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Cool, cooperative and competitive – Can we breed for a temperament that promotes performance in Standardbred trotters?

Paulina Berglund [a,*], Marina Solé [a], Maria Wilbe [a], Gabriella Lindgren [a,b], Susanne Eriksson [a]

[a] Swedish University of Agricultural Sciences, Department of Animal Biosciences, P.O. Box 7023, Uppsala 75007, Sweden
[b] KU Leuven, Center for Animal Breeding and Genetics, Department of Biosystems, Kasteelpark Arenberg 30, Leuven 3001, Belgium

A R T I C L E   I N F O

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A B S T R A C T

Physical and mental ability to compete is needed for trotters to be successful in harness racing. The ability to cope with a competition atmosphere and an elite training environment also influences the horses' welfare, career longevity, as well as the safety of the humans handling them. Standardbred trotters have long been bred to be well suited for the sport, but there is still temperament variation in the population. Therefore, the aim of this study was to investigate if there is an interrelationship between temperament traits and trotting performance in Standardbred trotters. Temperament traits in competition situations were assessed for Standardbred trotters through a survey aimed at Swedish and Norwegian trainers from 2019 to 2021. The trainers were asked to rate how often the horses expressed different temperament traits on a linear 7-point scale. A total of 12 temperament traits were included in a factor analysis. Thereafter, factor scores for the three formed factors F_Anxiousness, F_Agreeableness, and F_Excitability, were calculated and further analyzed for a total of 366 horses from 120 trainers. Seven generations of pedigree data as well as routinely recorded performance traits for more than 30 thousand horses were added, and (co)variance components were estimated in bivariate linear animal models. Low to moderate heritability estimates were found for all temperament and performance traits, ranging from 0.13 for F_Anxiousness to 0.50 for F_Excitability. F_Agreeableness was found to be positively correlated with all performance traits, except for with Best racing time for which lower values are desired. The opposite pattern was seen for F_Anxiousness that was negatively correlated with all performance traits, except for Best racing time. A similar, but less strong, tendency was seen for F_Excitability. The correlations between factors for temperament and performance traits showed a consistent pattern, in spite of high standard errors especially for the genetic correlations. The results indicate a genetic variation in temperament traits, and favorable associations between temperament and performance in Standardbred trotters. These promising findings need to be confirmed in a larger dataset with temperament trait observations but point out the possibility to breed for agreeableness and improved performance in trotters without increased anxiousness. In other words, it seems possible to breed cool, cooperative and competitive horses to improve welfare and performance in trotters.

1. Introduction

Besides physical ability to perform, horses need a suitable mentality to be competitive in harness racing. The ability to cope with a competition atmosphere and the high-pressure training environment also influences the horses' welfare, career longevity as well as the safety of the humans handling them (Holtby et al., 2023). It is thus not surprising that the breeding goal for Swedish Standardbred trotters emphasizes competitive horses that are well suited for the harness racing sport, that are easy to handle, with a good temperament for competitions, and a strong will to win (Svensk Travsport, 2024). Whereas information about trotting performance is routinely recorded and utilized in the genetic evaluation (Árnason, 1999), temperament traits and their correlations with performance have been much less studied in trotters. Cape and Van Vleck (1981) estimated a heritability of 0.10 for trainability in a small data set of 159 young Standardbreds, but otherwise research on temperament has focused on other breeds. König von Borstel (2013) showed in a review that heritability estimates for various temperament traits in horses ranged from low to moderate. Studies on the association between temperament traits and competition performance in horses are

* Corresponding author.
E-mail address: paulina.berglund@slu.se (P. Berglund).

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limited, with a few exceptions such as between temperament measures and jumping performance by Lansade et al. (2016) and Bonow et al. (2024), and a routinely recorded temperament trait in Icelandic horses and performance in gait competitions (Albertsdóttir et al., 2008).

Accurate phenotyping of temperament traits is challenging due to their subjective and complex nature. Different methods, such as behavioral assessments (e.g. novel object tests), tests where trained judges rate behaviors, physiological measures (e.g., cortisol levels), and owner-reported surveys, are employed to evaluate temperament (König von Borstel, 2013). A challenge for genetic studies of temperament in competition horses is to collect information on a sufficiently large number of horses in a relevant context, without disturbing the performance of the horse or its driver/rider. Whereas a survey can be criticized for providing subjective assessments by different respondents, it holds the advantages of capturing a wider picture of the horses' temperament, as the respondents have observed the horses in different situations over time (Momozawa et al., 2005).

