



Equine Research

Behavioral, demographic, and management influences on equine responses to negative reinforcement

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ABSTRACT

Understanding the factors that influence horse learning is critical to ensure horse welfare and rider safety. In this study, data were obtained from horses ($n = 96$) training to step backward through a corridor in response to bit pressure. After training, learning ability was determined by the latency to step backward through the corridor when handled on the left and right reins. In addition, horse owners were questioned about each horse's management, training, behavior, and signalment (such as horse breed, age, and sex). Factors from these 4 broad domains were examined using a multiple logistic regression (MLR) model, following an information theoretic approach, for associations between horses' behavioral attributes and their ability to learn the task. The MLR also included estimates of the rider's ability and experience as well as owner's perceptions of their horse's trainability and temperament. Results revealed several variables including explanatory variables that correlated significantly with rate of learning. Horses were faster at backing, a behavioral trait, when handled on the right side ($t = 3.65$; degrees of freedom = 94; $P < 0.001$) than the left side. Thoroughbred horses were slower at completing the tests than other breeds of horses when handled on the left side [linear model (LM), $F_{1,48} = 4.5$; $P = 0.04$] and right side (LM, $F_{1,45} = 6.0$; $P = 0.02$). Those in regular work, a training factor, did not learn faster than their unworked counterparts on the right rein but completed the task faster on the left rein ($F_{1,44} = 5.47$; $P = 0.02$). This may reflect differences in laterality and habituation effects. In contrast, more anxious horses were faster at completing the test when handled from the right rein (Spearman $r = -0.22$; $P = 0.04$). It is possible that these horses have an increased arousal level when interacting with handlers, resulting in more engagement with the lesson, accounting for the improved performance results. The findings of this study will help clarify how horse behavior, training, and management may influence learning and how their application may optimize learning outcomes. Future equine behavior assessment and research questionnaires should include items that assess these qualities.

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Introduction

Equestrianism is growing as a sport around the world, and today horses are trained for activities, such as show-jumping, dressage, and trail-riding, and to provide safe mounts for children to take to Pony Club or other structured equestrian events. In the developed world, horses have, during the past century, effectively transitioned from being primarily work animals to leisure animals. During this

time, training and management practices have changed enormously and, although equitation science has revealed how equine learning differs with environments (Thomas, 2010), how individual horses process information (Baragli et al., 2017), temperament (Lansade & Simon, 2010; Valençon et al., 2013b), stress (Olczak et al., 2016; Valençon et al., 2017), fearfulness (Christensen et al., 2012), personality (Lansade et al., 2017), perceived social rank (Krueger et al., 2014), and breed (Janczarek et al., 2014; McGreevy & Thomson, 2006), little published research has investigated how management and training practices are reflected in the horse's ability to learn novel behaviors.

In a fast-moving world, emphasis is often placed on how quickly a horse learns (Christensen et al., 2012; Lansade & Simon, 2010;

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Lansade et al., 2017; Valenchon et al., 2013a). This has also been reflected in the popular “Road to the Horse” (Bland, 2007) and “The Way of the Horse” (Events, 2016) so-called colt-starting competitions, where largely untouched horses are started under saddle and ridden through an obstacle course in a very short period (usually between 5 and 8 hours) during a 2- or 3-day period (Fenner et al., 2018; Henshall & McGreevy, 2014). More generally, speed and efficiency of training are valued by many sectors of the equestrian industry, with the average horse spending a mere 4–6 weeks for the initial foundation training when owners employ a professional horse trainer (McLean & McLean, 2008). Although this may represent ample training time for some horses, it is unlikely to meet the needs of the population as a whole.

It is probable that demographic and management variables affect horses' behavior, cognition, and learning ability. Responding to rein tension is a core element of foundation training, and several studies have focused on comparing the horses' responses to such contact, using various techniques (Clayton et al., 2010; Egenvall et al., 2016; Warren-Smith et al., 2007). The horse's response to rein signals is important for rider safety and, in turn, horse welfare. Once riders have established a balanced riding position and are fully aware of the consequences of all intentional and inadvertent pressure cues, the more responsive the horse is to the slow, stop, and turn cues from the bit, the safer the rider. It would be advantageous to understand the demographic, training, and management factors that optimize learning such fundamental lessons. Knowledge of how the individual horse has been trained is also important because some training methods, such as those that include Rollkur or hyperflexion, seem to increase the risk of fear in some horses and thus threaten their welfare (Nestadt et al., 2015; Von Borstel et al., 2009).

Horses' behavior and temperament affect horse-rider cooperation, with riders preferring to ride horses that are assessed as being attentive to the rider's aids (Visser et al., 2008). We know that certain potentially dangerous behaviors, such as the flight response, are difficult to extinguish once established (McLean et al., 2017; Starling et al., 2018), but we are less clear about how current training, riding, and management practices might promote the development of such behaviors in the future. Problem behavior may be a major cause of wastage (Odberg & Bouissou, 1999) where horses are sold on or euthanized, in the equestrian industry. This study opens the door to investigating wastage reasons by surveying owners about their current training and management practices and examining how they influence learning.

