 to 6 years	0.702	0.584	0.838	ROPE
Handling.V.Interactions with unfamiliar people*10 months to 3 years.v.3 to 6 years	0.846	0.704	0.977	ROPE
In kennel towards people.V.Out of kennel towards people*10 months to 3 years.v.3 to 6 years	0.662	0.538	0.796	YES
In kennel towards people.V.Eating food*10 months to 3 years.v.3 to 6 years	1.544	1.28	1.811	YES
In kennel towards people.V.Interactions with toys*10 months to 3 years.v.3 to 6 years	0.86	0.68	1.057	ROPE
In kennel towards people.V.Interactions with familiar people*10 months to 3 years.v.3 to 6 years	0.884	0.742	1.023	ROPE
In kennel towards people.V.Interactions with unfamiliar people*10 months to 3 years.v.3 to 6 years	1.066	0.919	1.225	NULL
Out of kennel towards people.V.Eating food*10 months to 3 years.v.3 to 6 years	2.349	1.891	2.925	YES
Out of kennel towards people.V.Interactions with toys*10 months to 3 years.v.3 to 6 years	1.309	0.99	1.664	ROPE
Out of kennel towards people.V.Interactions with familiar people*10 months to 3 years.v.3 to 6 years	1.346	1.07	1.644	ROPE
Out of kennel towards people.V.Interactions with unfamiliar people*10 months to 3 years.v.3 to 6 years	1.622	1.312	1.965	YES
Eating food.V.Interactions with toys*10 months to 3 years.v.3 to 6 years	0.56	0.425	0.689	YES
Eating food.V.Interactions with familiar people*10 months to 3 years.v.3 to 6 years	0.576	0.468	0.687	YES
Eating food.V.Interactions with unfamiliar people*10 months to 3 years.v.3 to 6 years	0.694	0.572	0.823	ROPE
Interactions with toys.V.Interactions with familiar people*10 months to 3 years.v.3 to 6 years	1.038	0.804	1.291	ROPE
Interactions with toys.V.Interactions with unfamiliar people*10 months to 3 years.v.3 to 6 years	1.252	0.963	1.522	ROPE
Interactions with familiar people.V.Interactions with unfamiliar people*10 months to 3 years.v.3 to 6 years	1.211	1.008	1.41	ROPE
Handling.V.In kennel towards people*10 months to 3 years.v.Over 6 years	0.283	0.23	0.338	YES
Handling.V.Out of kennel towards people*10 months to 3 years.v.Over 6 years	0.291	0.22	0.367	YES
Handling.V.Eating food*10 months to 3 years.v.Over 6 years	1.106	0.887	1.35	ROPE
Handling.V.Interactions with toys*10 months to 3 years.v.Over 6 years	0.938	0.722	1.178	ROPE
Handling.V.Interactions with familiar people*10 months to 3 years.v.Over 6 years	0.417	0.33	0.5	YES
Handling.V.Interactions with unfamiliar people*10 months to 3 years.v.Over 6 years	0.306	0.243	0.364	YES
In kennel towards people.V.Out of kennel towards people*10 months to 3 years.v.Over 6 years	1.032	0.776	1.295	ROPE
In kennel towards people.V.Eating food*10 months to 3 years.v.Over 6 years	3.92	3.125	4.74	YES
In kennel towards people.V.Interactions with toys*10 months to 3 years.v.Over 6 years	3.323	2.576	4.135	YES
In kennel towards people.V.Interactions with familiar people*10 months to 3 years.v.Over 6 years	1.478	1.18	1.763	ROPE

In kennel towards people.V.Interactions with unfamiliar people*10 months to 3 years.v.Over 6 years	1.083	0.879	1.287	ROPE
Out of kennel towards people.V.Eating food*10 months to 3 years.v.Over 6 years	3.843	2.867	4.862	YES
Out of kennel towards people.V.Interactions with toys*10 months to 3 years.v.Over 6 years	3.258	2.318	4.22	YES
Out of kennel towards people.V.Interactions with familiar people*10 months to 3 years.v.Over 6 years	1.449	1.068	1.823	ROPE
Out of kennel towards people.V.Interactions with unfamiliar people*10 months to 3 years.v.Over 6 years	1.062	0.805	1.342	ROPE
Eating food.V.Interactions with toys*10 months to 3 years.v.Over 6 years	0.853	0.658	1.071	ROPE
