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A rein tension signal can be reduced by half in a single training session

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ABSTRACT

Rein tension signals are, in essence, pressures applied on the horse's mouth or nose, via the bit/noseband, by a rider or trainer. These pressures may feel uncomfortable or even painful to the horse and therefore it is important to reduce rein tension magnitude to a minimum. The aim of this study was to investigate the magnitude of a rein tension signal for backing up, using negative reinforcement. We wanted to assess how much the magnitude of rein tension could be reduced over eight trials and if the learning process would differ depending on headstall (bridle/halter). Twenty Warmblood horses were trained to step back from a rein tension signal with the handler standing next to the horse, holding the hands above the horse's withers. As soon as the horses stepped back, rein tension was released. The horses were either trained with a bridle first (first treatment, eight trials) and then with a halter (second treatment, eight trials), or vice versa in a cross-over design. All horses wore a rein tension meter and behavior was recorded from video. The sum of left and right maximum rein tension from onset of the rein tension signal to onset of backing (signaling rein tension) was determined for each trial. Mixed linear and logistic regression models were used for the data analysis. In both treatments, signaling rein tension was significantly lower in trial 7–8 than the first trial ($p < 0.02$). Likewise, signaling rein tension was significantly lower ($p < 0.01$), and the horses responded significantly faster, ($p < 0.001$) in the second treatment compared to the first, regardless of headstall. The maximum rein tension was reduced from 35 N to 17 N for bridle (sum of left and right rein) and from 25 N to 15 N for halter in the first eight trials. Rein tension was then further reduced to 10 N for both bridle and halter over the eight additional trials in the second treatment, i.e. to approximately 5 N in each rein. There was no significant difference in learning performance depending on headstall, but the bitted bridle was associated with significantly more head/neck/mouth behaviors. These results suggest that it is possible to reduce maximum rein tension by half in just eight trials. The findings demonstrate how quickly the horse can be taught to respond to progressively lower magnitudes of rein tension through the correct application of negative reinforcement, suggesting possibilities for substantial improvement of equine welfare during training.

1. Introduction

At present, training horses to perform various tasks is mainly accomplished through the use of pressure signals to elicit desired responses from the horse. Pressure signals used in horse riding are generally rein tension creating mouth/nose pressure, leg pressure on the horse's belly, weight shifts in the saddle, and/or tapping with the whip.

The structures of the horse's mouth and head are sensitive and mouth injuries related to bridles and bits are common in horses (Björnsdóttir et al., 2014; Uldahl and Clayton, 2019; Tuomola et al., 2021). Whereas the noseband and the type of bit have been found to influence the occurrence of mouth injuries (Björnsdóttir et al., 2014; Uldahl and Clayton, 2019), it is likely that the magnitude of rein tension is an even more important factor for the development of oral lesions (Mellor, 2020). Likewise, research suggests that even naive horses may find pressure from the bit in the mouth aversive (Christensen et al., 2011)

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and it seems that horses prefer lower levels of rein tension than what riders generally apply (Piccolo and Kienapfel, 2019).

Well-informed horse trainers are aware of the principles of operant conditioning (McLean and Christensen, 2017) and systematically use pressure and timely release to train and maintain responses through negative reinforcement (Brown and Connor, 2017), i.e. releasing the pressure at the moment the horse performs the correct behavior, which increases the likelihood that the behavior appear again if the same stimulus is repeated (Pearce, 2008). Likewise, well-informed horse trainers will be aware of the associative learning principles of classical conditioning. In essence, by being consistent in starting each pressure signal with a light pressure, the initial light pressure becomes a conditioned stimuli, a signal, predicting the arrival of the increasing pressure (Baragli et al., 2015). Over repetitions, the horse will make an association between the initial, light pressure and the subsequent escalating pressure and will respond already at the light pressure signal (McGreevy and McLean, 2007). There are, however, knowledge gaps regarding the correct application of the learning principles among riders and horse trainers (Warren-Smith and McGreevy, 2008; Brown and Connor, 2017), e.g. the importance of the timing of the release of pressure and of always starting with a light signal (McLean and Christensen, 2017). Relentless pressure or unpredictable pressure signals can cause stress and discomfort for the horse (McLean and McGreevy, 2010) and therefore further education of equestrians in the principles of operant and classical conditioning is needed (Telatin et al., 2016). Moreover, it has been found that training horses through negative reinforcement can lead to a negative perception of humans (Sankey et al., 2010) and stress related behaviors (Hendriksen et al., 2011; Freymond et al., 2014). Subsequently, training horses to respond to rein tension signals using negative reinforcement, may pose welfare risks, and is important to investigate further.

