The ideal herding dog: personality and behavioral traits predict herding ability

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The value of herding dogs depends on how effectively they perform their job. Improving the rate of success for herding dogs requires understanding which dogs succeed and why. The present study determines whether dog personality and behavioral traits can be used to predict herding performance. We began by replicating Wilson and colleagues (2022), who found that personality traits predict herding ability in Australian kelpies. We asked American owners of herding dogs to complete an online survey about their dog's (n = 335) personality traits, behavioral traits, and herding ability. We grouped related personality traits together in a principal components analysis to create dog personality profiles. Next, we determined whether any dog personality profiles predicted herding ability. We partially replicate Wilson et al.'s (2022) findings, with similar personality profiles predicting herding ability. We then expanded on the previous study by creating a new set of profiles that also included behavioral traits. We found that both personality and behavioral traits predicted herding ability. We propose that herding dog handlers and breeders should focus on key personality and behavioral traits when making decisions about herding dog career paths and training efforts.

Keywords: dogs, herding, working dog, personality, survey

Introduction

Purchasing and training a livestock herding dog is a gamble. Farmers invest time, money, and energy into dogs with no guarantee that the investment will pay off. Dogs that become effective herders are well worth the investment. While the median cost of owning a herding dog is estimated at USD $6,676, the value of a herding dog's labor during its lifetime is roughly USD $34,396 (Arnott et al., 2014). However, roughly one in five dogs do not go on to become successful at their job (Arnott et al., 2014). Dog owners who must decide whether to continue investing resources and training in herding dogs rely on the perceived level of herding ability. The present study aims to inform herding dog owners about which traits they should focus on for career decisions and training to provide the best chances of herding dog success.

An owner's perception of their dog's overall herding *ability* is a mental representation that is built up over time. Each time the dog herds, the owner receives new information to incorporate into their mental representation. That information could tell the owner something about their dog's *personality*. We view personality as a "suite of correlated behaviors expressed either within a given behavioral context or across different contexts" (Sih et al., 2004). Owners also learn about their dogs' herding *behaviors*; the maneuvers and abilities that are specifically useful for herding livestock. The dog's personality and behavior then, in turn, influence the mental representation of the dog's herding ability. In this study, we focus on the relationship between owner's perceptions of their dogs' personality traits, behavioral traits, and herding ability.

Personality

In the world of working dogs, personality traits may be the key to success. For instance, bolder dogs achieved greater success in a working dog trial than less bold dogs (Svartberg,

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2002). Similarly, fear/reactivity predicts dogs' success in a service dog training program (Dollion et al., 2019). The impact of personality on working dog outcomes suggests that personality is a predictor worth exploring in herding dogs.

Dog owners' perceptions also suggest that personality traits play a key role in herding success. When asked to indicate which personality traits are valuable in herding dogs, owners tend to agree that motivation, confidence, friendliness, and trainability are desirable (Early et al., 2019). While each herding environment requires a slightly different skill set, herding dogs all share a similar set of core personality traits (Early et al., 2018). Across contexts, dog owners believe that dog personality traits influence herding ability.

Owners' ratings of their own dog's herding ability support their belief in the power of personality. Studies focused on a single herding breed, the kelpie, suggest that dog personality explains differences in both owner perceptions and dog behavior (McGreevy et al., 2015; Wilson et al., 2022). Personality traits in kelpies predict owner ratings of herding ability (Wilson et al., 2022). Owner perceptions of kelpie personalities also align with observed difference in how the dogs perform on behavioral tests (McGreevy et al., 2015). This validation suggests that owner reports of dog personality not only relate to owners' perceptions of herding ability but may reflect actual behavioral differences displayed by herding dogs.

Behavior

Herding dogs perform specific herding behaviors when moving livestock. These behaviors enable the dogs to manipulate the direction of movement, pace, and dispersion of a group of livestock. Like personality traits, dog owners consider these herding behaviors to be an important factor in a dog's ability to herd (Early et al., 2019).

Owner perceptions of how skilled their dog is at a herding behavior correspond with ratings provided by herding dog experts. When comparing owner ratings of dog behavior to expert ratings, McGreevy et al. (2015) saw fair to moderate agreement. Many herding dog owners train their own dogs, potentially giving them extra insight into the dog's behavior. For example, trainers of explosive detection dogs are even better at predicting training outcomes than behavioral tests are (Konno et al., 2025). Perceptions of herding dog owners about their own dog's behavior may similarly predict herding dog outcomes.

Here, we explore the relationship between working dog personality and behavior and owner perceptions of herding ability. First, we investigate which dog personality traits best predict overall herding ability (Research Question 1) by replicating the methods of Wilson et al. (2022) in a population of American herding dogs. Then, we explore which combinations of dog personality and behavioral traits best predict overall herding ability (Research Question 2).

Methods

Participants

Owners of herding dogs (n = 186) submitted online survey responses for a total of 390 individual dogs. After removing responses that were missing data for all of our study variables (personality traits, behavioral traits, ability rating), we had 373 usable observations. Dog owners met eligibility criteria if they currently owned at least one working herding dog, were at least 19 years old, lived in the United States, and could understand English. We recruited dog owners through a combination of recruitment methods. We posted recruitment materials in Facebook groups dedicated to dog- or farm-related topics and asked individual owners to share recruitment materials with others. We invited owners signed up for the Canine Cognition and Human Interaction Lab registry to participate in the study. For a more targeted recruitment approach, we also attended the 2024 United States National Cattledog Finals in Iowa and invited owners at the event to participate in the study. Lastly, we sent email study invitations to owners who competed in either the 2024 United States National Cattledog Finals or the 2024 United States National Sheepdog Finals and had an email address publicly available online. The pre-registered (https://osf.io/mshq9) sample size was determined by time constraints. Data collection began on September 15, 2024 and terminated on December 31, 2024.

