Applied Animal Behaviour Science 122 (2010) 41–47

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

Differences in temperament traits between crib-biting and control horses

Krisztina Nagy [a,*], Gábor Bodó [a], György Bárdos [b], Noémi Bánszky [c], Péter Kabai [a]

[a] Szent István University, Faculty of Veterinary Sciences, István u. 2, H-1078 Budapest, Hungary
[b] Eötvös Loránd University, Department of Physiology and Neurobiology, Pázmány P. stny. 1/C, H-1117 Budapest, Hungary
[c] Eötvös Loránd University, Faculty of Special Education, Ecseri u. 3, H-1097 Budapest, Hungary

ARTICLE INFO

Article history:
Accepted 11 November 2009
Available online 6 December 2009

Keywords:
Crib-biting
Stereotypic behaviour
Equine temperament
Trainability
Coping strategies

ABSTRACT

Recent studies have suggested that crib-biting in horses is associated with diminished capacity of learning or coping with stress. Such findings raise the question whether trainability, which is fundamentally important in practice, could also be affected by stereotypic behaviour. Trainability of a horse is difficult to assess in simple tests, however, it is reliably estimated by experienced riders.

To assess trainability and other characteristics related to that, a questionnaire survey was conducted with the owners of 50 crib-biting and 50 control horses. Where possible, control horses were selected from the same establishment as crib-biters. Groups did not differ significantly regarding age, breed, gender, training level or usage.

Principal component analysis revealed three main factors which can be labelled as 'Anxiety', 'Affability' and 'Trainability'. The 'Anxiety' factor consisted of the items 'Nervousness', 'Excitability', 'Panic', 'Inconsistent emotionality', 'Vigilance', 'Skittishness', and 'Timidity'. 'Affability' consisted of 'Friendliness toward people', 'Cooperation', 'Docility' and 'Friendliness toward horses'. 'Trainability' involved 'Concentration', 'Trainability', 'Memory', and 'Perseverance'.

Temperament traits were not affected by age, gender, breed or training level, but the usage of the horse and the presence of crib-biting behaviour had significant effects. Competition horses had lower level of 'Anxiety' ($p = 0.032$) and higher level of 'Trainability' ($p = 0.068$) than leisure horses.

Crib-biting horses had significantly lower level of 'Anxiety' than control horses ($p < 0.001$), while 'Trainability' and 'Affability' did not differ between groups ($p = 0.823$ and $p = 0.543$, respectively).

Competition horses are more often exposed to novel environment and to frightening stimuli (e.g. colourful obstacles) than leisure horses and therefore might have also become more habituated to these types of stimuli. Coping with novel situation may be enhanced by defusing nervous behaviour by the more experienced riders of competition.

Previous studies indicated crib-biting horses to be less reactive when challenged as compared to control horses. We suggest that the virtual calmness and lower nervousness of the crib-biting horses might be due to the passive coping style of these animals.

'Affability' of horses might be more related to housing and management conditions than to crib-biting. Contrary to expectations, scores on 'Trainability' had not coincided with the impaired learning of crib-biting horses reported in laboratory tests. However, previous behavioural tests on equine learning rarely had a direct relevance to the training abilities of the horses.

* Corresponding author. Tel.: +36 1 4784213; fax: +36 1 4784213.
E-mail address: kris.nagy@gmail.com (K. Nagy).

0168-1591/$ – see front matter
doi:10.1016/j.applanim.2009.11.005

Our results do not support crib-biting stereotypy to affect performance in training, which is a complex learning process involving cooperation and docility in the social environment.

1. Introduction

Abnormal stereotypy in animals is defined as repetitive behaviour induced by frustration, repeated attempts to cope and/or central nervous system dysfunction (Mason and Rushen, 2006). Crib-biting has been reported as the most prevalent stereotypic behaviour in horses, which involves the horse grasping fixed object with its incisors, contracting the muscles of the neck, and producing a grunting sound (McGreevy et al., 1995). Research suggests that the physiological mediation of crib-biting behaviour involves both gastrointestinal and central nervous system dysregulation, however, it is debated which one is causal of the other (Nicol et al., 2002; Hemmings et al., 2007; McBride and Hemmings, 2009).