A few previous studies on horses have used surveys to collect information on behavior or temperament of horses and examined them using principal component or factor analysis. For example, Sigurðardóttir et al. (2017) collected answers from 339 horses to a survey by horse trainers and owners, and in a subsequent factor analysis on the answers she found a factor for nerve strength and another for cooperation. From a factor analysis/PCA of survey answers by caretakers about behavior in 216 Tennessee Walking horses, Staiger et al. (2016) derived four factors: anxious, tractable, agonistic and gregarious. Also, Olsen and Klemetsdal (2017) used a survey followed by a factor analysis to analyze temperament traits in 1018 Norwegian horses of different breeds. They found five factors for temperament in all breeds: anxiousness, agreeableness, conscientiousness, openness and dominance, and the additional factor excitability in Coldblooded trotters only. The level of excitement was previously found to be the most obvious breed difference among the factors constructed for temperament traits based on answers to the standardized Horse Personality Questionnaire in a study of British horses by Lloyd et al. (2008).

To learn more about advantageous temperament traits for trotting performance, we used a survey to collect information about Standardbred trotters racing in Sweden and Norway. This information was combined with routinely recorded performance records. The aim was to study the interrelationship between temperament traits using a factor analysis, to estimate genetic parameters for the formed factors, and to estimate genetic and residual correlations between these and trotting performance traits.

2. Material and methods

2.1. Data collection through survey for temperament traits

A survey adapted from Momozawa et al. (2005) and Staiger et al. (2016), including 12 behavior traits, was used to describe the temperament of the horses at trotting races. The survey was adapted to describe temperament characteristics considered important for harness racing performance that could be answered by the horse's trainer. The traits Nervousness, Excitability, Concentration, Learning, Cooperation and Stubbornness were kept from the original survey. However, the traits Fearfulness, (Fear) memory, Will to win, (Loose) self-control, Recovery and (Poor) appetite were added. In the survey by Momozawa et al. (2005) there were also traits related to friendliness (e.g. friendliness towards people and horses) and a trait that was specific for thoroughbred racehorses (e.g. how easily the horse goes through the gate entrance), but also traits related to being anxious (e.g. vigilance and timidity) that were not included in the current study. The horses' trainers were asked to rate how often they observed each temperament trait in competition on a scale from 1 to 7. The scores were defined as follows: 1 =never, 2 =rarely, 3 =occasionally, 4 =sometimes, 5 =often, 6 =usually and 7 =always. The temperament traits and their descriptions together with descriptive statistics including calculations of mean, standard deviations, skewness and kurtosis are presented in Table 1. In addition, questions were asked about regular health and behavior problems. The survey was directed to professional and amateur trainers of horses that had started in at least one race when trained by the current trainer and was available as an online version and distributed by the Swedish Trotting Association to an email list of all registered trainers in Sweden. It was also advertised in the Swedish Standardbred breeders' magazine and distributed in relevant Facebook groups. Professional trainers near Uppsala were also contacted via phone. For survey answers to be included in the study, each respondent had to confirm that the horse owner was aware of and agreed to participate in the project. The respondents were also made aware that they had the right to cancel their participation in the study and remove the horse from the study if they so desired.

The data collection started in April 2019 and the final data set was extracted in June 2021. In total, surveys for 377 horses with at least one temperament question answered were collected. Most respondents were located in Sweden, and a few (answering for 5 % of the horses) were located in Norway. Two horses born in the 1990s were removed from the data, and the remaining horses were born 2005–2018, meaning that some had completed their racing careers at the time of the study. In addition, horses missing information about more than one of the temperament traits were removed, leaving 366 horses whereof 13 were missing one trait score.

The 366 horses with temperament trait data were from 142 sires with 1–21 offspring each, and from 339 dams with 1–2 offspring each. They were trained by 120 different trainers with 1–30 horses each, whereof 87 represented one horse only and only 23 trainers had more than two horses in the data. The survey and preliminary results were presented in a MSc thesis by Berglund (2021).