The sample of herding dogs had 188 females (50.4%), 158 males (42.4%), and 27 dogs with no reported sex (7.2%). Dog ages ranged from 0.4 to 18.6 years with a mean of 5.7 years. On average, each participating owner had 3.74 dogs. The sample (n = 373) consisted of purebred border collies (n = 239), Australian shepherds (n = 20), Australian cattle dogs (n = 14), other breeds recognized or unrecognized by the American Kennel Club (n = 89), and mixed breeds (n = 6). The majority of the dogs (n = 231) had some experience with working in both farm and competition settings, while others had farm experience but no competition experience (n = 102) or experience working only in competition settings (n = 12). Dogs with farm experience had an average of 2.5 years of experience. Dogs with competition experience had an average of 2.4 years- and 16.0 trials-worth of experience.

Instruments

We built and distributed online surveys through REDCap hosted at University of Nebraska-Lincoln (Harris et al., 2019, 2009).

Herding Dog Assessment Form-Personality. The present study directly reproduced the Herding Dog Assessment Form-Personality (HDAF-P) (Wilson et al., 2022) to capture personality traits of particular interest in herding dogs. This instrument combines and modifies items from the Monash Canine Personality Questionnaire-Revised (Ley et al., 2009), the Herding Trait Characterization (Arvelius et al., 2013), and the Dog Impulsivity Assessment Scale (Wright et al., 2012). The Herding Dog Assessment Form-Personality asks the respondent to indicate how well a specific personality trait (e.g. confidence) describes their dog. Each item is on a 5-point Likert-type scale (1 = very low, 2 = low, 3 = average, 4 = high, 5 = very high), plus a sixth option of "I don't know." The instrument includes 17 personality items and one rating of "overall ability."

Livestock Working (Herding) Dog Assessment Form (adapted). We used an adapted version of the Livestock Working (Herding) Dog Assessment Form (LWHDAF) (McGreevy et al., 2015), a large-scale survey of working dogs on farms in Australia developed as part of the University of Sydney Farm Dog Project. The instrument includes one section on personality traits, one section on working maneuvers (behaviors) and herding traits, and one section on training. The section on working maneuvers and herding traits was selected for adaptation and use in the present study. We will refer to the herding maneuvers and traits as "behavioral traits" for the rest of the article. Items on this section of the original Livestock Working (Herding) Dog Assessment Form use a 5-point Likert-style answering scheme (1 = Extremely poor, 2 = Poor, 3 = Average, 4 = Good, 5 = Excellent). We expanded the answer options to include a sixth "I don't know" option to better align with the answer options from the Herding Dog Assessment Form-Personality (see previous section). For each item, we included a brief narrative description of the behavioral trait drawn from the definitions provided by McGreevy et al. (2015). For example, force was described as "pressure applied by the dog in order to move livestock." Item descriptions were revised based on feedback from herding dog owners.

Analyses

This study's methods and analyses were pre-registered at https://osf.io/mshq9/.

Research Question 1. Our first research question asks which personality in dogs are associated with owner-reported overall herding ability. We evaluated the association between personality traits and overall herding ability by replicating Wilson et al.'s (2022) correlations between dog personality traits and owner ratings of overall herding ability. A principal components analysis (PCA) identified which personality traits clustered together and how each component impacted the variance in the sample. Components that fell above the inflection point on a scree plot were selected for use. We additionally ran a parallel analysis (Horn, 1965) to support the selection of components as predictors. We applied the weightings from each component to dog's scores on each personality item to create new weighted scores. We then summed the weighted scores across the personality items for each dog, producing a single weighted score for each dog. We repeated the process for each selected component so that each dog had one score per component. We then used the weighted scores for each component as variables in our regression analyses. We used model selection to determine which combination of PCA components and fixed effects variables would be included in the best-fit linear mixed regression for predicting owner-rated overall herding ability. Fixed effects included the identified components as well as dog sex, gonad removal, age, and work environment. Following Wilson et al., we first performed a series of univariate fixed effects regressions with owner included as a random effect. Each potential predictor variable (including the components) was run in its own linear regression with overall ability as the outcome variable (e.g. `overall_ability ~ dog_age + (1|owner_id)` or `overall_ability ~ comp1 + (1|owner_id)`). A reverse stepwise method based on Akaike Information Criterion (AIC) was used for model selection. We report Bayes factors for the correlations and regression model; however, we follow Wilson et al.'s (2022) approach by drawing on p-values and AIC for interpretations of the data.