A growing number of epidemiological studies have suggested that low forage or high grain diet are the major risk factors in the development of crib-biting (McGreevy et al., 1995; Waters et al., 2002). Feeding concentrated diet can affect the behaviour and ingestion physiology of horses because it reduces the time of foraging and also the amount of saliva which is produced exclusively during mastication (Nicol, 1999). Deprivation of horses of normal grazing in itself might be stressful; moreover, decrease of the flow of alkaline saliva may lead to over-acidification of the stomach. Saliva is produced and swallowed during crib-biting, thus it can be effective in buffering stomach pH level (Moeller et al., 2008). Indeed, Nicol et al. (2002) showed that faecal pH of crib-biting foals was lower, and antacid diet improved their condition somewhat more as compared to foals without stereotypy. Once fixed, this stereotypy can alter the reward system of the brain, making such habits so addictive.

Alternatively, chronic stress, especially early in life (e.g. weaning) in combination with genetic predisposition may be the cause of the development of a stereotypy (Cabib et al., 1998; Waters et al., 2002; Albright et al., 2009; McBride and Hemmings, 2009). Stress may induce changes in the mesoaccumbens dopamine neurophysiology resulting in an imbalance between the direct and indirect pathways of the basal ganglia and an enhanced efferent neural transmission from the striatum to the cortex (McBride and Hemmings, 2005). Imbalance in the dopaminergic system can cause a highly motivated state directed toward goal attainment even in the absence of any goal-oriented situation, which may later serve as a basis for the development of stereotypies (McBride and Hemmings, 2009).

Regardless of the exact nature of causation, basal ganglia dysfunction seems to be involved in stereotypic behaviour. This is corroborated by hundreds of laboratory studies in which stereotypic behaviour was successfully induced by dopaminergic agents or reduced by dopamine antagonists. Although subtelencephalic mediation of stereotypic behaviour cannot be ruled out (Kabai et al., 1999), the dopaminergic system does affect cognitive processes in the cortex through optimizing the level of attention to stimuli in relation to error of prediction, and influences working and long-term memory formation (for a review see Wise, 2004). Dysfunction of the dopaminergic system thus may diminish cognitive abilities, and as a consequence crib-biting horses can show deficits in learning.

Crib-biting horses were less successful and required longer time to perform an instrumental task (Hausberger et al., 2007) and persisted longer during extinction of a positive reinforcement operant task than control horses (Hemmings et al., 2007). Furthermore, crib-biting horses failed to recognise differences in short versus long delays in reinforcement in an instrumental choice procedure (Parker et al., 2008). Contrary to control horses, crib-biting horses seem to favour stimulus-response learning to response-outcome learning (Parker et al., 2009).

Performance in a learning test, however, can be affected by sensitivity to stress, temperament, and other persistent individual characteristics. Previous studies on stress sensitivity of crib-biting horses are inconsistent. Minero et al. (1999) found that crib-biting horses were less reactive while restrained with a lip-twitch. However, when horses were exposed to a rapidly inflating balloon, crib-biters tended to react more strongly to the stimulus (Minero et al., 1999). Bachmann et al. (2003) found that crib-biters had lower vagal and higher sympathetic tone during rest than control horses, resulting in less flexible physiological reactivity when facing a stressor. Crib-biting horses were more sensitive to stress and spent less time resting compared to control horses, which may further affect their performance (Minero et al., 1999; McGreevy et al., 2001; Bachmann et al., 2003; Hausberger et al., 2007). On the other hand, crib-biters seem to cope well with feeding related stress by proactive responses (Nagy et al., 2009). Such passive coping strategy in an active operant conditioning paradigm applied in most studies, however, may appear as diminished capacity for learning.

Diminished learning abilities in crib-biters raise the question whether such differences would also emerge in trainability, which is fundamentally important in practice. Trainability of a horse is difficult to assess in simple tests, however, it is reliably estimated by experienced riders.

A questionnaire relying on the opinion of caretakers regarding trainability and emotionality of horses was worked out by Momozawa et al. (2005). In their study, 3 caretakers completed a questionnaire consisting of 20 questions for each horse. Factor analysis revealed three distinct factors (‘Anxiety’, ‘Affability’ and ‘Trainability’) which were validated by similar results replicated in another group of race horses.

The 'Anxiety' factor consisted of items reflecting 'Nervousness', 'Excitability', 'Panic', 'Inconsistent emotionality', 'Vigilance', 'Skittishness', and 'Timidity'. This factor shares similarities to 'Neuroticism' found by McGrogan et al. (2008) or Morris et al. (2002) and to 'Anxiousness' reported by Lloyd et al. (2007).