2.2. Performance data and pedigree

Summarized performance records from Swedish trotting races for Standardbred trotters that were 2–5 years of age were edited and transformed following the standard for the routine genetic evaluation (Table 2), and pedigree information was provided by the Swedish Trotting Association. Descriptive statistics were calculated including mean, standard deviation and trait distribution (min and max) for the transformed performance traits (Table 2). Performance records were kept for all horses (N = 33,778) born in the same period (2005–2018) as the horses with temperament trait information. A total of 307 horses had both temperament and performance records. Up to seven generations of pedigree information was traced back for each horse with trait observations.

2.3. Raw phenotypic correlations between temperament and performance

Spearman rank correlations were estimated between the original temperament trait scores and the transformed performance traits using PROC CORR in SAS (SAS Institute Inc., 2015) to get a first impression of the interrelationships between traits. The level of significance for the correlations was set to $P < 0.05$.

2.4. Factor analysis

The twelve temperament traits: Nervousness, Excitability, Fearfulness, Concentration, Learning, Fear memory, Cooperation, Will to win, Lose self-control, Stubbornness, Recovery and Poor appetite, were included in an iterative factor analysis of temperament traits performed with PROC FACTOR (method prinit) in SAS, with orthogonal varimax rotation. The estimation of factor loadings included 353 horses with complete trait information. PROC PRINCOMP in SAS showed that the three first Eigenvalues were > 1. The corresponding scree-plot did not show clearly if three or four factors should be included, but preliminary analysis showed that only one of the temperament traits (stubbornness) loaded > 0.4 on the fourth factor. Based on this, the number of factors was determined to be three. The average KMO was 0.81 (range 0.65–0.88) for the twelve traits in the factor analysis, indicating that the correlation matrix was appropriate for factorization.

Standardized factor score coefficients were produced with PROC SCORE in SAS using all factor loadings and trait values. For 13 horses lacking only one temperament trait observation, missing values were replaced by the mean value in the dataset for that trait before forming factor scores, so that they could be included in the study. Horses missing more than one temperament trait observation were not assigned a factor score. Thereby, 366 horses were given factor scores and included in further analyses of temperament traits.

2.5. Estimation of variance components

Different linear models were tested using PROC GLM in SAS to select fixed effects to be included in the genetic analysis of the formed factors for temperament traits. Sex (stallion, gelding or mare), level of trainer license (professional, amateur, or both for trainers that changed from one license to another), and age groups of the horse at the time of the study (2, 3, 4, 5, 6, 7, 8, 9–10, or >10 years old), were found to be significant for at least one of the factors, and thus chosen for the statistical model. For the performance traits, a model including the fixed effect of the combination of the birth year (2005, 2006, …, 2018) x sex of the horse (male or female) was used, as in the current routine genetic evaluation for these traits.

Genetic parameters were estimated with the DMU software (Madsen and Jensen, 2013) using bivariate animal models:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Za} + \mathbf{e}$$

where $\mathbf{y}$ is the vector of trait observations, $\mathbf{X}$ and $\mathbf{Z}$ are incidence matrices, $\mathbf{b}$ is a vector with fixed effects, $\mathbf{a}$ is the vector of additive genetic effects, and $\mathbf{e}$ is the vector of random residuals. The (co)variance structures of random effect were assumed to be $\mathbf{a} \sim N(0, \mathbf{G_a} \otimes \mathbf{A})$ and $\mathbf{e} \sim N(0, \mathbf{R_0} \otimes \mathbf{I})$, where $\mathbf{A}$ is the additive genetic relationship matrix, $\mathbf{G_a}$ is the variance-covariance matrix of genetic effects, $\mathbf{I}$ is an identity matrix and $\mathbf{R_0}$ is the residual variance–covariance matrix.

Heritability estimates were calculated as $\sigma_a^2/(\sigma_a^2 + \sigma_e^2)$, where σ_a^2 is the estimated additive genetic variance, and σ_e^2 is the estimated residual variance.

Additional comparisons were made with results from PROC MIXED in SAS using models including also a random effect of trainer identity (not shown), but this had little effect on the results as could be expected as few trainers had multiple horses in the data.