Research Question 2. Our second research question asks which combination of personality and behavioral traits in dogs are associated with owner-reported overall herding ability. We performed a second set of analyses that incorporated behavioral traits (in addition to personality traits) as predictors of overall herding ability. We used a principal components analysis of both the personality and behavioral traits to identify principal components for the new model. We conducted a linear mixed regression with the components of the principal components analysis as predictors of overall herding ability. We selected components to include in the model as predictors based on a scree plot and supported by a parallel analysis. We created weighted scores from each component to use as predictors in the model. Any other fixed effects (e.g., dog sex) that were included in the final selected model for the replication were automatically included in the new models. Dog (individual) and owner were considered as random effects and tested for inclusion in the best-fit model. We based the previous model selection on AIC to replicate Wilson et al.'s (2022) selection methods. For the model including both personality and behavioral traits as predictors, we chose to perform model selection based on Bayes factors calculated from Bayes Information Criteria (BIC). Bayes factors provide the

amount of evidence for the alternative model relative to a reference model (Wagenmakers et al., 2010; Wagenmakers, 2007). First, we used an intercept-only model as the reference model for the random effects models. Models containing dog, owner, and dog nested in owner, were compared against the reference model. A Bayes factor of at least 3 was required for the reference model to be rejected in favor of the alternative model. If more than one model exceeds a Bayes factor of 3, then the model with the greatest Bayes factor was chosen. If no random effects model had a Bayes factor of at least 3 when tested against the intercept-only, then the intercept-only model was selected as the reference model for fixed effect model selection. To assess the fixed effects, we assigned a new reference model that included the random effect determined above and all fixed effects from the final personality-only model `(overall_ability ~ fixed_effects_fromPersonality + random_effects)`. The alternative models included the reference model plus every possible combination of the selected PCA components. For example, one fixed effects model was `(overall_ability ~ fixed_effects_fromPersonality + comp1 + random_effects)` and another was `(overall_ability ~ fixed_effects_fromPersonality + comp1 + comp2 + random_effects)`. These fixed effects models were each compared against the reference model including only the chosen random effects (or intercept-only model) and the fixed effects from the personality-only model. We again used the Bayes factor criteria outlined above to select the final best fit model and based our interpretations on the Bayes factor of the model.

Outliers and Exclusions. Following Wilson et al.'s data analysis plan, both missing data and "I don't know" responses were treated as missing data. Per the pre-registered analysis plan, we excluded missing data at the individual item level. Any observations missing data for all of the the predictor variables and the outcome variable (ability rating) were excluded from analyses. Following these methods, 21 observations were excluded from the personality-only regression (n = 369) and 17 were excluded from the personality and behavior regression (n = 373). No outliers were defined for this study.

Analysis software. We used R (Version 4.5.1; R Core Team, 2024) and the R-packages *cocoon* (Version 0.2.0; Stevens, 2025), *easystats* (Version 0.7.5; Lüdecke et al., 2022), *flextable* (Version 0.9.10; Gohel & Skintzos, 2024), *ggcorrplot* (Version 0.1.4.1; Kassambara, 2023), *gt* (Version 1.0.0; Iannone et al., 2024; Sjoberg et al., 2021), *gtsummary* (Version 2.4.0; Sjoberg et al., 2021), *knitr* (Version 1.50; Xie, 2015), *lme4* (Version 1.1.37; Bates et al., 2015), *papaja* (Version 0.1.3; Aust & Barth, 2024), *psych* (Version 2.5.6; William Revelle, 2025), *rempsyc* (Version 0.1.9; Thériault, 2023) and *tidyverse* (Version 2.0.0; Wickham et al., 2019) for our analyses. The manuscript was created using *rmarkdown* (Version 2.29, Xie et al., 2018) and *papaja* (Version 0.1.3, Aust & Barth, 2024). Data, analysis scripts, and reproducible research materials are available at the Open Science Framework (https://osf.io/3p5vx/). Additional tables are available in the Supplementary Materials.

Results

Personality Traits

The distribution of ratings across most personality traits was skewed toward higher values (Table S1). However, patience (skewness = 0.1), timidness (0.6), hyperactivity (0.4), nervousness (0.8), and impulsiveness (0.2) were all skewed toward lower values. Mean personality trait scores ranged from 2.0 (calmness) to 4.3 (trainability). We transformed all personality traits into centered z-scores for the remaining analyses.

We examined the correlations between the personality traits using Kendall's rank correlation coefficient (τ) (Figure 1). We observed associations between the personality traits of friendliness and sociability ($\tau = 0.84$, $p < 0.001$), confidence and boldness ($\tau = 0.69$, $p < 0.001$), and calmness and patience ($\tau = 0.63$, $p < 0.001$). Overall herding ability was associated with both confidence ($\tau = 0.45$, $p < 0.001$) and intelligence ($\tau = 0.44$, $p < 0.001$).

A Kaiser-Meyer-Olkin Test for Sampling Adequacy (Kaiser, 1974) returned a measure of sampling adequacy of 0.82, surpassing the suggested minimum score of 0.5 required for factor analysis (Hoelzle & Meyer, 2013). We performed a principal components analysis on the personality traits to summarize the variance in the sample. The principal components analysis reduced the 17 personality traits into a series of components that described a portion of the variance in the sample. Based on the scree plot of the components and supported by evidence from Horn's parallel analysis, we selected the first four components which collectively describe 66.3% of the variance in the sample (Figure 2).