'Affability' contained items as 'Friendliness toward people', 'Cooperation', 'Docility' and 'Friendliness toward horses' and shares similarities to factor labelled as 'Agreeableness' (Morris et al., 2002; McGrogan et al., 2008) or 'Dominance' (Lloyd et al., 2007).

'Trainability' was based on items reflecting 'Concentration', 'Trainability', 'Memory' and 'Perseverance'. Previous studies did not measured 'Trainability' per se (Morris et al., 2002; Lloyd et al., 2007), or revealed a factor which contained items related to 'Trainability, 'Dominance' and 'Neuroticism' as well ('Extraversion' factor of McGrogan et al., 2008). With the questionnaire of Momozawa et al. (2005), 'Trainability' could be measured separately from 'Anxiety'.

All three temperament traits revealed in the study of Momozawa et al. (2005) had sufficient internal consistency, and horses evaluated as highly anxious by the raters tended to show greater heart rate increases and defecate more often during exposure to novel stimuli than other horses (Momozawa et al., 2003).

Questionnaire studies on individual characteristics, especially in dogs and horses, have demonstrated that many traits are consistent and characteristic to the individuals (Jones and Gosling, 2005; Lloyd et al., 2007). Pattern of behaviour that is consistent across time and situations is often coined personality. In this study we did not address the question whether horses have human-like personality or not (Gosling, 2001), we simply applied the questionnaire method as a means to reveal possible differences in trainability between crib-biting and control horses.

2. Materials and methods

2.1. Animals

Fifty control and 50 crib-biting horses staying at different riding schools were studied. All crib-biting horses had performed the stereotypy for more than 6 months prior to the study. Where possible, control horses were selected from the same establishment, and stereotypic and control horses were matched for breed and management routine as well.

Mean age (±S.E.) was 9.8 ± 0.5 years for control and 9.3 ± 0.7 years for crib-biting horses. Groups did not differ regarding age ($t_{88} = -0.607$, $p = 0.546$), breed ($\chi^2_3 = 3.717$, $p = 0.294$), gender ($\chi^2_2 = 2.691$, $p = 0.260$), usage ($\chi^2_1 = 1.973$, $p = 0.160$) or training level ($\chi^2_1 = 0.703$, $p = 0.402$, Table 1).

All horses were fed oats and hay, turned out to pasture daily and were ridden regularly. No differences were found between crib-biting and control horses regarding the daily amount of oats fed ($t_{25} = 1.669$, $p = 0.107$), the weekly hours of being ridden ($t_{25} = 0.685$, $p = 0.499$) or staying in pasture ($t_{35} = 1.174$, $p = 0.248$).

Table 1
Number of horses in each level of the independent factors.

Independent factors	Levels of the factor	Number of control horses	Number of crib-biting horses
Breed	Thoroughbred	3	3
	Hungarian Halfbred	28	20
	Hungarian Sport Horse	14	16
	Other	5	11
Gender	Stallion	5	6
	Gelding	21	28
	Mare	24	16
Training level	Basic	20	15
	Upper	30	35
Usage	Leisure	31	23
	Competition	19	27

2.2. Questionnaire

The questionnaire created and validated by Momozawa et al. (2005) was slightly modified for the present study: a question corresponding only to race horses ('Gate entrance') was excluded. Horse-owners were asked to fill the questionnaire. For each 19-question item, translation of the original description was given. Owners could evaluate the horses item by item on a 1–5 scale with the latter being the highest rank for a given item (Table 2).

2.3. Statistical analysis

Principal component analysis (PCA) was used with Varimax rotation with Eigenvalue > 1 on the items of the questionnaire. The number of extracted factors was decided after visual inspection, using the rules of the Scree test. Factor scores were calculated by using the Regression method of Reise et al. (2000). Differences in the obtained factor scores among control and crib-biting horses were tested by general linear models, where 'Anxiety', 'Affability' and 'Trainability' served as dependent factors in the separate models and the effect of group (control or crib-biting horses), age, breed, gender, usage (horses used for competition or for leisure purposes), training level of the horses (basic or upper) and their possible interactions served as independent factors.