3. Results

3.1. Trait descriptions and distributions

Descriptions of temperament traits included in the survey together with descriptive statistics for each trait are shown in Table 1. The horses included in the study generally received lower scores for Nervousness, Excitability, Fearfulness, Fear memory, Lose self-control, Stubbornness and Poor appetite. Higher scores were used for Concentration, Learning, Will to win and Recovery. The definitions and distributions of the performance traits after transformation are shown in Table 2.

3.2. Phenotypic correlations

The phenotypic Spearman rank correlations between the original temperament trait scores and the transformed performance traits were weak, with the strongest correlations (~0.3) between the score for Will to win and the performance traits Placings and Earnings per start (Table 3).

3.3. Factor analysis

The factor analysis resulted in three factors for the temperament traits that were named based on the dominating (factor loadings >|0.4|) traits for each factor (Table 4). The first factor F_Anxiousness was dominated by Fearfulness, Fear memory, and Lose self-control. For the second factor F_Agreeableness, Learning, Cooperation, and Will to win loaded most strongly. Finally, for the factor F_Excitability, the traits Nervousness and Excitability were the dominating traits. These factors explained around 30–40 % of the variation each. Among the individual temperament traits, Stubbornness, Concentration, and Recovery were the ones least represented by the formed factors (16–26 % of the variance explained). Descriptive statistics for the three formed factors are

Table 2
Transformed accumulated competition traits from the age of 2–5 years for 33,778 horses born 2005–2018, mean, standard deviation (S.D.), minimum and maximum values.

Trait	Description	Mean	S.D.	Min	Max
Number of starts	(Number of starts in races)$^{0.2}$	1.76	0.27	1.00	2.49
Placings	(Number of first to third placings x 100 / number of starts)$^{0.8}$	14.70	8.10	0.00	39.81
Earnings	Ln (Prize sum in SEK + 1000)	11.35	1.47	6.91	16.57
Earnings per start	Ln ((Prize sum in SEK + 1000) / number of starts)	8.58	0.99	4.27	13.62
Best racing time	Ln (seconds per km −68.2)	4.38	0.25	3.09	5.96

Table 1
Temperament traits with descriptions and number of observations included in the study with mean, standard deviation (S.D.), skewness and kurtosis.

Trait[a]	Description	N	Mean	S.D.	Skewness	Kurtosis
Nervousness	Tends to become nervous	366	3.16	1.73	0.60	−0.58
Excitability	Tends to get excited or agitated easily	366	3.17	1.69	0.42	−0.81
Fearfulness	Tends to be afraid easily (e.g. novel environments)	366	2.46	1.47	0.97	0.17
Concentration	Tends to be focused and unaffected by the environment	365	5.01	1.59	−0.81	0.00
Learning	Tends to learn the task of competing quickly	366	5.75	1.29	−1.50	2.49
(Fear) memory[b]	Tends to memorize/remember unpleasant events	366	2.99	1.82	0.68	−0.69
Cooperation	Tends to be cooperative, have good attitude (willing to work/no resistance)	366	5.76	1.34	−1.34	1.68
Will to win	Tends to desire to win	356	5.17	1.73	−0.68	−0.64
(Lose) self-control[b]	Tends to panic, escape and lose control (impossible to handle/stop or damage itself)	366	1.93	1.42	1.62	1.90
Stubbornness	Tends to be obstinate once it resists a command	364	1.64	1.19	2.29	5.25
Recovery	Tends to relax quickly	366	5.58	1.43	−1.44	2.03
(Poor) appetite[b]	Tends to have poor appetite	366	2.36	1.67	1.38	1.19

[a] Scale from 1 =never to 7 =always for all traits, where the extreme values 1 and 7 were used by some respondents for all traits.
[b] The text in parentheses for the trait name was added for clarity in the text and tables in this article but was not in the original survey.

Table 3
Phenotypic Spearman rank correlations between the original temperament trait scores and the performance traits. Correlations with $P < 0.05$ are marked in bold.

