Supplementary Materials for

Dogs' Reversal of Dominance Preferences in Human Social Worlds

Shuting Dai, Qiming Xu, Zhentao Zuo, Yupei Liu, Yukang Yang, Xiqian Lu*, Yi Jiang*

Corresponding author: luxq@psych.ac.cn; yijiang@psych.ac.cn

The PDF file includes:

Supplementary Text
tables S1 to S3

Other Supplementary Materials for this manuscript include the following:

Movies S1 to S7

Supplementary Text

Control Analysis

1. Experiment 1a

To examine whether dogs' looking time was influenced by screen side (left vs. right). Paired comparisons revealed no significant difference in looking-time proportion between the left and right screen sides in either the Introduction phase (Wilcoxon signed-rank test; 0.21 ± 0.17 vs. 0.18 ± 0.12; V = 379, p = 0.687) or the Ownership Determination phase (paired t-test; 0.24 ± 0.15 vs. 0.17 ± 0.12; t (36) = 1.81, p = 0.079).

To examine whether dogs' looking time was influenced by performer identity (performer A vs. performer B), we used repeated-measures ANOVAs with factors of performer identity (performer A vs. performer B) and performer role (dominant vs. subordinate). Results revealed no significant interaction in either the Introduction phase (F (1, 36) = 0.579, p = 0.452, η^2_p = 0.016) or the Ownership Determination phase (F (1, 36) = 3.471, p = 0.071, η^2_p = 0.088). These results indicate that dogs' preference for the dominant individual cannot be explained by spatial bias or individual performer characteristics.

2.Experiment 1b

We employed a forward model selection approach using generalized linear mixed-effects models (GLMMs), starting with a null model including only subject ID as a random intercept, and incrementally adding predictors to test their contribution to model fit using likelihood ratio tests. The subsequent models included phase, performer role, and their interaction as fixed effects.

To examine whether dogs' looking time was influenced by screen side (left vs. right), we conducted a statistical analysis of their looking-time proportions to each side. Results revealed that dogs exhibited a spontaneous left-side bias during the Introduction phase (Wilcoxon signed-rank test; 0.31 ± 0.21, 0.18 ± 0.22; V = 292, p = 0.014) and the Ownership determination phase (Wilcoxon signed-rank test; 0.29 ± 0.23, 0.17 ± 0.12; V = 316, p = 0.033). To control spatial biases, screen position (left vs. right) was included as a fixed effect. We first fitted a full model including the three-way interaction between performer's role, phase, and screen side. Results revealed that the interaction was not significant (β = 0.37, SE = 0.54, z = 0.69, p = 0.494), nor was the two-way interaction between performer's role and screen side (β = 0.14, SE = 0.37, z = 0.38, p = 0.702). We therefore proceeded with a model including performer's role and phase, and screen side as covariate, with subject ID included as a random intercept. Results showed that the interaction between performer's role and phase was not significant (β = 0.36, SE = 0.26, z = 1.39, p = 0.165), indicating that dogs' attention to individuals of different roles did not vary across phases after controlling spatial biases.

To examine whether dogs' looking time was influenced by performer identity (performer A vs. performer B), we used GLMMs with factors of performer identity (performer A vs.

performer B) and performer role (dominant vs. subordinate). Results revealed no significant interaction in either the Introduction phase (β = 0.14, SE = 0.45, z = 0.30, p = 0.761) or the Ownership Determination phase (β = 0.47, SE = 0.40, z = 1.19, p = 0.235). These results indicate that dogs' preference for the dominant individual cannot be explained by spatial bias or individual performer characteristics.

3.Experiment 1c

Experiment 1c was analyzed using the same GLMM approach as described for Experiment 1b, including phase, performer role, and their interaction as fixed effects, and subject ID as a random intercept.

To examine whether dogs' looking time was influenced by screen side (left vs. right), we conducted a statistical analysis of their looking-time proportions to each side. Results revealed that dogs exhibited a spontaneous left-side bias during the Ownership determination phase (Wilcoxon signed-rank test; 0.26 ± 0.19, 0.15 ± 0.13; V = 333, p = 0.038) but not the Introduction phase (Wilcoxon signed-rank test; 0.18 ± 0.16, 0.11 ± 0.11; V = 305, p = 0.140). As in Experiment 1b, we first tested whether spatial position modulated the effect of performer's role. We found no significant interaction between performer's role, phase, and screen side (β = 0.01, SE = 0.52, z = 0.02, p = 0.986), nor a significant interaction between performer's role and screen side (β = -0.13, SE = 0.41, z = -0.31, p = 0.758). After controlling for screen position, the interaction between performer's role and phase remained non-significant (β = -0.30, SE = 0.26, z = -1.16, p = 0.247), indicating that dogs' attention to individuals of different roles did not vary across phases after controlling for spatial biases.