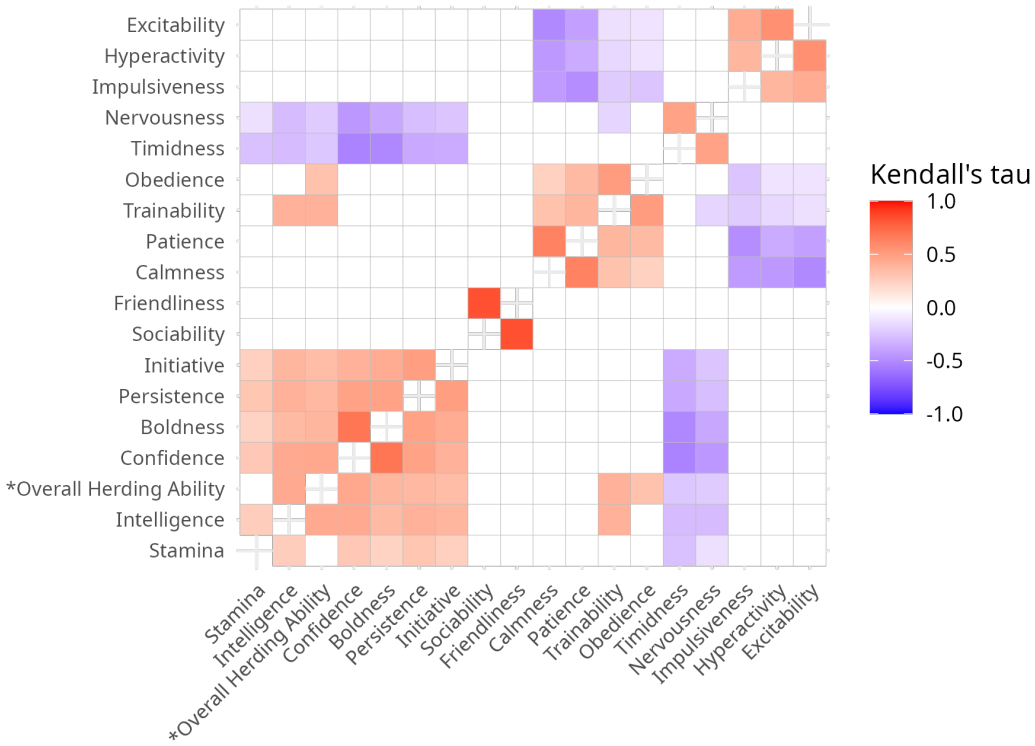

Figure 1. Personality trait correlations. Kendall's rank correlations for owner ratings of dog personality traits and overall herding ability (highlighted with an *). Only associations with $p < 0.05$ are included in the matrix.

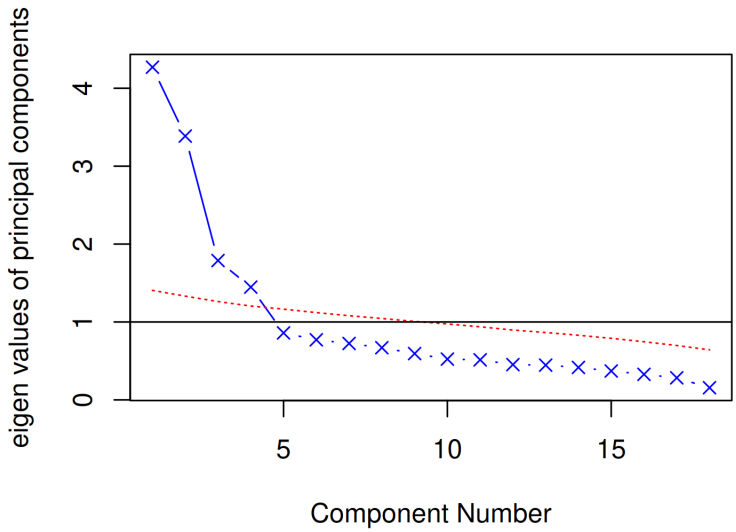

Figure 2. Scree plot of personality traits. Blue exes indicate observed eigenvalues of each component from the principal components analysis. The red dashed line represents simulated eigenvalues from the 95th percentile of a random correlation matrix of the same size as the observed.

Table 1
Loadings of four selected personality components

Personality trait	Confident[a]	Active[a]	Unsocial[a]	Willful[a]
Confidence	**0.40**	0.10	0.06	0.16
Calmness	0.14	**-0.40**	0.10	0.07
Intelligence	**0.33**	-0.01	0.10	-0.22
Trainability	0.22	-0.24	-0.01	**-0.38**
Boldness	**0.37**	0.17	0.03	0.19
Patience	0.14	**-0.40**	0.07	-0.11
Timidness	**-0.32**	-0.12	0.01	**-0.31**
Persistence	**0.33**	0.15	0.08	-0.10
Hyperactivity	-0.03	**0.36**	-0.13	**-0.33**
Initiative	**0.30**	0.16	0.03	-0.07
Excitability	0.02	**0.39**	-0.12	-0.23
Obedience	0.17	-0.23	-0.03	**-0.50**
Nervousness	**-0.31**	0.08	0.03	**-0.37**
Impulsiveness	-0.02	**0.39**	-0.08	-0.04
Stamina	0.23	0.08	0.01	-0.26
Sociability	0.10	-0.10	**-0.68**	0.05
Friendliness	0.07	-0.13	**-0.68**	0.04

[a]Bold values are loadings greater than/equal to 0.3 or less than/equal to -0.3.