Temperament trait	No. of starts	Placings	Earnings	Earnings/ start	Best racing time
Nervousness	0.00	**−0.12**	**−0.14**	**−0.16**	0.08
Excitability	−0.02	−0.02	−0.02	0.01	0.00
Fearfulness	−0.09	**−0.14**	−0.08	−0.07	0.06
Concentration	0.02	**0.19**	**0.12**	**0.16**	−0.10
Learning	0.02	**0.12**	0.05	0.07	−0.03
Fear memory	−0.09	**−0.14**	**−0.18**	**−0.20**	**0.17**
Cooperation	0.00	0.05	0.02	0.03	0.02
Will to win	0.04	**0.31**	**0.24**	**0.28**	**−0.22**
Lose self-control	0.01	−0.02	0.00	0.01	−0.01
Stubbornness	−0.03	−0.06	−0.08	−0.07	0.06
Recovery	0.02	0.03	−0.03	−0.05	0.02
Poor appetite	0.05	0.05	0.09	0.08	−0.11

Table 4
Factor loadings[a] after varimax rotation, and proportion of explained variance by the factors.

	Factor			% of variance explained
Trait	F_Anxiousness	F_Agreeableness	F_Excitability	
Nervousness	0.24	−0.11	**0.73**	61 %
Excitability	0.29	−0.16	**0.69**	59 %
Fearfulness	**0.64**	−0.26	0.19	52 %
Concentration	−0.31	0.36	−0.17	25 %
Learning	−0.28	**0.70**	−0.12	57 %
Fear memory	**0.67**	−0.03	0.15	47 %
Cooperation	−0.28	**0.72**	−0.11	61 %
Will to win	−0.03	**0.59**	0.03	35 %
Lose self-control	**0.74**	−0.28	0.20	66 %
Stubbornness	0.36	−0.18	0.06	16 %
Recovery	−0.19	0.35	−0.32	26 %
Poor appetite	0.01	−0.01	0.35	35 %
% of variance explained	37 %	35 %	27 %	

[a] Factor loadings > |0.4| in bold.

shown in Table 5.

The test of fixed effects to include in the model made in SAS PROC GLM, showed that the effect of sex was significant for F_Excitability, with the lowest scores for stallions. For F_Agreableness, the effect of the age group of the horse at the time of the survey was significant, with higher scores for older horses. Trainer level was significant for F_Anxiousness where lower scores were given by professional trainers than by amateurs.

3.4. Estimation of variance components and heritability

Estimated variance components and heritability values for the factors and performance traits, averaged from all bivariate analyses, are shown in Table 6. The heritability estimates were low to moderate for all traits, ranging from 0.13 for F_Anxiousness to 0.50 for F_Excitability. These were estimated with high standard errors for the factors for temperament traits in this data of limited size. However, there was a consistency in estimates between the different bivariate analyses (not shown). For example, the heritability estimated for F_Excitability ranged between 0.48 and 0.54 in the seven analyses together with different traits.

Table 5
Factor scores for temperament traits with number of observations, mean values, standard deviation (SD), and minimum and maximum values.

Factor	N	Mean	SD	Min	Max
F_Anxiousness	366	−0.016	0.837	−1.322	2.932
F_Agreeableness	366	−0.002	0.843	−4.157	1.365
F_Excitability	366	−0.009	0.821	−1.425	3.003

Table 6
Estimated genetic ($\hat{\sigma}_a^2$) and residual ($\hat{\sigma}_e^2$) variances (with standard errors as subscripts[a]) and heritability values (h^2), averaged from the different bivariate models.

Trait	N	σ_a^2	σ_e^2	h^2
Factors for temperament				
Anxiousness	366	$0.092_{0.095}$	$0.608_{0.098}$	$0.13_{0.132}$
Agreeableness	366	$0.195_{0.146}$	$0.476_{0.130}$	$0.29_{0.204}$
Excitability	366	$0.344_{0.163}$	$0.340_{0.163}$	$0.50_{0.218}$
Performance traits				
Number of starts	33778	$0.014_{0.001}$	$0.061_{0.001}$	$0.18_{0.015}$
Placings	33778	$25.092_{1.257}$	$39.698_{0.874}$	$0.39_{0.017}$
Earnings	33778	$0.814_{0.042}$	$1.350_{0.029}$	$0.38_{0.017}$
Earnings per start	33778	$0.434_{0.018}$	$0.480_{0.012}$	$0.48_{0.016}$
Best racing time	33778	$0.024_{0.001}$	$0.037_{0.001}$	$0.39_{0.016}$

[a] The highest standard errors from all bivariate analyses are presented.