To examine whether dogs' looking time was influenced by performer identity (performer A vs. performer B), we used GLMMs with factors of performer identity (performer A vs. performer B) and performer role (giver vs. receiver). Results revealed no significant interaction in either the Introduction phase (β = 0.27, SE = 0.44, z = 0.62, p = 0.538) or the Ownership Determination phase (β = 0.01, SE = 0.42, z = 0.02, p = 0.982). These results indicate that dogs' preference for the dominant individual cannot be explained by spatial bias or individual performer characteristics.

4.Experiment 2

To rule out potential confounds, we conducted control analyses analogous to those in Experiment 1. Paired comparisons revealed no significant effect of screen side on dogs' looking time (Wilcoxon signed-rank test; 0.16 ± 0.12, 0.13 ± 0.10; V = 498, p = 0.242). In addition, GLMM analyses showed no significant interaction between performer identity and social dominance (β = 0.22, SE = 0.34, z = 0.65, p = 0.513).

Given that the two performers wore different-colored clothing, we further examined whether dogs showed a preference for clothing color, results showed that no significant

effect was found (Wilcoxon signed-rank test; 0.15 ± 0.12, 0.13 ± 0.11; $V = 486$, $p = 0.314$). We also examined whether dogs' looking time was influenced by performer identity (performer A vs. performer B), we used GLMMs with factors of performer identity (performer A vs. performer B) and performer role (dominant vs. subordinate). Results revealed no significant interaction during the Interaction phase ($\beta = 0.22$, SE = 0.34, z = 0.65, $p = 0.513$). These results indicate that dogs' preference for the dominant individual cannot be explained by actors' clothing color, spatial bias or individual performer characteristics.

5.Experiment 3

To rule out potential confounds, we conducted control analyses analogous to those in Experiment 1. Paired comparisons revealed no significant effect of screen side on dogs' looking time (Wilcoxon signed-rank test; 0.18 ± 0.15, 0.22 ± 0.13; $V = 78$, $p = 0.330$).

6.Experiment 4

To rule out potential confounds, we conducted control analyses analogous to those in Experiment 1. Paired comparisons revealed no significant effect of screen side on dogs' looking time (Wilcoxon signed-rank test; 0.10 ± 0.11, 0.19 ± 0.17; $V = 57$, $p = 0.076$).

Experience with Humans Did Not Modulate Dogs' Responses to Human Social Hierarchy

To examine whether dogs' preferences for dominant humans could be explained by individual experience with humans, we analyzed data from all dogs that participated in Experiments 1a and 2 (n = 64). For dogs that participated in both experiments, these values were averaged across experiments.

We employed a forward model selection approach, starting with a null model including only subject ID as a random intercept, and incrementally adding predictors to test their contribution to model fit using likelihood ratio tests. Subsequent models included hierarchy (dominant vs. subordinate) and age as fixed effects, with sex included as a covariate.

GLMM results revealed no significant main effects of age ($\beta = 0.02$, SE = 0.03, z = 0.60, $p = 0.550$), and no significant interaction between hierarchy and age ($\beta = -0.002$, SE = 0.04, z = -0.06, $p = 0.953$), suggesting that accumulate experience with humans did not significantly modulate dogs' responses to human social hierarchy cues.

Divergence Is Not Driven by Differential Attention to Humans and Conspecifics

To examine whether the divergence between ΔHuman and ΔConspecific was driven by differential attention to humans versus conspecifics, we conducted a control analysis on

mean looking-time proportions. For each dog, we separately calculated the average of the total looking-time proportions toward dominant and subordinate human (Experiments 1a and 2) and the average of the total looking-time proportions toward dominant and subordinate dogs (Experiments 3 and 4). Results revealed no significant difference in overall looking-time proportions between human and conspecific videos (Wilcoxon signed-rank test; 0.30 ± 0.06, 0.35 ± 0.15; $V = 11$, $p = 0.383$), indicating that the divergence reflects differential processing of social status rather than differences in attention.

table S1. Owner-Reported Dog Behavior Items and Descriptive Statistics

We conducted a questionnaire survey with dog owners to assess dogs' sensitivity to human social status cues in everyday interactions. The survey included three parts: (1) owner and dog background information, (2) 16 behavior-related items, and (3) four additional items for multi-dog households. Owners responded based on the dog they interacted with most frequently. The full list of items and their descriptive statistics (mean ± standard deviation) is provided below. Responses were collected using a 7-point Likert scale (1 = completely disagree; 7 = completely agree), and items marked with an asterisk (*) were reverse-coded.