Eating food.V.Interactions with familiar people*10 months to 3 years.v.Over 6 years	0.379	0.3	0.465	YES
Eating food.V.Interactions with unfamiliar people*10 months to 3 years.v.Over 6 years	0.278	0.222	0.336	YES
Interactions with toys.V.Interactions with familiar people*10 months to 3 years.v.Over 6 years	0.449	0.341	0.565	YES
Interactions with toys.V.Interactions with unfamiliar people*10 months to 3 years.v.Over 6 years	0.329	0.255	0.412	YES
Interactions with familiar people.V.Interactions with unfamiliar people*10 months to 3 years.v.Over 6 years	0.738	0.59	0.887	ROPE
Handling.V.In kennel towards people*3 to 6 years.v.Over 6 years	0.357	0.291	0.43	YES
Handling.V.Out of kennel towards people*3 to 6 years.v.Over 6 years	0.558	0.409	0.709	YES
Handling.V.Eating food*3 to 6 years.v.Over 6 years	0.907	0.717	1.106	ROPE
Handling.V.Interactions with toys*3 to 6 years.v.Over 6 years	1.384	1.043	1.753	ROPE
Handling.V.Interactions with familiar people*3 to 6 years.v.Over 6 years	0.597	0.469	0.727	YES
Handling.V.Interactions with unfamiliar people*3 to 6 years.v.Over 6 years	0.363	0.292	0.438	YES
In kennel towards people.V.Out of kennel towards people*3 to 6 years.v.Over 6 years	1.569	1.151	1.993	ROPE
In kennel towards people.V.Eating food*3 to 6 years.v.Over 6 years	2.55	2.009	3.069	YES
In kennel towards people.V.Interactions with toys*3 to 6 years.v.Over 6 years	3.892	2.959	4.921	YES
In kennel towards people.V.Interactions with familiar people*3 to 6 years.v.Over 6 years	1.678	1.357	2.054	YES
In kennel towards people.V.Interactions with unfamiliar people*3 to 6 years.v.Over 6 years	1.019	0.825	1.217	NULL
Out of kennel towards people.V.Eating food*3 to 6 years.v.Over 6 years	1.648	1.205	2.106	ROPE
Out of kennel towards people.V.Interactions with toys*3 to 6 years.v.Over 6 years	2.516	1.737	3.322	YES
Out of kennel towards people.V.Interactions with familiar people*3 to 6 years.v.Over 6 years	1.085	0.79	1.413	ROPE
Out of kennel towards people.V.Interactions with unfamiliar people*3 to 6 years.v.Over 6 years	0.659	0.489	0.84	ROPE
Eating food.V.Interactions with toys*3 to 6 years.v.Over 6 years	1.536	1.149	1.957	ROPE
Eating food.V.Interactions with familiar people*3 to 6 years.v.Over 6 years	0.662	0.523	0.824	ROPE
Eating food.V.Interactions with unfamiliar people*3 to 6 years.v.Over 6 years	0.402	0.317	0.486	YES
Interactions with toys.V.Interactions with familiar people*3 to 6 years.v.Over 6 years	0.436	0.332	0.564	YES
Interactions with toys.V.Interactions with unfamiliar people*3 to 6 years.v.Over 6 years	0.265	0.201	0.335	YES

Interactions with familiar people.V.Interactions with unfamiliar people*3 to 6 years.v.Over 6 years	0.612	0.481	0.743	YES
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Table S4. Bayesian hierarchical model parameter estimates for aggression towards dogs in different contexts. Mean and 95% highest density interval (HDI) estimates for all parameters from the Bayesian hierarchical logistic model assessing measurement invariance for contexts reflecting aggressiveness towards dogs. Differences between levels of categorical variables are indicated by ‘.v.’ in the parameter name; interactions are denoted with ‘*’ in the parameter name. The decision rule for each parameter is given except for those variables not interpreted inferentially: YES = 95% HDI falls completely outside the region of practical equivalence (ROPE); NULL = 95% HDI falls completely inside the ROPE; ROPE = 95% HDI partly covers the ROPE.