The four personality components can be described by the traits weighted the heaviest (magnitude > 0.3) within each component (Table 1). Personality component 1 captures 24% of the total variance and includes high levels of confidence, boldness, intelligence, persistence, and initiative with low levels of timidness and nervousness. We refer to this personal profile as *confident*. Personality component 2 describes 22% of the variance and is characterized by positive representations of hyperactivity, excitability, and impulsiveness and negative representations of calmness and patience (*active* profile). Personality component 3 (11%) contained negative effects of sociability and friendliness (*unsocial* profile). Lastly, personality component 4 (9%) contained negative weightings on trainability, obedience, nervousness, and stamina (*willful* profile).

We ran a series of univariate linear regressions to consider the effect of fixed variables on overall herding ability. Following Wilson et al. (2022), we considered dog sex, gonad removal, age, and work environment as fixed effects in addition to the four PCA components. The work environment variable describes whether dogs have experience working in farm and/or competition settings. Within farm settings, owners indicated whether their dog had experience working in paddock (large spaces), yard (small spaces), utility (large and small), droving (long distances), or trucks (transporting). For each univariate regression we included one of the possible fixed effects along with owner as a random effect. The univariate regressions suggest that the *confident* personality profile (β = 0.32, SE = 0.02, t = 15.93) and *willful* personality profile (β = -0.14, SE = 0.04, t = -3.27) were both associated with differences in overall herding ability. The *confident* profile was associated with higher ratings on herding ability, while the *willful* profile was associated with lower ability ratings. For non-personality fixed effects, we see that intact dogs (vs. spayed/neutered) were rated more highly in herding ability (β = -0.52, SE = 0.11, t = -4.75). The yard environment was the only working environment not associated with overall herding ability. We combined the predictors of interest in a linear mixed regression model to predict overall herding ability. Replicating Wilson et al. (2022) we used a reverse stepwise method to find the best fit model based on Akaike Information Criterion (AIC). Starting from a model including all possible fixed effects and owner as a random effect, we progressively removed predictors to achieve the lowest possible AIC. The best fit model determined by this method included sex, age, gonad removal status, utility work environment, trial work environment, *confident* personality profile, and *willful* personality profile as predictors of overall herding ability (Table S2).

Personality and Behavioral Traits

Building on the associations between personality traits and overall herding ability, we added behavioral traits as a new set of predictors (Table S3).

Mean behavioral trait scores ranged from 3.7 (force) to 4.3 (cover). All of the behavioral traits skewed toward higher values. Natural ability had the greatest skewness (-0.3) of all the traits. Notably, back, bark, and bite were excluded from analyses due to a large amount (n > 50) of missing data for each trait.

We conducted Kendall's rank correlations between all 28 personality and behavioral traits (Figure 3). Among the 11 behavioral traits, correlation coefficients (τ) ranged from 0.13 to 1. Natural herding ability correlated with the majority of the personality and behavioral traits and overall herding ability (τ = 0.64, $p < 0.001$). Also, overall herding ability was correlated with the majority of the behavioral traits. Cast and gather were also strongly associated (τ = 0.54, $p < 0.001$). Correlations between personality traits and behavioral traits were weaker than among personality traits or behavioral traits. Nonetheless, we observed associations between force (behavior) and confidence (personality) (τ = 0.48, $p < 0.001$), force and boldness (personality) (τ = 0.47, $p < 0.001$), and anticipation (behavior) and intelligence (personality) (τ = 0.44, $p < 0.001$). Natural herding ability was also strongly correlated with the personality traits intelligence (τ = 0.46, $p < 0.001$) and confidence (τ = 0.43, $p < 0.001$).

A Kaiser-Meyer-Olkin Test for Sampling Adequacy on the combined personality and behavioral traits yielded a score of 0.9, so we proceeded with the Principal Components Analysis on the combined personality and behavioral traits. Based on the scree plot, the first five components had eigenvalues greater than one. However, Horn's parallel analysis showed that the fifth component did not offer additional explanatory power when compared to the simulated eigenvalues generated from a random matrix (Figure 4). We selected only the first four components which collectively describe 56.8% of the variance in the sample.