While negative reinforcement is an operant learning principle that has been recognized and quantified since the experiments conducted by Skinner (1938), Ahrendt et al. (2015) was, to our knowledge, the first to conduct a standardized test for investigating negative reinforcement learning in horses. They trained horses to yield the hindquarters by applying pressure on the horses' hindquarters using an algometer. Inspired by Ahrendt et al. (2015), this study was designed to learn more about negative reinforcement learning of rein tension signals in horses.

Our hypothesis was that through the correct application of negative reinforcement, the magnitude of a rein tension signal can be substantially reduced over the course of a single training session. Further, it was hypothesized that the type of headstall used (bridle/halter) would not affect learning performance. The aim of this study was therefore to investigate the magnitude of a rein tension signal over repeated trials. We wanted to assess how much the magnitude of a rein tension signal could be reduced over eight trials of a backing up exercise and if the learning process would be similar regardless if the horse was trained with a bitted bridle or a halter.

2. Materials and methods

This study was carried out over three days in May 2019 at an Equestrian Center in Sweden. The Animal Ethics Board in Uppsala, Sweden, had given an ethical approval for the study, Dnr 5.8.18-02567/2019.

A study describing the characteristics of the rein tension signal has been published previously using the same data collection. Materials and methods will thus be summarized, and further details can be found in Eisersiö et al. (2021).

Twenty Warmblood horses participated in the study: 10 young horses (4–5 years old, five mares, five geldings) and 10 mature horses (>7 years old, mean 10.3 years ± 2.65, four mares, six geldings). The young horses had been in training under saddle 1–2 years. The mature horses had been trained in dressage and jumping more than 4 years. The horses were school horses at an Equestrian Center. The horses had all been backed up before, as part of normal handling and training, but the riding exercise rein back had not been specifically trained in the young horses. All horses were checked for soundness and health by a veterinarian and the staff at the Center on a regular basis. Oral exams of all horses were conducted two weeks prior to the data collection by a veterinarian with expertize in equine dentistry. The veterinarian considered all horses fit to participate in the experiment.

In brief, the experiment was conducted in an aisle (7 * 2 m) in a grooming area at the Equestrian Center. The order in which the horses entered the experiment was based on the daily activities of that horse, e.g. participation in riding lessons. Every other horse was placed in Group 1 (four young, six mature horses) and every other in Group 2 (six young, four mature horses). Group 1 was first fitted with the bridle and then the halter, and Group 2 was tested with the opposite order of headstalls. Each horse was tested once and on one day. For the bridle treatment, the horses wore their own bridle and bit (noseband removed). Eleven horses wore three-piece snaffles, five horses wore two-piece snaffles, and four horses had straight bits. The bits had a diameter of 13–20 mm close to the bit-rings. The halter treatment used the same full size, standard, nylon halter for all horses (noseband 35 mm wide) (Fig. 1). The staff at the Equestrian Center and the research team were in agreement that the bridles, bits and the halter fitted the horses properly.

2.1. The rein tension meter

To collect rein tension data, a custom-made rein tension meter was used. The rein tension meter for each rein consisted of a load cell (Futek, CA, USA) wired to amplifiers and an IMU (x-io technologies, Bristol, UK). The load cell had a measuring range of 0–500 N and weighted 20 g. The IMU had 10 bit resolution, 3.1 V battery and weighed 46 g. The sampling rate was 100 Hz. The load cells were attached to flat leather reins, with leather stoppers (15 mm wide), close to the bit. The amplifier and IMU were taped together and fastened on the crown piece of the headstall using tape (Fig. 1). The rein tension meter was attached to the headstall before it was fitted on the horse. The reins were attached to the side rings of the halter to exert pressure on the bridge of the nose during the halter treatment and to the rings of the bit to exert pressure on the oral tissues during the bridle treatment. Before and after the experiment, the rein tension meter was calibrated using ten known weights ranging from 0 to 10 kg suspended from each meter to confirm stability of voltage output.