3.5. Genetic correlations between temperament and trotting performance

The estimated genetic and residual correlations between the factors for temperament traits were estimated with high standard errors, and there were convergence problems for the analysis of F_Agreeableness with F_Anxiousness. These two traits appeared to be very strongly negatively genetically correlated (Table 7), but these values should be interpreted with care. Weak phenotypic correlations were estimated between the factors for temperament traits, for which the strongest phenotypic correlation (0.17) was seen between F_Excitability and F_Anxiousness.

The correlations between factors for temperament traits and performance traits (Table 8) showed a consistent pattern, in spite of high standard errors, where F_Anxiousness was negatively correlated with all performance traits, except for with Best racing time for which lower values are desired. A similar, but less strong, tendency was seen for F_Excitability. In contrast, F_Agreeableness was found to be positively correlated with all performance traits except Best racing time. Only some of the estimated genetic and residual correlations were significantly deviating from zero in this data, however.

4. Discussion

Certain temperamental traits can predispose horses to success or difficulty in specific disciplines. However, the relationship between temperament and performance is complex, as environmental factors such as handling, training techniques, and trainer experience also play critical roles, in addition to genetic predispositions (Hausberger et al., 2004). The number of studies looking into genetics behind temperament or behavior traits in horses is still limited, why additional research

Table 7
Estimated genetic (r_g), residual (r_e), and phenotypic (r_p) correlations[a] from bivariate analysis, with standard errors as subscripts, between factors for temperament traits.

Factor	F_Agreeableness			F_Excitability		
	r_g	r_e	r_p	r_g	r_e	r_p
F_Anxiousness	$(-1.00_{0.696})$	$(-0.02_{0.134})$	(−0.14)	$0.64_{0.450}$	$0.01_{0.180}$	0.17
F_Agreeableness				$0.55_{0.392}$	$-0.38_{0.263}$	−0.02

[a] A lower convergence criterion had to be used in the bivariate analysis of F_Agreeableness with F_Anxiousness due to convergence issues and are therefore presented in parenthesis. Standard errors were not provided for phenotypic correlations by the software used.

Table 8
Estimated genetic (r_g), residual (r_e), and phenotypic (r_p) correlations[a], with standard errors as subscripts, between factors for temperament traits and performance traits.

Perfor-mance trait	Factors for temperament traits								
	F_Anxiousness			F_Agreeableness			F_Excitability		
	r_g	r_e	r_p	r_g	r_e	r_p	r_g	r_e	r_p
Number of starts	$-0.16_{0.326}$	$-0.17_{0.086}$	−0.16	$\mathbf{0.59}_{0.262}$	$-0.09_{0.094}$	0.06	$\mathbf{-0.38}_{0.186}$	$0.08_{0.118}$	−0.07
Placings	$-0.60_{0.392}$	$-0.13_{0.092}$	−0.22	$0.30_{0.217}$	$\mathbf{0.28}_{0.103}$	0.28	$-0.29_{0.167}$	$0.22_{0.136}$	0.00
Earnings	$-0.60_{0.315}$	$\mathbf{-0.18}_{0.092}$	−0.27	$\mathbf{0.41}_{0.197}$	$\mathbf{0.25}_{0.107}$	0.31	$-0.32_{0.170}$	$0.07_{0.129}$	−0.10
Earnings per start	$-0.62_{0.361}$	$-0.13_{0.097}$	−0.23	$0.23_{0.178}$	$\mathbf{0.43}_{0.120}$	0.34	$-0.20_{0.157}$	$0.03_{0.138}$	−0.08
Best racing time	$0.55_{0.363}$	$0.10_{0.091}$	0.19	$\mathbf{-0.37}_{0.186}$	$-0.20_{0.108}$	−0.26	$0.27_{0.168}$	$-0.12_{0.126}$	0.05

[a] Significant ($P < 0.05$) correlations marked in bold, standard errors were not provided for phenotypic correlations by the software used.