As the factor structure in the present study did not match precisely that obtained by Momozawa et al. (2005), we tested the differences between groups in two ways. First, we used factor scores obtained by our PCA. Second, we recalculated the profile of every horse to match the factor structure obtained by Momozawa et al. (2005). This was done by summing the scores of items listed by Momozawa et al. (2005) as 'Anxiety', 'Affability' and 'Trainability' (Table 2). The levels of significance (p-values) are referred as p_{PCA} for the first and p_{SUM} for the second analysis.

Diagnostic plots of the residuals and standardized residuals were used to check the normality and variance homogeneity assumptions of the models. The distribution of the error terms proved to be normal. All analyses were carried out using the R 2.7.2. Statistical Software (R

Table 2
Questionnaire items with description and the factor loadings of each questionnaire item.

Item	Description (this horse tend to ...)	Scale (1 ↔ 5)	Factor1	Factor2	Factor3	Factor4	Factor5
Nervousness	become nervous about insects, noises, etc.	Calm Nervous		<u>**0.682**</u>			
Concentration	be trainable and undisturbed by the environment	Poor Excellent	<u>**0.702**</u>	−0.381			
Self-reliance	be at ease if left alone away from the herd	Restless At ease		−**0.535**			
Trainability	be trained easily and promptly	Poor Excellent	<u>**0.875**</u>				
Excitability	get excited easily	Not excitable Excitable		–		−0.632	
Friendliness toward people	be never aggressive or fearful	Unfriendly Friendly			<u>**0.836**</u>		
Curiosity	be interested in novel objects and approach them	Rarely Frequently			0.404	**0.5554**	
Memory	memorize what it learned or was trained	Poor Excellent	<u>**0.822**</u>				
Panic	get excited to an abnormal extent	Rarely Frequently		<u>**0.714**</u>			
Cooperation	be cooperative with caretaker when handled	Rarely Frequently	**0.668**		<u>0.342</u>		
Inconsistent emotionality	be unpredictable from day to day	Consistent Inconsistent		–		**0.727**	
Stubbornness	be obstinate once it resists a command	Obedient Stubborn	−**0.468**		−0.374	0.482	
Docility	be docile in general	Active Docile	**0.772**		–		
Vigilance	be vigilant about surroundings	Rarely Frequently		<u>0.364</u>			**0.768**
Perseverance	be patient with various stimuli	Impatient Patient	–	−**0.666**	**0.490**		
Friendliness toward horses	interact with other horses in a friendly manner	Unfriendly Friendly			<u>**0.721**</u>		
Competitiveness	be dominant in agonistic encounters with other horses	Subordinate Dominant					**0.796**
Skittishness	get surprise easily	Not skittish Skittish		<u>**0.826**</u>			
Timidity	be timid in a novel environment	Audacious Timid		<u>**0.698**</u>			

Question items are listed according to the order in the actual questionnaire sheet. Bold font represents that the item's absolute value is more than 0.4, which indicates that the item belongs to the given factor. Empty cells indicate that the absolute value of the factor loading is below 0.3. Scores underlined symbolise items that belong to a certain factor according to Momozawa et al. (2005).

Development Core Team, 2007). The significance level was set at $p < 0.05$, whereas an effect was considered a *trend* when p was between 0.05 and 0.10.

3. Results

3.1. Factor structure

Principal component analysis yielded 5 factors accounting for 65.1% of the common variance. Factor 1 consisted of 3 out of the 4 items listed as 'Trainability' by Momozawa et al. (2005) and contained 3 extra items ('Concentration', 'Trainability', 'Memory', 'Cooperation', 'Docility', and with negative score 'Stubbornness'). In the 2003 survey of Momozawa et al. (2005) 'Docility' also belonged to 'Trainability' but not in the 2002 survey. Factor 2 consisted of 4 out of the 7 items listed as 'Anxiety' by Momozawa et al. (2005) and of 2 extra items: 'Self-reliance' and 'Perseverance'. Both extra items belonged to 'Anxiety' in one of the two surveys of Momozawa et al. (2005). Factor 3 consisted of 2 out of the 4 items listed as 'Affability' by Momozawa et al. (2005) and of 1 extra item: 'Perseverance' (Table 2).

3.2. Differences between groups

Analysis of group differences yielded similar results whether we used the raw factors scores obtained by PCA of our data or the sum of item scores rearranged to match factor structure obtained by Momozawa et al. (2005).