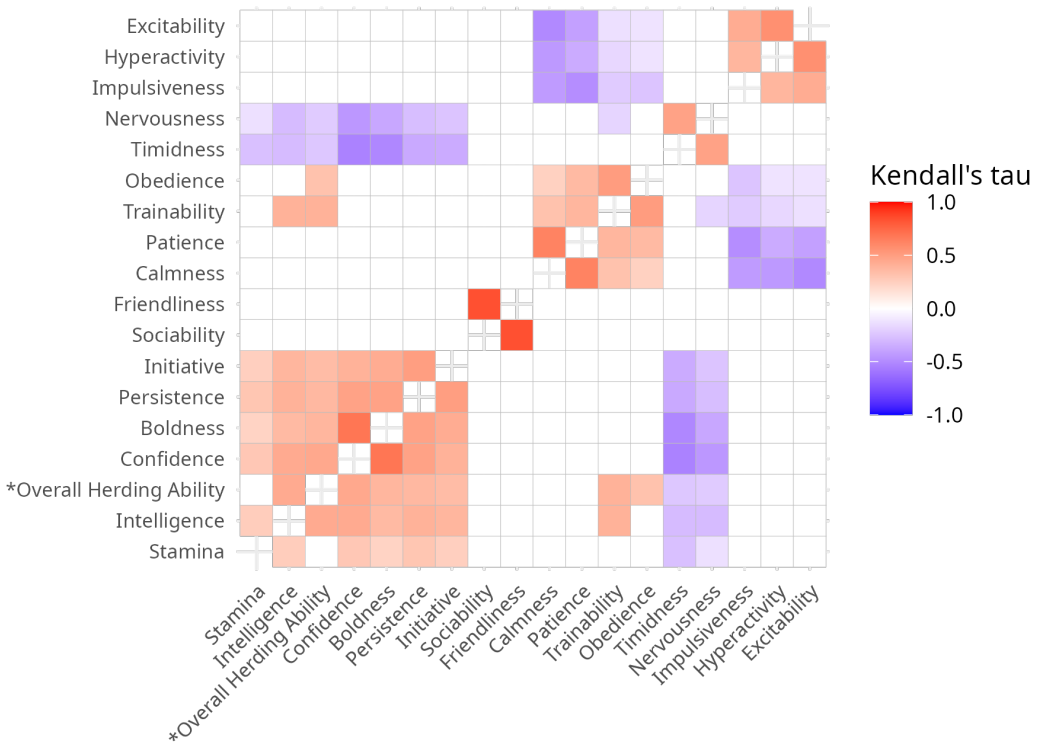

Figure 3. Personality and behavioral trait correlations. Kendall's rank correlations for owner ratings of dog personality and behavioral traits and overall herding ability (highlighted with an *). The behavioral traits are Cast, Gather, Force, Cover, Head, Hold, Balance, Break, Eye, Anticipation, and Natural. All other traits are personality traits. Only associations with $p < 0.05$ are included in the matrix.

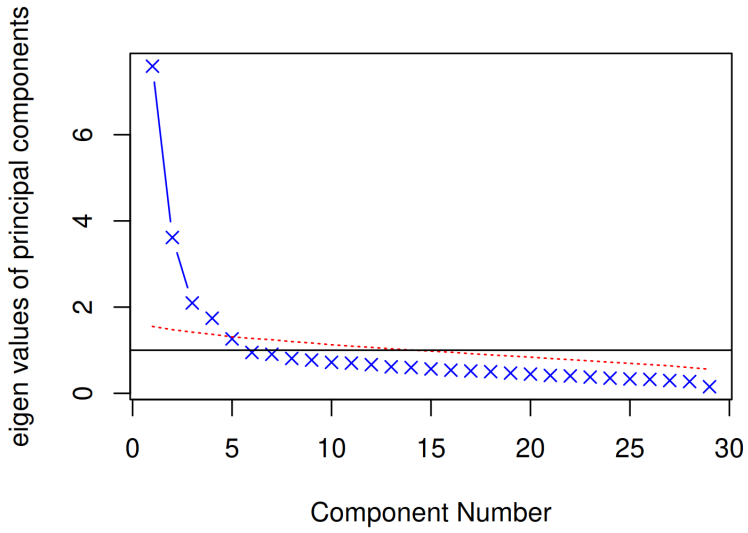

Figure 4. Scree plot of personality and behavioral traits. Blue exes indicate observed eigenvalues of each component from the principal components analysis. The red dashed line represents simulated eigenvalues from the 95th percentile of a random correlation matrix of the same size as the observed.

Table 2
Loadings of four selected personality and behavior components

Trait	Proactive[a]	Active[a]	Fearful[a]	Social[a]
Cast[b]	0.22	0.07	0.13	0.17
Gather[b]	0.25	0.08	0.17	0.09
Force[b]	0.21	-0.16	-0.04	-0.10
Cover[b]	0.25	0.01	0.17	0.06
Head[b]	0.22	-0.10	0.07	-0.01
Hold[b]	0.23	0.04	0.19	-0.03
Balance[b]	0.21	0.13	0.24	0.09
Break[b]	0.25	0.05	0.12	0.02
Eye[b]	0.18	0.01	0.20	0.11
Anticipation[b]	0.27	-0.01	0.10	0.04
Natural[b]	0.28	0.00	0.14	0.04
Confidence[c]	0.25	-0.16	-0.24	-0.15
Calmness[c]	0.13	**0.36**	-0.10	-0.15
Intelligence[c]	0.23	-0.03	-0.04	-0.05
Trainability[c]	0.16	0.20	-0.08	0.07
Boldness[c]	0.21	-0.23	-0.26	-0.14
Patience[c]	0.13	**0.36**	-0.06	-0.07
Timidness[c]	-0.16	0.18	**0.36**	0.16
Persistence[c]	0.22	-0.19	-0.04	-0.04
Hyperactivity[c]	-0.02	**-0.33**	0.17	0.27
Initiative[c]	0.20	-0.19	-0.05	0.00
Excitability[c]	-0.02	**-0.37**	0.05	0.20
Obedience[c]	0.14	0.20	-0.02	0.12
Nervousness[c]	-0.16	-0.01	**0.42**	0.18
Impulsiveness[c]	-0.04	**-0.37**	0.09	0.13
Stamina[c]	0.13	-0.10	-0.06	0.02
Sociability[c]	0.04	0.08	**-0.37**	**0.56**
Friendliness[c]	0.03	0.11	**-0.33**	**0.57**

[a]Bold values are loadings greater than/equal to 0.3 or less than/equal to -0.3.
[b]Behavioral traits
[c]Personality traits

Personality and behavior component 1 described 28% of the variance and was characterized by moderate weighting (magnitude > 0.3) across multiple traits (Table 2). Behavioral traits gather, cover, break, anticipation, and natural ability were all positively represented (> 0.25) along with the personality trait confidence. A dog fitting this trait profile might be described as *proactive*, with a strong ability to read and respond to the livestock. Personality and behavior component 2 (14%) focused on stronger (magnitude > 0.3) positive representations of hyperactivity, excitability, and impulsiveness paired with negative representations of calmness and patience. This is the same *active* trait profile found in the previous personality analysis. Personality and behavior component 3 (8%) had strong (magnitude > 0.3) positive representations of timidness and nervousness and negative representations of friendliness and sociability (*fearful* profile). Lastly, personality and behavior component 4 (6%) had strong (magnitude > 0.5) positive representations of sociability and friendliness (*social* profile).