Even today, horses are mostly handled and mounted from the left side, a tradition that began with the cavalry and a result of the positioning of the cavalryman's sword (Kelekna, 2009). Such a disproportionate amount of handling on one side of the animal may desensitize horses to the use of negative reinforcement on that side, making responding to cues from that side more difficult. Horses are mostly led from the left side, and they may be subjected to unrelenting, inconsistent, or meaningless pressure on that side simply as a result of handlers being unaware of best practice pressure-release techniques (McLean & McGreevy, 2015). The modern horse may have evolved to be less sensitive on the left-hand side as a result. The misuse of negative reinforcement in this way could adversely affect learning on the left sides of horses by desensitizing them to pressure cues and thus rendering such cues less effective. Furthermore, the lateral bias of individual horses facilitated by kinematic differences in limb characteristics is likely to have a significant effect on the outcome of trained responses of locomotion (Chateau et al., 2004; Clayton et al., 2007a,b; Murphy et al., 2005).

Previous studies have investigated breed differences in horse temperament (Lloyd et al., 2008), but more work is required to investigate the differences between how individual breeds learn operant tasks. Certain breeds, if found to learn relatively easily,

might be more suitable for particular types of owners. Matching horses to owners, using a combination of breed, temperament, and learning ability, should help reduce the high wastage rates seen in certain sectors of the industry (O'Brien et al., 2005; Thomson et al., 2014).

Many common handling procedures are based on tradition or practicality rather than necessarily being in the best interest of the animal. In the Western world, in some disciplines such as horse racing, horses may be started under saddle before the age of 2 years to be ready for 2-year-old races. The horses' mental, physical, and emotional capacity for learning may also be wanting at such a young age, and comparing how horses of different ages acquire new behaviors may help us discover the optimal age to start a horse under saddle. This may differ among breeds (Strand et al., 2007) and riding disciplines (Gorecka-Bruzda et al., 2015).

Management practices applied to horses vary widely from country to country, and these differences are reflected in horse welfare (Lesimple et al., 2016), handling behavior (Hockenhull & Creighton, 2014), and active locomotory patterns (Lesimple et al., 2011). Competition horses are often housed in individual stables, and the type of turnout such horses receive appears to influence not only their behavior during exercise and training but also the level of stress they encounter and their willingness to perform (Werhahn et al., 2012). Discovering which management practices assist with equine learning would be very helpful. A few studies have investigated how housing affects behavior (Freire et al., 2009; Hockenhull & Creighton, 2014; Werhahn et al., 2012), but, to date, nothing has been published on how housing might influence learning directly. It seems evident that behavior must influence learning, but there are currently few published data on how behavior (Fenner et al., 2017a) and temperament (Valenchon et al., 2013a,b) are reflected in the horse's ability to learn. Discovering how training and management influence behavior and learning should lead to strategies that reduce wastage while optimizing rider safety and horse welfare.

Materials and methods

Participants

Participants were recruited through a Facebook post asking for experienced horse riders and owners, with 2 or more horses of various breeds (between 94.5 cm/9.3 hh and 174.8 cm/17.2 hh with a mean height of 14.3 ± 1.2 hh and were aged from 2 to 25 years with a mean age of 9.8 ± 6.1 years) in the greater Canberra region, Australia. The 96 respondents included amateur riders, breeders, riding school owners, coaches, and trainers.

The learning test involved stepping backward on cue through a 5-m corridor a total of 8 times, 4 with the handler on the left side of the horse, motivating the horse to step back only with the left rein and 4 with the handler on the right side of the horse, motivating only with the right rein. Because of the wide variation in handling experience of the animals used (Fenner et al., 2017a), each horse began the trials on the left rein. Trials 1–6 were considered the training trials and trial 7, on the left rein, and trial 8, on the right rein, were considered the test trials. Latency to complete the test trials was analyzed to investigate learning ability.

Materials

Survey

An online questionnaire was designed using the program SurveyMethods (SurveyMethods, Inc, TX; <https://app.surveymethods.com/>) to gather information on the training, management,

and behavior of horses for the week before administration of the learning test. The survey consisted of 50 questions and was completed by the horses' owners. Questions included items relating to horse and owner demographics, such as the horse's age, breed, and sex, as well as those on how the horse was currently housed, ridden, managed, and trained.

Learning test

The learning test involved stepping backward along a 5-m corridor (Figure 1). In addition to latency to complete the task, rein tension, heart rate, and behavior were also measured (Fenner et al., 2017a) and analyzed. The backing exercise was trained using only the negative reinforcement of bit pressure from rein tension. Time to complete the task was a measurement of the time taken to complete the final trial on each rein, that is, test trials 7 and 8.

The test involved the use of rein tension from 1 rein only and, as an operant response to bit pressure, may have led to head-turning and then lateral movement of the legs, thus the corridor was set against a fence (Figures 1 and 2). Latency to complete the task and behavior were recorded using The Observer XT software (Noldus Information Technology bv, Wageningen, The Netherlands; v11.5, 2013).

Statistical analysis

We used linear regression modeling, and specifically the information theoretic approach, to investigate learning when handled on the left and right reins (the dependent variables). Using linear regression allows for inclusion of continuous, ordinal, and categorical variables in the model to improve predictive power (Burnham & Anderson, 2002). We modeled our 2 dependent variables against the explanatory variables encompassing horse factors, behavior, training, and management. The latency to complete the tests was natural log transformed to meet assumptions for parametric analysis.