Crib-biting horses had lower level of 'Anxiety' as compared to control horses ($p_{PCA} = 0.019$, $p_{SUM} < 0.001$), and the usage of the horse (leisure or competition) had significant effect as well ($p_{PCA} = 0.078$, $p_{SUM} = 0.032$). Among both crib-biting and control horses, those used for competition had lower level of 'Anxiety' than the ones used for leisure purposes. No differences were found among crib-biting and control horses regarding 'Trainability' ($p_{PCA} = 0.351$, $p_{SUM} = 0.823$) or 'Affability' ($p_{PCA} = 0.232$, $p_{SUM} = 0.543$), but on 'Trainability', the usage of the horse had some effect (Fig. 1). There was a trend for competition horses to have higher level of 'Trainability' compared to leisure horses ($p_{PCA} = 0.501$, $p_{SUM} = 0.068$). No other factors (age, breed, gender or training level of the horses) contributed significantly to the variance of the examined temperament

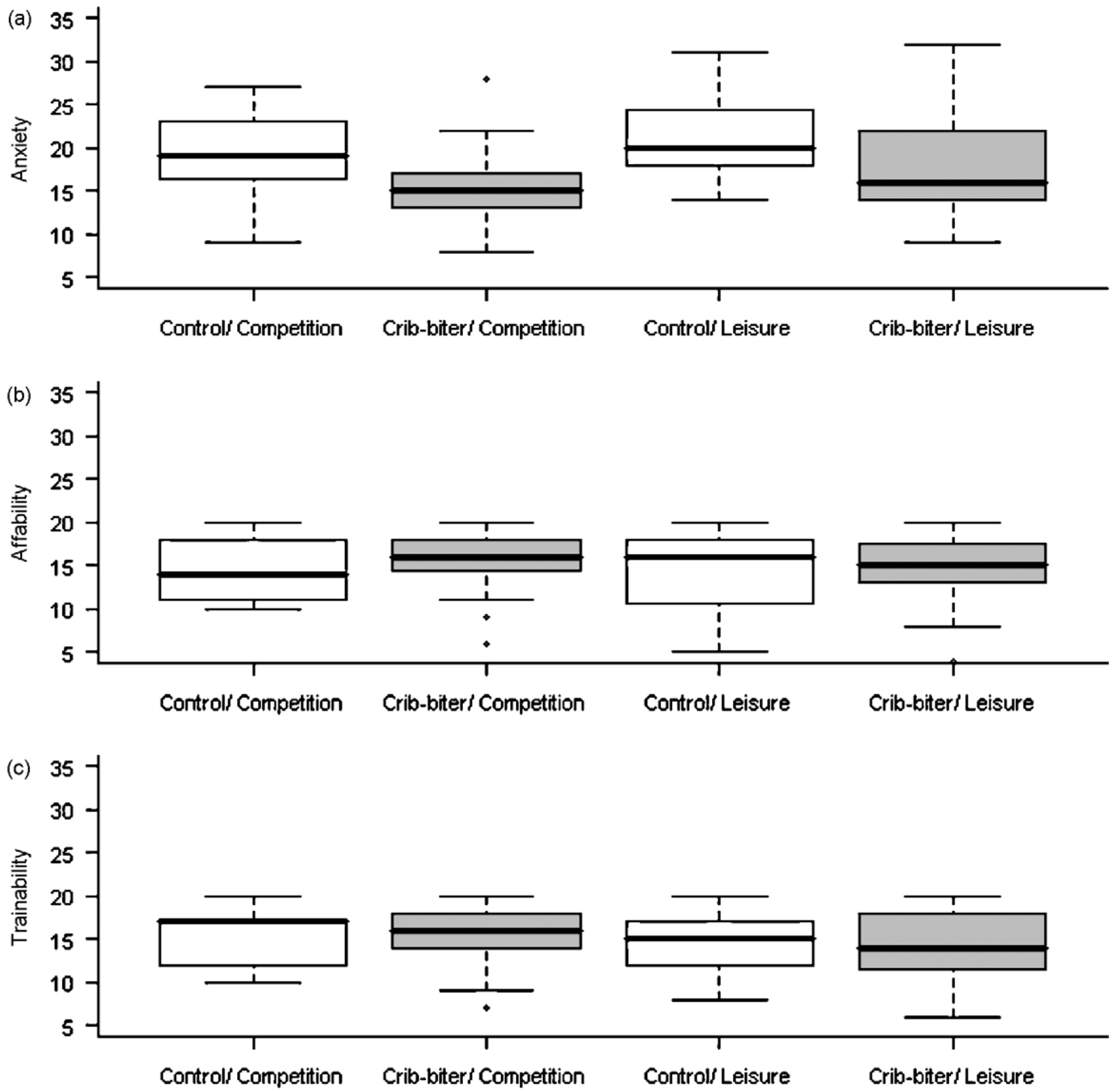

Fig. 1. The box plot of 'Anxiety' (a), 'Affability' (b) and 'Trainability' (c) in control and crib-biting horses used for competition or leisure purposes.

traits. However, regarding 'Trainability', the confounding effect of training level and breed can not be ruled out, since competition horses had higher training level compared to horses used for leisure purposes ($\chi^2_1 = 23.811$, $p < 0.001$) and most of the Hungarian Sport Horses were used for competition ($\chi^2_1 = 8.606$, $p = 0.003$).

4. Discussion

Factors extracted in the present study explained 65% of the common variance which is somewhat lower than those reported by Momozawa et al. (2005). The possible causes of the difference can be that the horse population in our study was heterogeneous, consisting of leisure and sport horses, normal and stereotypic individuals. Additionally, excluding a variable ('Gate entrance') which formed a separate factor in the study of Momozawa et al. (2005) could also have an effect on the strength of PCA. Nevertheless, the focal questions of our study, namely whether 'Trainability' is affected by crib-biting, and how it may be related to 'Anxiety' and 'Affability' can be addressed by our results, as these three factors were consistent with the previous studies. Moreover, differences among groups did not change whether tested by factor scores obtained by PCA or item scores rearranged according to the factors of Momozawa et al. (2005).