We replicated the previously described regression analysis with the four personality and behavior components as predictors. For this analysis, we performed model selection based on Bayes factors calculated from Bayes Information Criteria (BIC) (Wagenmakers et al., 2010; Wagenmakers, 2007). First, we selected the best fitting random effects model based on Bayes factor. We compared models including dog, owner, and both dog and owner as random effects. Each potential random effects model was tested against the intercept-only reference model. None of the random effects models achieved a Bayes factor greater than 3, so we did not include random effects in our model. We then created a reference model for the fixed effects. The reference model included only the fixed effects that were present in the final best-fit model for personality `(overall_ability ~ dog_spay + dog_farm_utility + dog_trial)`. We did not include any PCA components in the reference model. The alternative models included the reference model plus every possible combination (n = 15) of the four selected personality and behavior components. For example, one fixed effects model was `(overall_ability ~ dog_spay + dog_farm_utility + dog_trial + comp1)` and another was `(overall_ability ~ dog_spay + dog_farm_utility + dog_trial + comp2 + comp3)`. These fixed effects models were each compared against the reference model and we again used the Bayes factors to select the final best fit model. In the end, the best fit model with the highest Bayes factor when compared against the reference model included gonad removal status, utility work environment, trial work environment, and personality profiles *proactive* and *active* ($BF_{10} = 3.0\times10^{55}$) (Table S4).

The inclusion of the *proactive* and *active* profiles indicates that both personality and behavioral traits are associated with overall herding ability. From the included profiles we see that overall herding ability was greater in dogs with higher levels of natural ability and confidence, and more skill at anticipation and many of the more concrete herding behaviors (e.g., cover, break, gather, etc.). On the other hand, the inclusion of the *active* profile indicates some positive effects of more excitability, impulsiveness, and hyperactivity and potential negative effects of greater patience and calmness.

Exploratory Analyses

In addition to the pre-registered analyses, we performed a series of exploratory post hoc analyses.

We investigated the relationship between herding environment and herding ability by directly comparing dogs with different herding experiences. Dogs who had experience herding in both farm and trial settings (n = 231) received the highest ability ratings on average (M = 3.8). Dogs with only farm experience (n = 102) had the next highest mean rating (M = 3.5), followed by dogs with only trial experience (n = 12, M = 3.4). Mean ability rating differed between the dogs with only farm experience and with experience in both farm and trial settings (M = 0.4, 95% CI [0.2, 0.6], $t(203.7) = 3.3$, p = .001). We did not statistically compare the trial-only group to the other groups due to the limited sample size (n = 12).

Next, we explored how the amount of herding experience a dog had related to ability rating. For dogs with trial experience, the number of trials a dog participated in was correlated with ability rating (τ = 0.20 p = 0.002). The number of years a dog had participated in trials, however, was not correlated with ability. A linear regression showed that number of trials competed in predicted herding ability (β = 0.01, SE = 0.00, t = 3.73, $p < 0.001$). This result persisted even when holding number of years participating in trials constant. We then calculated a ratio of trials participated in per year for each dog. This ratio also predicted herding ability in a linear regression (β = 0.05, SE = 0.01, t = 4.26, $p <$ 0.001).

Discussion

In this study, we replicated and built upon previous literature addressing the complex associations between dogs personality, behavior, and success at herding.

The first research question investigated which personality traits in dogs are associated with owner-reported overall herding ability. We found that the personality traits in our sample of dogs clustered into four personality profiles (Table 1). The personality profiles in our sample are similar to those reported by Wilson et al. (2022). Our *confident*

personality profile, which describes the largest portion of the variance in our sample, emphasizes intelligence, confidence, boldness, and initiative (Figure 2). Wilson et al.'s (2022) first component also heavily weights intelligence, but focuses more on calmness and patience. Our *active*, *willful*, and *unsocial* personality profiles similarly align with the traits included in Wilson and colleagues' second, third, and fourth (respectively) personality components.

Our best-fit model for predicting herding ability rating included both the *confident* and *willful* personality profiles. The *confident* profile describes a dog that is intelligent and does their job without hesitation. Dogs with the *willful* personality profile are low on traits related to ease of training, energy level, and fear. Dogs that fit the *confident* profile and do not fit the *willful* profile have greater herding ability ratings. Both profiles include low ratings on fear-related traits. A dog matching that description might either be seen as brave (positive) or reckless (negative). The role of fear in both the *confident* and *willful* personality profiles shows that individual personality traits are less informative than whole personality profiles when predicting herding ability.

Multiple non-personality variables emerged in the best-fit model for predicting herding ability. Younger dogs were rated more highly for their herding ability than older dogs in this sample. The age range in our study sample was wide, with the youngest dog being 0.4 years and the oldest dog being 18.6. While young dogs may benefit from high energy and enthusiasm, they lack the experience of older dogs. We used a multiple linear regression to focus on the role of personality, but the inverted U-shaped curve from a quadratic regression might better fit the age-ability relationship. Male dogs with intact gonads were also more likely to be rated highly for herding ability. Dogs that work in utility settings (a combination of large and small spaces) and compete in herding trials were more likely to be rated highly. We dig deeper into the role of herding environment in our exploratory analyses.