Data on 32 potential explanatory variables were collected from the questionnaire. We assessed the data for potential multicollinearity by testing all possible pairs of variables using Spearman rank correlation coefficients, Kruskal-Wallis nonparametric tests, or chi-square tests for categorical variables. To avoid including highly correlated explanatory variables, we omitted some variables or created composite variables in cases where it was biologically

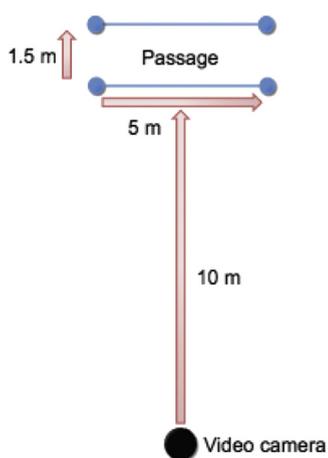


Figure 1. A 5-m corridor was marked by poles on the ground and set against a fence. Bollards at each end marked start and finishing points for the handler and later video analysis.

meaningful to do so. This selection resulted in 10 explanatory variables (Table 1). This reduction in variables proved effective in reducing collinearity, and all models within 7 Akaike information criterion (AICc) (Johnson et al., 2004) of the most parsimonious model for both dependent variables had variance inflation factors under 1.5 for all explanatory variables.

To account for the potential of the blinded handler improving her technique throughout the series of horses, order (1-96) was included as a covariate. Similarly, preconditioning of some horses using the give-to-bit procedure, where the horses were conditioned to move their heads laterally in response to rein tension, may have affected learning and was also considered as a covariate.

Linear regression models with all possible combinations of the explanatory variables were built using the R software program (The R Foundation; R Core Team (2013)). AICc was used to rank all possible candidate models. We used the second order variant of AICc as this is more appropriate when the sample size divided by the number of explanatory variables is less than 40, as was the case here (Matthew et al., 2011). Models within 2 AICc (Δ_i) of the most parsimonious model were considered to have considerable empirical support (Burnham & Anderson, 2002). Although it has been suggested that models with an Δ_i range of 2-7 should be considered (Burnham & Anderson, 2002), examination of the models within this range mostly showed variations in the combinations of the same factors and covariates as models within an $\Delta_i < 2$. Comparison of the relative importance of each independent variable was determined using standardized coefficients, calculated using the *lm.beta* package in R.

Results

Eight models when handled on the left and 17 models when handled from the right were within 2 AICc of the most parsimonious model (Table 2). In general, R^2 was in the region of 20%-30%, which is not unusual when attempting to predict behavior (Table 2). Breed was included in all 25 of the best models for left and right sides. Breed was significant for the most parsimonious models when handled on the left side (LM, $F_{1,48} = 4.5$; $P = 0.04$) and right side (LM, $F_{1,45} = 6.0$; $P = 0.02$). As can be seen in Table 2, models with only breed were within Δ_2 of the most parsimonious model for the left and right sides, and both were significant. Thoroughbred horses took 37.3 ± 4.6 and 30.1 ± 3.0 seconds to complete the test when handled on the left and right sides, respectively. Other breeds of horses took 28.8 ± 2.8 and 23.1 ± 1.7 seconds to complete the test when handled on the left and right sides, respectively. Post hoc tests on the nontransformed data provided some support for the prospect that thoroughbred horses were slower at completing the test than other breeds (Mann-Whitney, $N = 15, 37$; left side $U = 191.5$; $P = 0.08$; right side $U = 159$; $P = 0.02$). Horses were significantly faster at completing the test when handled on the left (Wilcoxon, $N = 92$; $W = 1243$; $P < 0.001$). Standardized coefficients for breed ranged from 0.29 to 0.46.

Initial examination of the best models indicated some surprising disagreement as to the best fits for learning the test when handled from the left versus the right. The variable work was added to all but 2 of the best models when handled on the left but none of the best models when handled from the right. It was significant in the second-most parsimonious model (LM, $F_{1,44} = 5.47$; $P = 0.02$), with P values ranging from 0.02 to 0.06. Coefficient for work was negative in all the models that included work, indicating that more work contributed to a faster time to complete the test. Standardized coefficients for work varied from -0.24 to -0.31 .

Sex was included in 2 of the most parsimonious models when handled on the left but was not significant ($P = 0.60$ and 0.47).

Conversely, anxiety was in 11 of the best models when handled on the right but only one of the best models when handled on the



Figure 2. Rein tension applied to 1 rein only. The handler on one side and the fence on the contralateral side of the horse prevented lateral movement of the hindquarters.

left (Table 2). The significance of anxiety in these 11 models ranged from $P = 0.04$ to $P = 0.1$. Standardized coefficient of anxiety in these models ranged from -0.27 to -0.30 , suggesting that horses ranking lower on the anxiety scale took longer to complete the test. Post hoc analysis also suggested that the horses scoring highly on the anxiety scale were quicker to complete the test when handled from the right (Spearman $r = -0.22$; $P = 0.04$; Figure 3).

The explanatory variable defensiveness was found in 8 of the 17 most parsimonious models involving horses when handled from the right. P values for conflict behavior ranged from 0.04 to 0.17, and standardized coefficients ranged from 0.09 to 0.22, suggesting that horses with a higher defensiveness score took longer to complete the test. However, defensiveness was not significantly positively correlated with the latency to complete the test when handled from the right (Spearman $r = 0.09$; $P = 0.39$).