1) Owner and dog background information:

Num	Question	Response Format
1	您曾经养过或者目前养着几只狗 Number of dogs currently or previously owned	1 / 2 / 3 or more
2	您的狗狗品种 Dog breed	Open-ended
3	您的狗狗性别 Dog sex	Male / Female
4	您的狗狗年龄 Dog age	Open-ended (in years)
5	您与狗狗的生活时间 Duration living with the dog	<6 months / 6–12 months / 1–3y / 3–6y / >6y

2) Main Behavior Questionnaire Items:

Num	Question	hierarchy-related	Mean ± SD
1	当遇到陌生事物（如新玩具或与它第一次见面的陌生人）时，我的狗会先观察我的反应再决定是否接近。 When encountering unfamiliar objects (e.g., a new toy or a stranger), my dog observes my reaction before deciding whether to approach.	Yes	5.59 ± 1.14
2	面对常来家里的亲戚朋友，狗狗会开心地摇尾巴迎接。 My dog wags its tail happily when meeting familiar guests or relatives.	No	6 ± 1.09
3	当狗狗进食时，我突然靠近它，它会停止吃饭，并看向我。 When I approach my dog suddenly while it is eating, it stops eating and looks at me.	Yes	5.27 ± 1.42
4	如果家里突然发生刺耳的声音，比如打碎盘子等，我的狗狗会立刻跑到我身边寻求庇护。 My dog runs to me for safety when a sudden loud noise (e.g., broken dish) occurs in the house.	Yes	5.73 ± 1.08
5	当我制止狗狗的某一项行为（比如它想要上床或上桌吃饭），用严厉的语气进行制止可以让它更快停止这项行为。 When I stop my dog from doing something (e.g., jumping on the bed), using a stern tone makes it stop faster.	Yes	5.83 ± 1.06
*6	当我带狗狗出去玩的时候，狗狗有时会走几步就停下，我想要让它继续往前走，它并没有听我的话。 When walking outside, my dog sometimes stops and does not obey my instruction to move on.	Yes	3.5 ± 1.83
7	我的狗在犯错后（比如打碎物品），它会表现出回避（比如低头避免直视我）或道歉行为（比如舔我的手、 叼玩具过来想要和我玩）。 After doing something wrong (e.g., breaking something), my dog shows appeasement behaviors (e.g., avoiding eye contact, licking, bringing a toy).	Yes	5.98 ± 0.86
8	如果需要制止狗狗的某一项行为，当我站着并增加手势动作（比如用手指它），并通过语言制止它的行为时，要比我蹲着说更快速地让它听话。 When I stand and use gestures (e.g., pointing) along with verbal commands, my dog responds faster than when I speak while squatting.	Yes	5.54 ± 106
*9	当我在家时，我的狗不会主动跟随我的行动（比如进出房间）。 My dog does not tend to follow me around the house (e.g., into different rooms).	Yes	3.86 ± 1.92
10	当家庭成员发生激烈争吵时，我的狗会表现出不安（如躲藏，吠叫）。 My dog shows signs of anxiety (e.g., hiding, barking) during intense family arguments.	No	5.41 ± 1.41
11	我的狗能识别家庭中的“权威人物”，当该成员发出禁止命令，狗狗会很快停止不被允许的行为（比如一些破坏行为），而对其他家庭成员的相同指令可能不予理睬或需要说很多次它才会听话。 My dog can distinguish the "authority figure" in the household and responds more readily to their commands.	Yes	5.22 ± 1.54
12	带狗狗去宠物医院时，我的狗明显更听从兽医的指令，比在小区或者公园面对陌生人时更听话。 My dog is more obedient to the veterinarian than to unfamiliar people in other contexts (e.g., at the park).	Yes	4.98 ± 1.53
13	打哈欠有“人传狗”现象，当我和狗玩耍的时候打了一个哈欠，发现狗也会打哈欠。 My dog yawns after I yawn, especially during play, indicating contagious yawning.	Yes	5.25 ± 1.37
*14	我的狗无法通过观察家庭成员的日常动作（如拿钥匙、穿外套）预测即将发生的事件（如出门、散步）。 My dog cannot predict events (e.g., going out) by observing routine actions (e.g., picking up keys, putting on coat).	No	3.84 ± 2.09
15	当我对其他狗狗表示关注（如抚摸、赞美）时，我的狗会试图吸引我的注意（如吠叫、挤入我的怀中）。 When I give attention to another dog, my dog tries to draw my attention back (e.g., barking, squeezing in).	No	5.91 ± 0.86
16	当我情绪低落（如伤心、沮丧）时，我的狗会主动靠近我，表现出安慰行为（如轻舔我的手、把头靠在我的腿上、安静地依偎在我身边等。 When I feel sad or upset, my dog approaches and shows comfort behaviors (e.g., licking, resting its head on my leg).	No	6.13 ± 0.77

3) Additional Items for Multi-Dog Households:

Num	Question	Status-related	Mean ± SD
1	我家里的狗狗们，在他们的群体里是有地位之分的，比如有的狗狗会更多表现出身体前倾，向上摇尾巴，有的狗狗更多尾巴耷拉着走。 There is a hierarchy among my dogs, with some showing more dominant postures (e.g., upright tail) and others more submissive (e.g., low tail).	Yes	5.13 ± 1.57
2	我拿出一个玩具和狗玩时，比如抛出一个球，狗狗们的反应也是不同的，其他狗会先观察某一只狗的反应之后再决定要不要做出行动，比如去捡那个球。 When I throw a toy, some dogs wait and observe one particular dog before deciding whether to fetch the toy.	Yes	5.39 ± 1.75
3	当我准备带它们出门时，出门顺序也是不同的，其他狗会先等待某一只狗出门后再出门。 When preparing to go out, the dogs tend to leave in a specific order, often waiting for one dog to go first.	Yes	5.13 ± 1.8
4	当遇到陌生事物时，某只狗优先做出反应之后，其他狗才模仿这只狗的反应行动。 When encountering new things, one dog reacts the first and the others tend to follow that dog’s lead.	Yes	5 ± 1.56

table S2. Expert evaluation of the dog social hierarchy stimuli of Experiment 3.

Professional dog trainers rated the videos of Experiment 3 on a set of items assessing the clarity, naturalness, and ecological validity of the depicted social interactions. The table presents all questionnaire items along with their mean ratings and standard deviations. Responses were collected using a 7-point Likert scale (1 = completely disagree; 7 = strongly agree).

Num	Question	Mean±SD
1	您从事犬类训练工作的年限（年） How many years of experience do you have in dog training?	4.17 ± 3.89
2	在该视频中，两只狗之间存在明显的社会等级差异。 In the video, there is a clear social hierarchy between the two dogs.	4.5 ± 0.76
3	争夺过程中狗的动作和反应是自然的。 The dogs’ actions and reactions during the competition are natural.	5.33 ± 1.70
4	胜负结果（一只狗叼走绳子）符合现实中的互动情况。 The outcome (one dog taking the rope) is consistent with real-life interactions.	5.00 ± 1.53
5	我可以明确判断哪一只狗处于较高社会等级。 I can clearly identify which dog has the higher social status.	4.67 ± 0.75
6	该视频中狗的争夺行为符合现实中的争夺情境。 The competitive behavior shown in the video reflects realistic conflict situations.	5.33 ± 1.70
7	视频中体现的社会等级关系不需要额外解释就能被理解。 The social hierarchy depicted in the video can be understood without additional explanation.	4.33 ± 1.25

table S3. Expert evaluation of the dog social hierarchy stimuli of Experiment 4.

Professional dog trainers rated the videos of Experiment 4 on a set of items assessing the clarity, naturalness, and ecological validity of the depicted social interactions. The table presents all questionnaire items along with their mean ratings and standard deviations. Responses were collected using a 7-point Likert scale (1 = strongly disagree; 7 = strongly agree).

Num	Question	Mean ± SD
1	在该视频中，两只狗之间存在明显的社会等级差异。 In the video, there is a clear social hierarchy between the two dogs.	4.67 ± 0.94
2	争夺过程中狗的动作和反应是自然的。 The dogs' actions and reactions during the competition are natural.	4.5 ± 1.89
3	吼叫、目光直视等行为在现实中符合狗对另一只狗进行威慑的动作特征。 Behaviors such as growling and direct staring are consistent with real-life threatening signals used by dogs toward another dog.	5.67 ± 0.94
4	另一只狗的回避姿态符合服从行为的表现。 The other dog's avoidance posture is consistent with submissive behavior.	4.33 ± 1.49
5	视频中体现的社会等级关系不需要额外解释就能被理解。 The social hierarchy depicted in the video can be understood without additional explanation.	4.5 ± 1.12

Movie S1. (Separate file)

An example stimulus video used in Experiment 1a, illustrating the full sequence of the Introduction, Ownership Determination, and Choice phases.

Movie S2. (Separate file)

An example stimulus video used in Experiment 1b, illustrating the full sequence of the Introduction, Ownership Determination, and Choice phases.

Movie S3. (Separate file)

An example stimulus video used in Experiment 1c, illustrating the full sequence of the Introduction, Ownership Determination, and Choice phases.

Movie S4. (Separate file)

An example stimulus video used in Experiment 2, illustrating the full sequence of the Conversation and Choice phases.

Movie S5. (Separate file)

An example stimulus video used in Experiment 3, illustrating the full sequence of the Ownership Determination phase.

Movie S6. (Separate file)

An example stimulus video used in Experiment 4, illustrating the full sequence of the Conversation phase.

Movie S7. (Separate file)

An example video of the naturalistic interaction task used in Experiment 5, showing the dominance demonstration and the two subsequent choice tests.