When it comes to the predictive power of dog personality traits, we partially replicate Wilson et al. (2022). While their best-fit regression model included four PCA components, our model only included two. The traits most heavily weighted in the *confident* and *willful* profiles are also included in Wilson et al.'s personality components. Both our models included sex as well as utility work environment as predictors. Their model also included droving, a working environment that is extremely uncommon in the United States. We did not include droving in our survey. Our fixed effects additionally included trial work, age, and gonad removal. Altogether, our findings suggest that personality traits do have predictive power for overall herding ability.

The second research question asked whether a combination of personality and behavioral traits could predict herding ability. We found that a combination of both personality and behavioral traits significantly predict overall herding ability. Four personality and behavioral trait profiles emerged: *proactive*, *active*, *fearful*, and *social* (Table 2). The *proactive* and *active* trait profiles both appeared in the best-fit regression model predicting herding ability. The herding behaviors in the *proactive* profile collectively paint a picture of a dog that is skilled at reading and anticipating the actions of livestock. The *active* profile, on the other hand, describes a hyperactive dog that is impulsive and excitable. Both trait profiles predicted higher herding ability ratings.

Our exploratory analyses focused in on the relationship between a dog's life experiences and their herding ability. We found that dogs with experience working in both farm and trial settings had significantly higher ability ratings than those with only farm experience. Our sample did not have a large enough group of dogs with trial-only experience to statistically compare with the other two groups. However, the mean ability rating of dogs that only had trial experience was the lowest of the three groups.

Approaching experience from a different angle, we explored the relationship between amount of trial experience and herding ability. Dogs who competed in more trials were given higher ability ratings than those who competed in fewer trials. In a linear regression model predicting herding ability, we found that number of trials predicted herding ability even while holding number of years competing in trials constant. We interpret this to suggest that dogs who compete in herding trials more frequently may have greater herding abilities than those who compete in trials on a less frequent basis. Following this line of thinking, we calculated a ratio of trials per year for each dog and input it as a predictor of herding ability in a linear regression. The number of trials a dog competes in per year is a significant predictor of ability rating. Dogs who work on farms and also frequently compete in herding trials have the highest ratings for overall herding ability. We cannot say whether there is a causal relationship between herding environment/experience and ability rating based on the evidence provided by this study. It may be the case that dogs with higher ability in a farm working environment are more likely to be entered into trials. And dogs who perform well may be entered in trials more frequently. On the other hand, frequent participation in trials may in some way improve herding ability. Future studies could systematically examine the effect of herding environment on herding ability by collecting longitudinal data.

Limitations

Our findings are limited by the cross-sectional design of this study. Though our sample represented a wide geographical range within the United States, we cannot generalize to

herding dogs living in other countries. Similarly, our sample predominantly consists of border collies, limiting our ability to generalize across herding breeds. The present study focuses on dog owner perceptions of dog traits and abilities. There is evidence to support the validity of owner report for dog personality and behavioral traits. However, we do not claim that owner perceptions are accurate representations of some underlying "true" level of herding ability. The construct that we are operationalizing with owner ratings of herding ability is a human perception of herding. Importantly, these perceptions are what drive decision making about herding dog populations. Though we did not measure ability directly, measuring perceptions is useful since these perceptions inform decisions about which dogs are selected and bred for herding, as well as how they are trained.

Implications

Ultimately, our goal is to improve the success rates of herding dogs. This study can inform decision making and training for the success of adult herding dogs in the United States. Prior literature suggests that dog personality and behavior are influenced by a combination of genetics and environment (Fratkin et al., 2013; Salonen et al., 2023; Strandberg et al., 2025). The present study focuses on environmental factors.

Interventions for herding dog success should focus on traits that are susceptible to environmental interventions. For instance, exposure to fearful stimuli in puppyhood can influence traits related to fear/reactivity in adults (Dollion et al., 2019; Mai et al., 2021; Rooney et al., 2016). Persistence, another personality trait which appears to be positively associated with herding success, may be increased through training (Cavalli et al., 2022). Dogs that receive more training also tend to be rated as more trainable (Kubinyi et al., 2009). While this relationship is not necessarily causal or unidirectional, Kubinyi and colleagues found that the dogs that were rated the lowest on trainability in their sample were dogs over the age of three who had received no professional training. This provides initial evidence that training itself may increase the personality trait of trainability in dogs. Training for herding dogs already focuses on herding behaviors, but could more intentionally target the behaviors identified in this study to make the most of training efforts. Additionally, training dogs to work in different environments could be beneficial. Dogs who frequently participate in herding trials may practice or learn new skills that benefit their overall herding ability. Taken together, this evidence suggests that training may be able to increase levels of personality and behavioral traits that are associated with herding ability in dogs.

Conclusions

Herding dogs play a critical role in the management of livestock worldwide. Yet we know little about the factors underlying their herding performance. In this study, we have replicated previous work in a new sample of herding dogs and expanded the narrow body of knowledge on herding dogs. The personality and behavioral traits identified in this study may be used to inform dog owner's decisions about dog career paths and training efforts for herding dog success.

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