The explanatory variable beginner was included in 10 of the most parsimonious models and found in models both when handled from the left and right sides. However, beginner was not significant in any of these models (P ranged from 0.41 to 0.92) and had standardized coefficients ranging from 0.06 to 0.14.

Discussion

Horse performance is assessed and judged in a specific equestrian discipline, be it dressage, show-jumping round, or racing. To date, little research has been published investigating how horses are trained to this point. The horse's prior learning experience is an important, but often overlooked, factor in training the horse. The poor execution of negative reinforcement can lead horses to desensitize to pressure cues and thus become less responsive to handlers' signals. Rein tension studies have measured differences in rein tension at a specific point in time (Egenvall et al., 2016; Heleski et al., 2009) rather than examining the tension required over time to produce a given response. As a previous study (Fenner et al., 2017a) had found that these same horses' heart rate and head-tossing behavior decreased, together with the required rein tension, over the course of several trials, here we focused on the time the horse took to learn the new behavior.

In the present study, horses with higher anxiety scores, being a composite variable including spooking or shying and calling-out when alone, were faster at completing the test than those with lower scores on this variable but only when handled on the right side. It is possible that these horses have an increased arousal level when interacting with handlers, resulting in more engagement

with the lesson, accounting for the improved performance results (Starling et al., 2013). An alternative explanation may be that these horses with high anxiety scores back away faster to evade the handler and, as such, may not perform so well when the task involved moving toward the handler. Association between lateral bias and personality traits has been found in the domestic dog (Barnard et al., 2017), and our results may reflect a similar response in the horse. As the horses with higher anxiety levels were also learning more efficiently, future research should focus on finding the optimal level of arousal for engagement when learning new tasks. Neither the overly aroused horse nor the suboptimally aroused horse will reach its learning potential, as the Yerkes-Dodson Law (Dodson, 1915) sets out, as the 10th International Society for Equitation Science Training Principle espouses (International Society for Equitation Science, 2015).

The explanatory variable defensiveness appeared an important determinant of learning time when handled on the right rein, in that those horses with higher scores on this variable tended to take longer to complete the test. These behaviors included ear-pinning, tail-swishing, and bucking under saddle, and the increased learning time could indicate that these horses may struggle to learn new tasks possibly becoming frustrated or confused and being less willing to engage positively with new lessons.

Horses completed the test faster when handled on the right rein. By convention, more handling is conducted on the horse's left side, from leading and tacking-up to mounting, and this asymmetry may result in the horse becoming desensitized to pressure cues from the left. As horses did not require significantly less rein tension on the right side throughout the trials (Fenner et al., 2017a), they could have

Table 1
Final explanatory variables used in the models

Name	Scale	Construction
Breed	Yes/no	Thoroughbred/other
Age	Nominal	Age at time of testing
Sex	Mare/gelding	Stallions removed
Work	Frequency	Worked in the arena and groundwork
Beginner	Yes/no	Ridden by beginners
Anxiety	0-4	Spook/shy and calls out when alone
Defensiveness	0-4	Swish tail when ridden/handled, pin ears, pigroot/hump when ridden
Responsiveness	0-4	Stop easily, go easily, steer easily, and loads on to trailer first time
Float	Frequency	Frequency of floating/trailering
Head-tossing	Nominal	Number of head tosses during trials

Table 2

Models within 2 AICc of the most parsimonious model when handled on the (a) left and (b) right reins

Model	Covariate	df	AICc	R ²	P	ΔAICc
(a) Left rein						
Breed + work	Order	48	57.6	0.26	0.002	0
Sex + beginners + breed + work	Order	44	57.9	0.31	0.004	0.25
Sex + breed + work	Order	47	58.5	0.28	0.003	0.84
Beginners + breed + work	Order	45	58.5	0.26	0.007	0.86
Breed + work + head-tossing	Order	47	58.8	0.28	0.003	1.12
Breed + work + anxiety	Order	46	58.9	0.31	0.003	1.19
Breed	Order	49	58.8	0.20	0.003	1.20
Sex + beginner + breed + work + head-tossing	Order	43	59.1	0.33	0.005	1.43
Breed + float + work	Order	46	59.2	0.25	0.008	1.52
Beginners + breed	Order	46	59.3	0.21	0.01	1.61
Sex + breed + work + head-tossing	Order	46	59.7	0.31	0.004	1.97
b) Right rein						
Beginners + breed + anxiety	None	45	58.9	0.20	0.02	0
Breed + anxiety	None	48	59.0	0.17	0.02	0.05
Breed + defensiveness	None	47	59.4	0.17	0.02	0.40
Breed	None	50	59.8	0.08	0.03	0.80
Breed + anxiety + defensiveness	None	45	59.8	0.24	0.02	0.86
Beginners + breed + defensiveness	None	44	59.9	0.19	0.04	0.95
Breed + anxiety	Treatment	47	60.2	0.20	0.02	1.18
Breed + float + defensiveness	None	46	60.2	0.20	0.03	1.2
Breed + anxiety	Order	47	60.4	0.19	0.03	1.41
Age + breed + anxiety	None	47	60.4	0.19	0.03	1.43
Age + beginners + breed + anxiety	None	44	60.5	0.22	0.03	1.57
Beginners + breed + anxiety + defensiveness	None	42	60.6	0.27	0.03	1.65
Beginners + breed + anxiety	Treatment	44	60.7	0.22	0.04	1.74
Breed + float + anxiety + defensiveness	None	44	60.8	0.27	0.02	1.80
Age + breed + defensiveness	None	46	60.8	0.19	0.04	1.88
Beginners + breed + float + defensiveness	None	43	60.9	0.22	0.04	1.90
Beginners + breed + anxiety	Order	44	60.9	0.22	0.04	1.95

df, degrees of freedom; AICc, Akaike information criterion.