Crib-biting horses, used either for competition or leisure purposes, have been given significantly lower scores for items belonging to 'Anxiety' than control horses. This is an apparent contradiction to previous studies reporting that horses being more reactive have higher risk for developing stereotypies (Albright et al., 2009). Crib-biting, however, may be associated not simply with a general level of reactivity, but rather with specific sensitivity to stress imposed by feeding related frustration. Once developed, crib-biting as a passive coping strategy to frustration may reduce subjective stress (Nagy et al., 2009). Thus low level of 'Anxiety' in crib-biting horses does not necessary imply that these horses are 'calmer' than non-stereotypic horses. Less reactivity to threatening situations also can be caused by apathetic or ambivalent behaviour tendencies typical for a passive coping strategy prevalent in crib-biting horses (Koolhaas et al., 1999; Horváth et al., 2007; Koolhaas, 2008; Nagy et al., 2009).

Competition horses, either cribbers or controls, were reported by the owners to have lower 'Anxiety' as compared to leisure horses. Such differences can be due to either the use or the selection of individuals for competition. Competition horses are more often exposed to novel environment and to frightening stimuli (e.g. colourful obstacles) than leisure horses and therefore might have also become more habituated to these types of stimuli. Coping with novel situation may be enhanced by defusing nervous behaviour by the more experienced riders of competition. On the other hand, horses incapable to cope with stress are not favoured for competition purposes, therefore selection my also be important to explain the differences found between leisure and competition horses.

There were no significant differences between crib-biting and control, or competition and leisure horses regarding 'Affability'. Reactions of horses to interactions with humans are mostly the result of the interplay between their own temperament, the temperament and skills of the human and the experience acquired with humans. Studies show that deficits in the management conditions (housing, feeding, possibilities for social contact and training methods) may lead to relational problems between horses and humans (Hausberger et al., 2008). Since management practices were very similar for all horses in our study, differences in 'Affability' were not expected.

There was a slight trend for competition horses to obtain higher scores for items belonging to 'Trainability', which can be a result of their higher training level compared to horses used for leisure purposes, and/or considering trainability traits when selecting horses for competition. Contrary to expectations, there was no difference in 'Trainability' between crib-biting and control horses. Experimental studies published so far on differences in learning between crib-biting and control horses addressed cognition at a moderately basic level in artificial environments, and relied almost exclusively on positive reinforcement by food (Hausberger et al., 2007; Hemmings et al., 2007; Parker et al., 2008, 2009).