2.2. Experimental setup

During the treatments (bridle and halter), the handler (author M.E., right-handed) was standing on the horse's left side near the horse's withers. Each treatment began with a 2 min rest period where the horse was standing still on the aisle with the handler next to the withers. After 2 min had passed, the handler shortened the reins while lifting the arms and positioned the hands above the horse's withers. Rein tension was then gradually increased, by the handler closing the hands to exert tension on the reins, until the horse took a step back. The handler stepped back along with the horse, staying next to the horse's withers. The handler released rein tension by opening and lowering the hands. The release of rein tension was given immediately when the horse stepped back with a front leg. For each horse and in each treatment, the criterion for release of rein tension started with one step backwards. During the course of the treatment, if the handler felt that the horse was responding immediately to a light rein tension signal, the criterion was raised to one additional step. Rein tension was released for each step back by the handler slightly lowering or moving the hands forward. The criterion was lowered again (to fewer steps) if the horse resisted, hesitated or seemed to have difficulty stepping back. After each backing event, the horse and handler stood still on the aisle until one minute had passed since the onset of the previous rein tension signal. The rein tension signal and rest period were repeated eight times. After the eighth

Fig. 1. The headstalls. The headstalls used in data collection with the rein tension meter attached. Bitted bridle to the left and halter to the right. The horses also wore a halter underneath the treatment headstall.

time, there was a 2 min recovery period standing still on the aisle. The horse was then led to a grooming stall to change headstall and the above described procedure was repeated.

2.3. Data extraction

The horse was video recorded from a left side view during the treatments (25 Hz, Canon Legria HF R806, Canon Inc, Tokyo, Japan). Each treatment began and ended by synchronizing the rein tension meter with the video camera. This was done by pulling on the left rein tension meter five times (not affecting the horse's mouth) while counting out load.

From the video, the different events within each treatment were annotated on a frame-by-frame level using the video editing program Adobe Premiere Elements (Adobe, CA, USA). The point in time when the handler had shortened the reins and positioned the hands above the horse's withers was recorded as the onset of the rein tension signal, while the release of the rein tension was annotated when the handler started to lower the hands. The moment when the horse's chest started to move backwards, i.e. a weight shift to the rear, was noted in the protocol as the beginning of the backing response. The onset of backing was recorded at the moment when the horse's first front hoof was lifted off the floor to step back. The number of front limb steps back that the handler applied the rein tension signal was recorded.

An equine ethologist (author ME) recorded the horse's behavior from the video. Behavior was recorded in the form of one-zero sampling (Martin and Bateson, 2009) during the time interval between onset of the rein tension signal and onset of backing as well as between onset of the rein tension signal and the release of rein tension. The ethogram can be found in Table 1. The horse's backing responses were defined as successful or unsuccessful. A successful response being one where the horse started to back within two seconds, to a light rein tension signal (visible slack in the rein) without showing any other behaviors. Videos 1–4 show the experimental setup and the application of rein tension signals. All videos show the same mature horse who started with the bitted bridle as first treatment.

Table 1
The ethogram used for behavioral observations during the application of the rein tension signal. Originally