become desensitized to handling on their left side as a result of inconsistent and contradictory signals when leading, handling, and riding. One limitation of the present study was that all horses began trials on the left-hand side study (Fenner et al., 2017a). Future research should randomize this variable to investigate the effect on learning.

The current finding that thoroughbred horses were slower at completing the task than other horses, on both left and right sides, merits some discussion. This was one of the most influential variables in all our models. As the current stepping-back task was based solely on the use of negative reinforcement, one possibility is that thoroughbred horses receive minimal well-executed negative

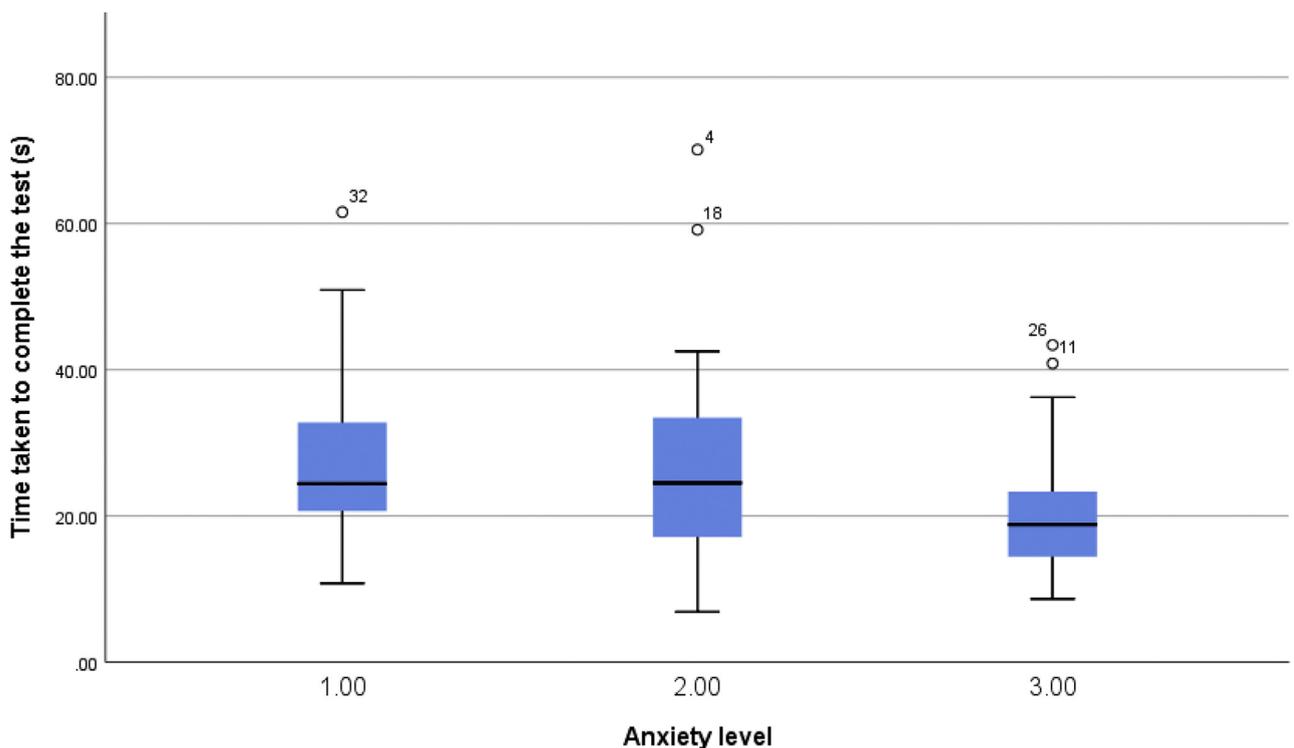


Figure 3. Latencies to complete the test when handled on the right side for horses with anxiety levels of 1 (n = 30), 2 (n = 36), and 3 (n = 22).

reinforcement during their foundation training, leading to a general desensitization to pressure and a tendency to be more difficult to engage with learning based on negative reinforcement. After racing, the wastage rates in the industry (Thomson et al., 2014) make thoroughbred horses an inexpensive purchase option for riders. Accordingly, it is believed that many are paired with inexperienced riders, which must be considered a risk to both horse welfare and rider safety. That said, the market seems to be cautious of safety descriptors in thoroughbreds (McGreevy et al., 2015) in ways that are not detected in other breeds (Hawson et al., 2011; Oddie et al., 2014).