Certain skills of horses (e.g. stimulus discrimination, association learning, spatial navigation) can be assessed by simple tests, however, training is fundamentally different from simple operant conditioning. Training capitalizes on natural behaviour of horses and aims to change the direction and mode of locomotion under direct command by the rider. Training, thus, contrary to operant conditioning, has a strong social context and builds on cooperation and docility as reflected by the 'Trainability' factor. Positive reinforcement with food exclusively used in learning studies on horses is rarely applied in training which involves positive feedback by social cues, negative reinforcement, and more importantly physical aid (McGreevy and McLean, 2009). This may explain why previous research on equine learning have not had a direct application to training methods commonly applied in the horse industry (McCall, 1990; Murphy and Arkins, 2007).

Concentrated food as reinforcement may be alone a critical factor in poor performance of crib-biting horses in the conditioning paradigm, as cribbers can become passive or stressful when not able to reach a seen or predicted food source (Nagy et al., 2009). We suggest that trainability cannot be inferred in simple operant conditioning paradigm and further research is needed to work out appropriate methods to quantify trainability.

5. Conclusions and limitations

The present study suggests that crib-biting is not associated with imbalanced emotionality or diminished training ability. We are aware of the limitations of the present work, as epidemiological studies cannot address the question of causation. More research is needed to clarify the role of selection and possible differential treatment of sport and leisure, crib-biting and control horses.

Acknowledgements

The authors are grateful for the help of Kinga Gavalda, Rita Benedek, Georgina Kiss, and to the horse-owners who contributed with their animals to this study. Two anonymous referees gave valuable comments on an earlier version of this manuscript.

References

Albright, J.D., Mohammed, H.O., Heleski, C.R., Wickens, C.L., Houpt, K.A., 2009. Crib-biting in US horses: breed predispositions and owner perceptions of aetiology. Equine Vet. J. 41, 455–458.

Bachmann, I., Bernasconi, P., Hermann, R., Weishaupt, M.A., Stauffacher, M., 2003. Behavioural and physiological responses to an acute stressor in crib-biting and control horses. Appl. Anim. Behav. Sci. 82, 297–311.

Cabib, S., Giardino, L., Calza, L., Zanni, M., Mele, A., Puglisi-Allegra, S., 1998. Stress promotes major changes in dopamine receptor densities within the mesoaccumbens and nigrostriatal systems. J. Neurosci. 84, 193–200.

Gosling, S.D., 2001. From mice to men: what can we learn about personality from animal research? Psychol. Bull. 127, 45–86.

Hausberger, M., Gautier, E., Müller, C., Jego, P., 2007. Lower learning abilities in stereotypic horses. Appl. Anim. Behav. Sci. 107, 299–306.

Hausberger, M., Roche, H., Henry, S., Visser, E.K., 2008. A review of the human–horse relationship. Appl. Anim. Behav. Sci. 109, 1–24.

Hemmings, A., McBride, S.D., Hale, C.E., 2007. Perseverative responding and the aetiology of equine oral stereotypy. Appl. Anim. Behav. Sci. 104, 143–150.

Horváth, Zs., Igyártó, B.Z., Magyar, A., Mikósi, Á., 2007. Three different coping styles in police dogs exposed to a short-term challenge. Horm. Behav. 52, 621–630.

Jones, A.C., Gosling, S.D., 2005. Temperament and personality in dogs (Canis familiaris): a review and evaluation of past research. Appl. Anim. Behav. Sci. 95, 1–53.

Kabai, P., Liker, A., Csillag, A., 1999. Methamphetamine-induced stereotypies in newly-hatched decerebrated domestic chicks. Neurochem. Res. 24, 1563–1569.

Koolhaas, J.M., Korte, S.M., De Boer, S.F., Van Der Vegt, B.J., Van Reenen, C.G., Hopster, H., De Jong, I.C., Ruis, M.A.W., Blokhuis, H.J., 1999. Coping styles in animals: current status in behavior and stress-physiology. Neurosci. Biobehav. Rev. 23, 925–935.

Koolhaas, J.M., 2008. Coping style and immunity in animals: making sense of individual variation. Brain Behav. Immun. 22, 662–667.

Lloyd, A.S., Martin, J.E., Bornett-Gauci, H.L.I., Wilkinson, R.G., 2007. Evaluation of a novel method of horse personality assessment: rater agreement and links to behaviour. Appl. Anim. Behav. Sci. 105, 205–222.