adding knowledge on how to clearly define and use relevant traits in breeding programs for horses in general is needed. In this study, data was gathered through a survey completed by horse trainers. While the accuracy of the data may depend on the trainer's experience and understanding of horse behavior, significant associations between the horses' behavior, assessed trough a caretaker survey, and their heart rate during a novel object test was reported by Momozawa et al. (2005). Jolivald et al. (2022) found sufficient internal consistency, inter-rater reliability and test-retest reliability for factors such as agreeableness and neuroticism when validating their subjective equine personality questionnaire. In addition, factor analysis or principal component analysis (PCA) are commonly used methods for reducing data complexity and identifying the most significant temperament traits that characterize a horse breed (Olsen and Klemetsdal, 2017; Sigurðardóttir et al., 2017). The use of a factor analysis thus helps to define more distinctive underlying traits representing different aspects of temperament.

In the present study, the factor analysis revealed three distinct temperament factors, each accounting for a substantial proportion of the explained trait variance. The first two factors identified, F_Anxiousness (for which aspects of fearfulness were important) and F_Agreeableness (on which aspects related to cooperation loaded strongly), are fairly similar to the results of previous studies (Momozawa et al., 2005; Staiger et al., 2016) from which we adapted our own survey. Hence, the results from our survey showed consistency to already validated surveys analyzing horse temperament, in spite of the modifications made. Factors or principal components representing aspects of anxiety or fearfulness seem to be commonly found also in other studies of temperament and behavior in horses (Roberts et al., 2016; Olsen and Klemetsdal, 2017; Sigurðardóttir et al., 2017). To what extent aspects of nervousness load together with fearfulness or excitability seem to differ between surveys as well as between breeds within survey. Fearfulness is recognized as one of the fundamental traits of an individual's temperament, showing stability across different fear-eliciting situations and over time in horses (Lansade et al., 2016). Being shaped by the evolution as prey animals, horses are prone to experience anxiety, and prolonged exposure to stressful situations can harm their wellbeing (Hernández-Avalos et al., 2021). It is therefore beneficial also for animal welfare if horses can perform well with low levels of anxiousness.

In our study, the average scores revealed that most horses appeared not to be fearful or panicked during competitions but willing to cooperate, indicating a good adaptation to the racing environment. This adaptation likely results from both selective breeding among racing horse breeds and domestication, which have contributed to increased docility and tameness (Holtby et al., 2023). However, results need to be interpreted with caution, as some factors like F_Anxiousness may be somewhat biased by trainer level, in that professional trainers tend to assign lower scores according to our findings, which was therefore corrected for in our statistical model for the genetic analysis. It also appeared that not all questions in our survey were well enough described. Stubbornness was the trait with the most skew distribution (Table 1) and this trait did not load strongly on any of the three factors. Some responding trainers commented that this trait was difficult to assess and could be interpreted in more than one way, whereas the other traits seemed to be easier to score. For any future studies, this should be considered.

Staiger et al. (2016) found a positive correlation between age and the factor anxiousness. In the present study, age also influenced temperament, with older horses often showing higher levels of agreeableness. However, there is also a possibility that horses that struggle to learn the task of harness racing will be discarded during their initial years of competition. The last factor identified, F_Excitability, seems to be commonly found in other racing horse breeds, such as Coldblooded trotters (Olsen and Klemetsdal, 2017) and Thoroughbreds (Lloyd et al., 2008). Interestingly, it appears that sex differences play a role, as stallions tended to show lower levels of excitement compared to mares and geldings in our study. This aligns with findings from other studies that have reported similar results (Duberstein and Gilkeson, 2010; Budzyńska et al., 2014; Roberts et al., 2016).

Different breeds display unique temperament profiles, which can be attributed to genetic variation and the selection for specific traits (Rankins and Wickens, 2020). For example, clear breed differences in nervousness and anxiousness have been presented, where such temperament was more associated with Arabian horses and Thoroughbreds than with Quarter or draft horses (Sackman and Houpt, 2019). Anxiousness together with excitability showed higher levels of variability between breeds compared with other personality traits studied by Lloyd et al. (2008). The breed differences observed for traits similar to the last factor in our study: F_Excitability, therefore, support a strong genetic influence.