Those horses that had recently received more regular ridden or groundwork completed the current test more quickly when handled on the left side than their unworked counterparts. However, there were no differences in learning performance between the 2 groups when handled on the right rein. This was surprising because it might be expected that horses that were regularly being trained new behaviors might be more receptive to learning in general, although previously, it has been found that horses ridden fewer hours per week displayed significantly fewer abnormal behaviors than those ridden more frequently (Normando et al., 2011). This may reflect the greater amount of time owners and riders may have spent, as convention holds, interacting on the left side of their horses when on the ground. Alternatively, this may be an indication that trainers, riders, and handlers are not routinely incorporating the best practice principles of learning theory when training and handling horses. Deviations from best practice may result in unstable foundation training and a possible resistance to learning new behaviors.

Many riders believe that their horses enjoy being ridden and the Fédération Equestre Internationale (Fédération Equestre Internationale, 2018) refers to happy athletes; however, studies have failed to demonstrate the horses' preference for longer or shorter riding bouts (Konig Von Borstel & Keil, 2012). There remain myriad questions surrounding riding frequency and experience that would be helpful to address. For example, is there an optimal training schedule that improves behavior, performance, and learning ability? Perhaps rider skill, experience, and fitness (Williams & Tabor, 2017), together with an understanding of equine cognition and learning theory (Warren-Smith & McGreevy, 2008), are determining factors in the horses' learning experience. It is possible that beginner riders, through poor application of negative reinforcement, desensitize the horse to pressure (Strunk, 2017), rendering negative reinforcement schedules less effective (Telatin et al., 2017).

To fully understand how behavior, demographics, and management practices influence learning, large volumes of data are needed on a variety of different breeds of horses, kept under varying management schemes. To this end, the coauthors are currently developing a survey instrument, the Equine Behavior Assessment and Research Questionnaire (Fenner et al., 2017). According to the authors' knowledge, the canine equivalent of this instrument, the Canine Assessment and Research Questionnaire, is already proving useful for investigating dog behavior and has been used in more than 70 published studies and has collected data on more than 80,000 dogs (Canine Assessment and Research Questionnaire). An equine database that captures large amounts of data on behavioral variables, management and training would be a valuable resource for researchers and equestrian professionals, as well as riders and owners, and may help match owners to horses, thereby improving horse welfare and rider safety. It might also be used to describe horses' behavior, with defined terms, as a reflection of ongoing training or even at the point of sale.

Conclusions

The use of best practice management and training techniques will positively influence both learning and behavior. Further

investigation of these techniques will help us optimize learning outcomes, resulting in improved horse welfare.

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Conflict of interest

The authors declare no conflict of interest. They have no financial or personal relationships that could inappropriately influence or bias the content of the article.

References

- Baragli, P., Vitale, V., Sighieri, C., Lanata, A., Palagi, E., Reddon, A.R., 2017. Consistency and flexibility in solving spatial tasks: different horses show different cognitive styles. *Sci. Rep.* 7, 16557.
- Barnard, S., Wells, D., Hepper, P., Milligan, A., 2017. Association between lateral bias and personality traits in the domestic dog (*Canis familiaris*). *J. Comp. Psychol.* 131, 246–256.
- Bland, T., 2007. Road to the Horse, Limited Edition Box Set. 2003, 2005, 2006. Ride the Remuda Productions Inc, Sylvester, TX.
- Burnham, K.P., Anderson, D.R., 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. Springer, New York, NY.
- Chateau, H., Degueurce, C., Denoix, J., 2004. Evaluation of three-dimensional kinematics of the distal portion of the forelimb in horses walking in a straight line. *Am. J. Vet. Res.* 65, 447–455.
- Christensen, J.W., Ahrendt, L.P., Lintrup, R., Gaillard, C., Palme, R., Malmkvist, J., 2012. Does learning performance in horses relate to fearfulness, baseline stress hormone, and social rank? *Appl. Anim. Behav. Sci.* 140, 44–52.
- Clayton, Larson, B., Kaiser, L., Lavagnino, M., 2010. Length and elasticity of side reins affect rein tension at trot. *Vet. J.* 188, 291–294.
- Clayton, Sha, D., Stick, J., Elvin, N., 2007a. 3D kinematics of the equine metacarpophalangeal joint at walk and trot. *Vet. Comp. Orthop. Traumatol.* 20, 86–91.
- Clayton, Sha, D., Stick, J., Robinson, P., 2007b. 3D kinematics of the interphalangeal joints in the forelimb of walking and trotting horses. *Vet. Comp. Orthop. Traumatol.* 20, 1–7.
- Dodson, J.D., 1915. The relation of strength of stimulus to rapidity of habit-formation in the kitten. *J. Anim. Behav.* 5, 330–336.
- Egenvall, A., Roepstorff, L., Rhodin, M., Eisersjö, M., Clayton, H.M., 2016. Maximum and minimum peaks in rein tension within canter strides. *J. Vet. Behav.: Clin. Appl. Res.* 13, 63–71.
- Events, D., 2016. Equitana Australia, Melbourne, Australia. Available at: <http://www.definitiveevents.com.au/equitana-australia.html>. Accessed January 16, 2018.
- Fédération Equestre Internationale, 2018. Dressage rules. FEI, Lausanne, Switzerland. Available at: https://inside.fei.org/sites/default/files/DRE-Rules_2018_Clean_Version_0.pdf. Accessed March 20, 2018.
- Fenner, K., Webb, H., Starling, M., Freire, R., Buckley, P., McGreevy, P., 2017a. Effects of pre-conditioning on behavior and physiology of horses during a standardised learning task. *PLoS One* 12, e0174313.
- Fenner, K., Freire, R., McLean, A., McGreevy, P. 13th International Equitation Science Conference. In: Randle, H., Waran, N. & Kent, L., eds. Equitation Science in Practice: Collaboration, Communication and Change. 2017. Charles Sturt University, Wagga Wagga, Australia. 43.
- Fenner, K., McLean, A., McGreevy, P., 2018. Cutting to the chase: how round-pen, lunging and high-speed liberty work may compromise horse welfare. *J. Vet. Behav.: Clin. Appl. Res.* In Press.
- Freire, R., Buckley, P., Cooper, J.J., 2009. Effects of different forms of exercise on post inhibitory rebound and unwanted behaviour in stabled horses. *Equine Vet. J.* 41, 487–492.
- Gorecka-Bruzda, A., Kosinska, I., Jaworski, Z., Jezierski, T., Murphy, J., 2015. Conflict behavior in elite show jumping and dressage horses. *J. Vet. Behav.: Clin. Appl. Res.* 10, 137–146.
- Hawson, L.A., Oddie, C., McLean, A.N., McGreevy, P.D., 2011. Is safety valued in the Australian pony market? *J. Vet. Behav.: Clin. Appl. Res.* 6, 254–260.
- Heleski, C.R., McGreevy, P.D., Kaiser, L.J., Lavagnino, M., Tans, E., Bello, N., Clayton, H.M., 2009. Effects on behaviour and rein tension on horses ridden with or without martingales and rein inserts. *Vet. J.* 181, 56–62.
- Henshall, C., McGreevy, P.D., 2014. The role of ethology in round pen horse training—a review. *Appl. Anim. Behav. Sci.* 155, 1–11.
- Hockenull, J., Creighton, E., 2014. Management practices associated with owner-reported stable-related and handling behaviour problems in UK leisure horses. *Appl. Anim. Behav. Sci.* 155, 49.
- International Society for Equitation Science, I. S. F. E. S. 2015. Principles of Learning Theory in Equitation. In: McLean, A., McGreevy, P. & Christensen, J. W. (eds.) Available at: <https://equitation-science.com/about/ises-training-principles>. Accessed September 27, 2018.