Mason, G., Rushen, J. (Eds.), 2006. Stereotypic Animal Behaviour: Fundamentals and Applications to Welfare. 2nd ed. CAB International, Wallingford OXON.

McBride, S.D., Hemmings, A., 2005. Altered mesoaccumbens and nigro-striatal dopamine physiology is associated with stereotypy development in a non-rodent species. Behav. Brain Res. 159, 113–118.

McBride, S., Hemmings, A., 2009. A neurologic perspective of equine stereotypy. J. Equine Vet. Sci. 29, 10–16.

McCall, C.A., 1990. A review of learning behavior in horses and its application in horse training. J. Anim. Sci. 68, 75–81.

McGreevy, P.D., Cripps, P.J., French, N.P., Green, L.E., Nicol, C.J., 1995. Management factors associated with stereotypic and redirected behaviour in the thoroughbred horse. Equine Vet. J. 27, 86–91.

McGreevy, P.D., Webster, A.J.F., Nicol, C.J., 2001. A study of the digestive efficiency, behaviour and gut transit times of crib-biting horses. Vet. Rec. 148, 592–596.

McGreevy, P.D., McLean, A.N., 2009. Punishment in horse-training and the concept of ethical equitation. J. Vet. Behav. Clin. Appl. Res. 4, 193–197.

McGrogan, C., Hutchison, M.D., King, J.E., 2008. Dimensions of horse personality based on owner and trainer supplied personality traits. Appl. Anim. Behav. Sci. 113, 206–214.

Minero, M., Canali, E., Ferrante, V., Vegra, M., Odberg, F.O., 1999. Heart rate and behavioural responses of crib-biting horses to two acute stressors. Vet. Rec. 145, 430–433.

Moeller, B.A., McCall, C., Silverman, S.J., McElhenney, W.H., 2008. Estimation of saliva production in crib-citing and normal horses. J. Equine Vet. Sci. 28, 85–90.

Momozawa, Y., Ono, T., Sato, F., Kikusui, T., Takeuchi, Y., Mori, Y., Kusunose, R., 2003. Assessment of equine temperament by a questionnaire survey to caretakers and evaluation of its reliability by simultaneous behaviour test. Appl. Anim. Behav. Sci. 84, 127–138.

Momozawa, Y., Kusunose, R., Kikusui, T., Takeuchi, T., Mori, Y., 2005. Assessment of equine temperament questionnaire by comparing factor structure between two separate surveys. Appl. Anim. Behav. Sci. 92, 77–84.

Morris, P.H., Gale, A., Howe, S., 2002. The factor structure of horse personality. Anthrozoos 15, 300–322.

Murphy, J., Arkins, S., 2007. Equine learning behaviour. Behav. Proc. 76, 1–13.

Nagy, K., Bodó, G., Bárdos, Gy., Harnos, A., Kabai, P., 2009. The effect of a feeding stress-test on the behaviour and heart rate variability of crib-biting horses (with or without inhibition). Appl. Anim. Behav. Sci. 121, 140–147.

Nicol, C.J., 1999. Understanding equine stereotypies. Equine Vet. J. Suppl. 28, 20–25.

Nicol, C.J., Waters, A.J., Wilson, A.D., Davidson, H.P.D., Harris, P.A., 2002. Study of crib-biting and gastric inflammation and ulceration in young horses. Vet. Rec. 151, 658–662.

Parker, M., Redhead, E.S., Goodwin, D., McBride, S.D., 2008. Impaired instrumental choice in crib biting horses (Equus caballus). Behav. Brain Res. 191, 137–140.

Parker, M., McBride, S.D., Goodwin, D., 2009. Differential place and response learning in horses displaying an oral stereotypy. Behav. Brain Res. 200, 100–105.

R Development Core Team, 2007. A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna. , http://www.r-project.org.

Reise, S.P., Waller, N.G., Comrey, A.L., 2000. Factor analysis and scale revision. Psychol. Assess. 12, 287–297.

Waters, A.J., Nicol, C.J., French, N.P., 2002. Factors influencing the development of stereotypic and redirected behaviours in young horses: findings of a four year prospective epidemiological study. Equine Vet. J. 34, 572–579.

Wise, R.A., 2004. Dopamine, learning and motivation. Nat. Rev. Neurosci. 6, 483–494.