Parameter	Mean	HDI low	HDI high	Decision
Weight	1.163	1.107	1.218	Not interpreted
Total days	2.232	2.125	2.342	Not interpreted
London .v. Brands Hatch centre	0.756	0.697	0.813	Not interpreted
London .v. Old Windsor shelter	0.941	0.886	0.996	Not interpreted
Brands Hatch .v. Old Windsor shelter	0.804	0.736	0.874	Not interpreted
Not neutered .v. neutered on site	2.013	1.884	2.147	Not interpreted
Not neutered .v. neutered	1.454	1.362	1.546	Not interpreted
Neutered .v. neutered on site	1.385	1.294	1.472	Not interpreted
Gift.v.Return	0.762	0.686	0.845	Not interpreted
Gift.v.Stray	1.227	1.157	1.295	Not interpreted
Stray.v.return	0.622	0.555	0.692	Not interpreted
Females.v.males	1.187	1.128	1.250	Not interpreted
Interactions with female dogs.v.Interactions with male dogs	0.699	0.661	0.737	YES
Interactions with female dogs.v.In kennel towards dogs	2.095	1.969	2.230	YES
Interactions with female dogs.v.Out of kennel towards dogs	1.306	1.234	1.380	ROPE
Interactions with male dogs.V.In kennel towards dogs	3.00	2.822	3.191	YES
Interactions with male dogs.V.Out of kennel towards dogs	1.306	1.234	1.380	ROPE
In kennel towards dogs.V.Out of kennel towards dogs	0.624	0.585	0.662	YES
4 to 10 months.v.10 months to 3 years	0.571	0.527	0.616	YES
4 to 10 months.v.3 to 6 years	0.513	0.471	0.555	YES
4 to 10 months.v.Over 6 years	0.616	0.559	0.678	YES
10 months to 3 years.v.3 to 6 years	0.899	0.850	0.956	NULL
10 months to 3 years.v.Over 6 years	1.078	0.995	1.155	NULL
3 to 6 years.v.Over 6 years	1.200	1.113	1.291	ROPE
Interactions with female dogs.V.Interactions with male dogs*female.v.male	1.542	1.400	1.704	YES
Interactions with female dogs.V.In kennel towards dogs*female.v.male	1.018	0.907	1.128	NULL
Interactions with female dogs.V.Out of kennel towards dogs*female.v.male	1.444	1.301	1.603	YES
Interactions with male dogs.V.In kennel towards dogs*female.v.male	0.661	0.590	0.732	YES

Interactions with male dogs.V.Out of kennel towards dogs*female.v.male	0.938	0.838	1.029	NULL
In kennel towards dogs.V.Out of kennel towards dogs*female.v.male	1.420	1.269	1.587	YES
Interactions with female dogs.V.Interactions with male dogs*4 to 10 months.v.10 months to 3 years	1.198	1.003	1.391	ROPE
Interactions with female dogs.V.In kennel towards dogs*4 to 10 months.v.10 months to 3 years	0.984	0.808	1.171	NULL
Interactions with female dogs.V.Out of kennel towards dogs*4 to 10 months.v.10 months to 3 years	0.595	0.495	0.688	YES
Interactions with male dogs.V.In kennel towards dogs*4 to 10 months.v.10 months to 3 years	0.824	0.683	0.983	ROPE
Interactions with male dogs.V.Out of kennel towards dogs*4 to 10 months.v.10 months to 3 years	0.499	0.422	0.575	YES
In kennel towards dogs.V.Out of kennel towards dogs*4 to 10 months.v.10 months to 3 years	0.608	0.505	0.728	YES
Interactions with female dogs.V.Interactions with male dogs*4 to 10 months.v.3 to 6 years	1.202	1.015	1.412	ROPE
Interactions with female dogs.V.In kennel towards dogs*4 to 10 months.v.3 to 6 years	0.956	0.773	1.133	ROPE