- Janczarek, I., Stachurska, A., Wilk, I., 2014. Which horses are most susceptible to the initial natural training? *Ann. Anim. Sci.* 14, 637–648.
- Johnson, B., Jerald, B., Omland, Kristian, S., 2004. Model selection in ecology and evolution. *Trends Ecol Evol* 19, 101–108.
- Kelekna, P., 2009. *The Horse in Human History*. Cambridge University Press, New York, NY.
- Konig Von Borstel, U., Keil, J., 2012. Horses' behavior and heart rate in a preference test for shorter and longer riding bouts. *J. Vet. Behav.: Clin. Appl. Res.* 7, 362–374.
- Krueger, K., Farmer, K., Heinze, J., 2014. The effects of age, rank and neophobia on social learning in horses. *Anim. Cogn.* 17, 645–655.
- Lansade, L., Marchand, A.R., Coutureau, E., Balle, C., Polli, F., Calandreau, L., 2017. Personality and predisposition to form habit behaviours during instrumental conditioning in horses (*Equus caballus*). *PLoS One* 12, e0171010.
- Lansade, L., Simon, F., 2010. Horses' learning performances are under the influence of several temperamental dimensions. *Appl. Anim. Behav. Sci.* 125, 30–37.
- Lesimple, C., Fureix, C., Lescolan, N., Richard-Yris, M.-A., Hausberger, M., 2011. Housing conditions and breed are associated with emotionality and cognitive abilities in riding school horses. *Appl. Anim. Behav. Sci.* 129, 92–99.
- Lesimple, C., Poissonnet, A., Hausberger, M., 2016. How to keep your horse safe? An epidemiological study about management practices. *Appl. Anim. Behav. Sci.* 181, 105–114.
- Lloyd, A.S., Martin, J.E., Bornett-Gauci, H.L.I., Wilkinson, R.G., 2008. Horse personality: variation between breeds. *Appl. Anim. Behav. Sci.* 112, 369–383.
- Matthew, R.E., Symonds, Moussali, 2011. A brief guide to model selection, multi-model inference and model averaging in behavioural ecology using Akaike's information criterion. *Behav. Ecol. Sociobiol.* 65, 13–21.
- McGreevy, P.D., Thomson, P.C., 2006. Differences in motor laterality between breeds of performance horse. *Appl. Anim. Behav. Sci.* 99, 183–190.
- McLean, A., McGreevy, P.D., 2015. Principles of learning theory in equitation. Revisiting the ISES principles. Available at: <http://www.equitation-science.com/learning-theory-in-equitation>. Accessed September 27, 2018.
- McLean, A., McGreevy, P., Christensen, J., 2017. Principles of Learning Theory in Equitation. International Society for Equitation Science. Available at: <https://equitation-science.com/about/ises-training-principles>. Accessed September 27, 2018.
- McLean, M., McLean, A., 2008. *Academic Horse Training: Equitation Science in Practice*. Australian Equine Behaviour Centre, Victoria, Australia.
- Murphy, J., Sutherland, A., Arkins, S., 2005. Idiosyncratic motor laterality in the horse. *Appl. Anim. Behav. Sci.* 91, 297–310.
- Nestadt, C., Lusi, C., Davies, H., 2015. Effect of different head-and-neck positions on nuchal ligament dimensions in fetal foals. *J. Equine Vet. Sci.* 35, 153–160.
- Normando, S., Meers, L., Samuels, W.E., Faustini, M., Ödberg, F.O., 2011. Variables affecting the prevalence of behavioural problems in horses. Can riding style and other management factors be significant? *Appl. Anim. Behav. Sci.* 133, 186–198.
- O'Brien, E., Stevens, K., Pfeiffer, D., Hall, J., Marr, C., 2005. Factors associated with the wastage and achievements in competition of event horses registered in the United Kingdom. *Vet. Rec.* 157, 9–13.
- Ödberg, F., Bouissou, M.-F., 1999. The development of equestrianism from the baroque period to the present day and its consequences for the welfare of horses. *Equine Vet. J.* 31, 26–30.