The heritability estimates obtained in the present study based on trainer-reported surveys ranged from low to moderate but were only significant for the excitability factor, likely due to the limited data size. The results are consistent with findings from previous studies in horses as exemplified above and indicate a genetic variation in excitability. Despite large standard errors of the estimations, the results are consistent across analyses, suggesting that selecting for specific temperament traits could be beneficial for trotting performance success. These findings are in line with previous studies and support existing hypotheses, suggesting potential associations between personality traits, health and performance in horses (Rankins and Wickens, 2020).

Specific temperament traits are required for success in a given discipline (McBride and Mills, 2012). Thoroughbreds, for example, are selected for heightened awareness and the ability to learn and adapt to stress (Holtby et al., 2023). In this study, the temperament trait Will to win was included to reflect differences in horses' awareness of their race position and their willingness to strive towards the lead without much driver encouragement. This trait, recognized by trainers and part of the breeding goal for Swedish Standardbred trotters (Svensk Travsport, 2024), helps to distinguish between horses but is ultimately a human interpretation as it is difficult to know the actual motivation of the horse. For future surveys, a description of the trait that is less colored by anthropomorphism and more descriptive of the behavior should be used. The closest comparison in literature is the trait spirit in Icelandic horses, previously used in breeding field tests, which showed genetic progress (Sigurðardóttir et al., 2017). Spirit encompassed forward drive, energy, and manageability (Albertsdóttir et al., 2008; Sigurðardóttir et al., 2017). In this study, Will to win, together with Cooperation and Learning, was central to F_Agreeableness in Standardbred trotters. Sigurðardóttir et al. (2017) found spirit favorably correlated with cooperation at breeding tests and in home environments, supporting our results. Comparing temperament in competition versus home settings was beyond this study's scope but would be valuable for future research on trotters.

The results of this study are also in agreement with studies of Swedish Warmbloods and Icelandic horses (Wallin et al., 2003; Albertsdóttir et al., 2008) revealing moderate to high favorable genetic correlations between desired temperament traits and competition performance. In contrast to the study by Lansade et al. (2016), we did not see any favorable associations between fearfulness and competition performance. Bonow et al. (2024) found a favorable effect of a having a behavior score towards "less tense", on a linear scale from less tense to tense at young horse tests, in show jumping horses on their competition performance. The same study found that horses bred for show jumping were assessed as significantly less tense than horses bred for dressage at young horse tests. Trotters are generally known for their tractability, which suggests that some level of co-selection may occur when selecting for competition performance.

The interplay between genetic predisposition and environment highlights the importance of considering both temperament and performance when selecting and training horses for specific roles. Although further validation with more comprehensive data is needed, our results suggest that breeding for higher agreeableness in trotters is feasible and may improve performance in trotting races. Before practical applications, the form for data collection needs to be further considered. If survey answers would directly impact breeding values of horses, and thus their economic values, that may impact answers from certain respondents with personal interest in the horses, and strategies to avoid this are needed. Future studies of alternatives to routinely assess temperament in young trotters, for example at breeding assessments of stallions, auctions or competitions, would thus be useful.

5. Conclusions

Three factors explaining temperament characteristics of Standardbred trotters were found, describing aspects related to anxiousness, agreeableness, and excitability in the horses. Heritability estimates were low to moderate, but only significant for the factor F_Excitability in this limited data set. The correlations in this study were estimated with high standard errors, but uniformly point at a favorable association between high agreeableness and trotting performance, whereas strong anxiousness appears to be unfavorable for performance. Weaker correlations between excitability and performance traits were seen. These findings need to be confirmed in more comprehensive data but indicate that breeding for higher agreeableness in trotters is feasible, and would benefit overall performance in trotting races.

6. Ethics

The study was based on surveys to trainers of horses, ensuring their consent to participate, and following the EU GDPR legislation.

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CRediT authorship contribution statement

Gabriella Lindgren: Writing – review & editing, Funding acquisition. **Susanne Eriksson:** Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization. **Marina Solé:** Writing – review & editing, Writing – original draft, Funding acquisition, Data curation, Conceptualization. **Maria Wilbe:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Data curation, Conceptualization. **Paulina Berglund:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: usanne Eriksson has commitments to the Swedish Trotting Association, regarding development of the genetic evaluation. Besides this, the authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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