Interactions with female dogs.V.Out of kennel towards dogs*4 to 10 months.v.3 to 6 years	0.263	0.22	0.307	YES
Interactions with male dogs.V.In kennel towards dogs*4 to 10 months.v.3 to 6 years	0.798	0.65	0.944	ROPE
Interactions with male dogs.V.Out of kennel towards dogs*4 to 10 months.v.3 to 6 years	0.22	0.185	0.256	YES
In kennel towards dogs.V.Out of kennel towards dogs*4 to 10 months.v.3 to 6 years	0.277	0.227	0.331	YES
Interactions with female dogs.V.Interactions with male dogs*4 to 10 months.v.Over 6 years	1.441	1.175	1.697	ROPE
Interactions with female dogs.V.In kennel towards dogs*4 to 10 months.v.Over 6 years	0.965	0.768	1.172	ROPE
Interactions with female dogs.V.Out of kennel towards dogs*4 to 10 months.v.Over 6 years	0.38	0.308	0.449	YES
Interactions with male dogs.V.In kennel towards dogs*4 to 10 months.v.Over 6 years	0.672	0.545	0.816	ROPE
Interactions with male dogs.V.Out of kennel towards dogs*4 to 10 months.v.Over 6 years	0.265	0.219	0.315	YES
In kennel towards dogs.V.Out of kennel towards dogs*4 to 10 months.v.Over 6 years	0.396	0.316	0.481	YES
Interactions with female dogs.V.Interactions with male dogs*10 months to 3 years.v.3 to 6 years	1.005	0.897	1.117	NULL
Interactions with female dogs.V.In kennel towards dogs*10 months to 3 years.v.3 to 6 years	0.973	0.85	1.09	NULL
Interactions with female dogs.V.Out of kennel towards dogs*10 months to 3 years.v.3 to 6 years	0.443	0.39	0.499	YES
Interactions with male dogs.V.In kennel towards dogs*10 months to 3 years.v.3 to 6 years	0.97	0.862	1.103	NULL
Interactions with male dogs.V.Out of kennel towards dogs*10 months to 3 years.v.3 to 6 years	0.442	0.389	0.496	YES
In kennel towards dogs.V.Out of kennel towards dogs*10 months to 3 years.v.3 to 6 years	0.456	0.396	0.516	YES
Interactions with female dogs.V.Interactions with male dogs*10 months to 3 years.v.Over 6 years	1.205	1.052	1.374	ROPE
Interactions with female dogs.V.In kennel towards dogs*10 months to 3 years.v.Over 6 years	0.982	0.829	1.131	NULL
Interactions with female dogs.V.Out of kennel towards dogs*10 months to 3 years.v.Over 6 years	0.639	0.544	0.734	YES

Interactions with male dogs.V.In kennel towards dogs*10 months to 3 years.v.Over 6 years	0.817	0.696	0.945	ROPE
Interactions with male dogs.V.Out of kennel towards dogs*10 months to 3 years.v.Over 6 years	0.532	0.457	0.611	YES
In kennel towards dogs.V.Out of kennel towards dogs*10 months to 3 years.v.Over 6 years	0.653	0.545	0.751	YES
Interactions with female dogs.V.Interactions with male dogs*3 to 6 years.v.Over 6 years	1.201	1.043	1.365	ROPE
Interactions with female dogs.V.In kennel towards dogs*3 to 6 years.v.Over 6 years	1.011	0.862	1.182	NULL
Interactions with female dogs.V.Out of kennel towards dogs*3 to 6 years.v.Over 6 years	1.446	1.229	1.656	ROPE
Interactions with male dogs.V.In kennel towards dogs*3 to 6 years.v.Over 6 years	0.844	0.721	0.976	ROPE
Interactions with male dogs.V.Out of kennel towards dogs*3 to 6 years.v.Over 6 years	1.206	1.033	1.394	ROPE
In kennel towards dogs.V.Out of kennel towards dogs*3 to 6 years.v.Over 6 years	1.435	1.205	1.681	ROPE