- Oddie, C., Hawson, L., McLean, A., McGreevy, P., 2014. Is safety valued in the Australian recreational (non-thoroughbred) riding horse market? *J. Vet. Behav.: Clin. Appl. Res.* 9, 375–381.
- Olczak, K., Nowicki, J., Klocek, C., 2016. Motivation, stress and learning—critical characteristics that influence the horses' value and training method—a review. *Ann. Anim. Sci.* 16, 641–652.
- R Core Team, 2013. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. Available at: <http://www.R-project.org/>.
- Starling, Cody, D., Branson, N., McGreevy, P., 2013. Conceptualising the impact of arousal and affective state on training outcomes of operant conditioning. *Animals* 3, 300.
- Starling, McLean, A., McGreevy, P., 2018. The contribution of equitation science to minimising horse-related risks to humans. *Animals* 6, 15.
- Strand, E., Braathen, L., Hellsten, M., Huse-Olsen, L., Bjornsdottir, S., 2007. Radiographic closure time of appendicular growth plates in the Icelandic horse. *Acta Vet. Scand.* 49, 19.
- Strunk, R., 2017. Effects of rider experience level on horse kinematics and behavior. Masters of Science, Clemson University. Available at: <https://equitation-science.com/about/ises-training-principles>. Accessed September 27, 2018.
- Telatin, A., Franklin, J., Bargali, P., Greene, E., 2017. A pilot study: can whip use changes to improve equine welfare have unintended consequences? In: Randle, H., Waran, N., Kent, L. (Eds.), 13th International Equitation Science Conference. Charles Sturt University: Wagga Wagga, Australia.
- Thomas, R., 2010. Predictability in an unpredictable environment: training the police horse using learning theory. *J. Vet. Behav.: Clin. Appl. Res.* 5, 218.
- Thomson, P.C., Hayek, A.R., Jones, B., Evans, D.L., McGreevy, P.D., 2014. Number, causes and destinations of horses leaving the Australian Thoroughbred and Standardbred racing industries. *Aust. Vet. J.* 92, 303–311.
- Valençon, M., Levy, F., Fortin, M., Leterrier, C., Lansade, L., 2013a. Stress and temperament affect working memory performance for disappearing food in horses, *Equus caballus*. *Anim. Behav.* 86, 1233–1240.
- Valençon, M., Levy, F., Prunier, A., Moussu, C., Calandreau, L., Lansade, L., 2013b. Stress modulates instrumental learning performances in horses (*Equus caballus*) in interaction with temperament. *PLoS One* 8, e62324.
- Valençon, M., Levy, F., Moussu, C., Lansade, L., 2017. Stress affects instrumental learning based on positive or negative reinforcement in interaction with personality in domestic horses. *PLoS One* 12, e0170783.
- Visser, E., Van Reenen, C.G., Blokhuis, M.Z., Morgan, E.K.M., Hassmen, P., Rundgren, T.M., Blokhuis, H.J., 2008. Does horse temperament influence horse-rider cooperation? *J. Appl. Anim. Welf. Sci.* 11, 267–284.
- Von Borstel, U.U., Duncan, I.J.H., Shoveller, A.K., Merckies, K., Keeling, L.J., Millman, S.T., 2009. Impact of riding in a coercively obtained Rollkur posture on welfare and fear of performance horses. *Appl. Anim. Behav. Sci.* 116, 228–236.
- Warren-Smith, A.K., Curtis, R., Greetham, L., McGreevy, P.D., 2007. Rein contact between horse and handler during specific equitation movements. *Appl. Anim. Behav. Sci.* 108, 157–169.
- Warren-Smith, A.K., McGreevy, P.D., 2008. Equestrian coaches' understanding and application of learning theory in horse training. *Anthrozoös* 21, 153–162.
- Werhahn, H., Hessel, E.F., Van Den Weghe, H.F.A., 2012. Competition horses housed in single stalls (II): effects of free exercise on the behavior in the stable, the behavior during training, and the degree of stress. *J. Equine Vet. Sci.* 32, 22–31.
- Williams, J.L., Tabor, G., 2017. Rider impacts on equitation. *Appl. Anim. Behav. Sci.* 190, 28–42.