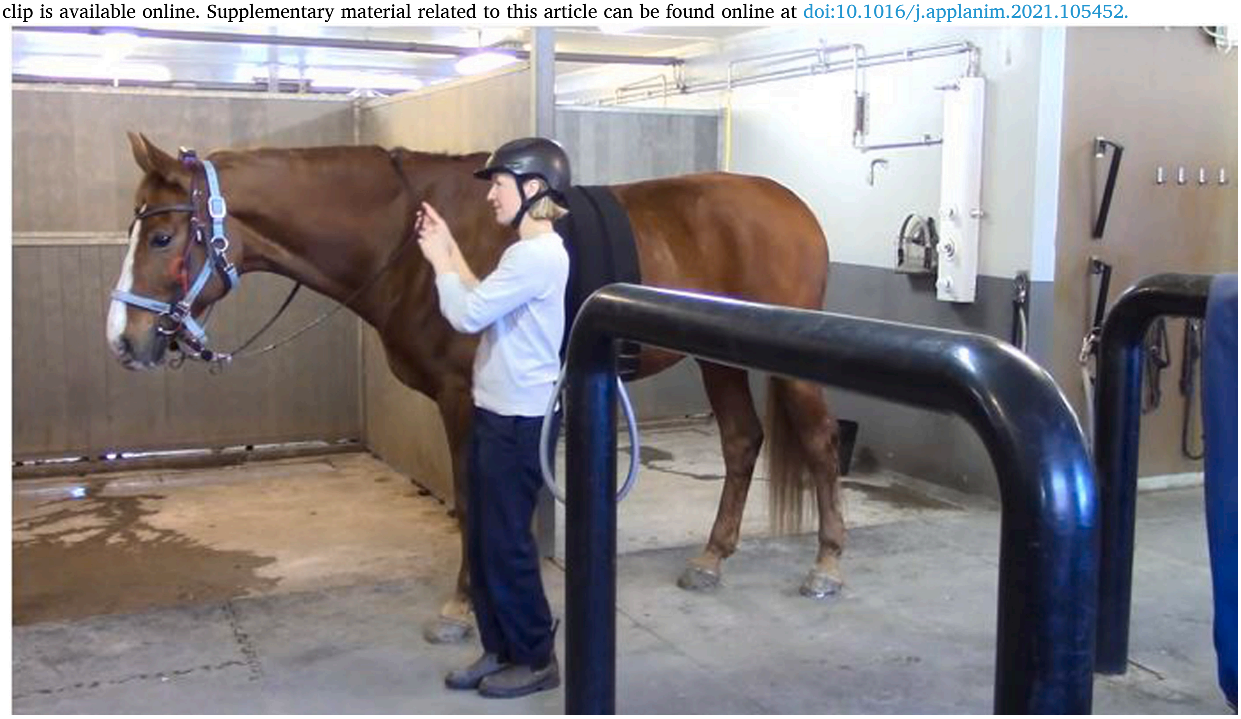
Behavioral category		Behavior	Description
Backing response	Performance	Successful	Backing within two seconds, slack rein, no reluctant behaviors shown
	Backing	Steps	Number of steps back the handler applied the rein tension signal
Inattentive behavior	Attention	Looking at something	Directed gaze, pointed ears and immobile posture
		Investigating	Investigating the environment with nose and/or mouth
	Turning head/neck	Away	Turning the head and neck away from handler
		Towards	Turning the head and neck towards the handler for contact
Head/neck/mouth behavior	Head/neck movement	Upward	Head/neck is raised upward
		Downward	Head/neck is lowered downward
		Forward	Nose is pushed forwards
		Backward	Nose is drawn in towards the chest
		Toss	Quick upward vertical movement of the head
	Mouth behavior	Biting on bit	The bit is pulled up inside the mouth and horse is biting on it
		Open mouth	Visible gap between upper and lower jaw

Source:(a) Modified from Eisersiö et al. (2021). (b) Adapted from Egenvall et al. (2012) and Fenner et al. (2017).

3. Data analysis

Behavior, event records and rein tension data were imported into Matlab (2019b, MathWorks Inc., MA). Descriptive variables were calculated using custom-written code. Response latency was determined by calculating the time duration from onset of the rein tension signal to the onset of backing. Signaling rein tension was taken as the sum of left and right maximum rein tension during the response latency period. Response rein tension was taken as the sum of left and right maximum rein tension during the time period between the beginning of the backing response and onset of backing. If the horse started to back when the handler shortened the reins, before the rein tension signal was given, only response rein tension was recorded for that trial, and response latency had a negative value. The resulting dataset was imported into RStudio (version 1.2.5019, RStudio, MA, USA) for statistical analysis.

Video S1. The first trial in the first treatment (in this case bridle). Rein tension applied for one step back. The behavior head forward is present. All videos are of the same mature horse.
A video clip is available online. Supplementary material related to this article can be found online at doi:10.1016/j.applanim.2021.105452.

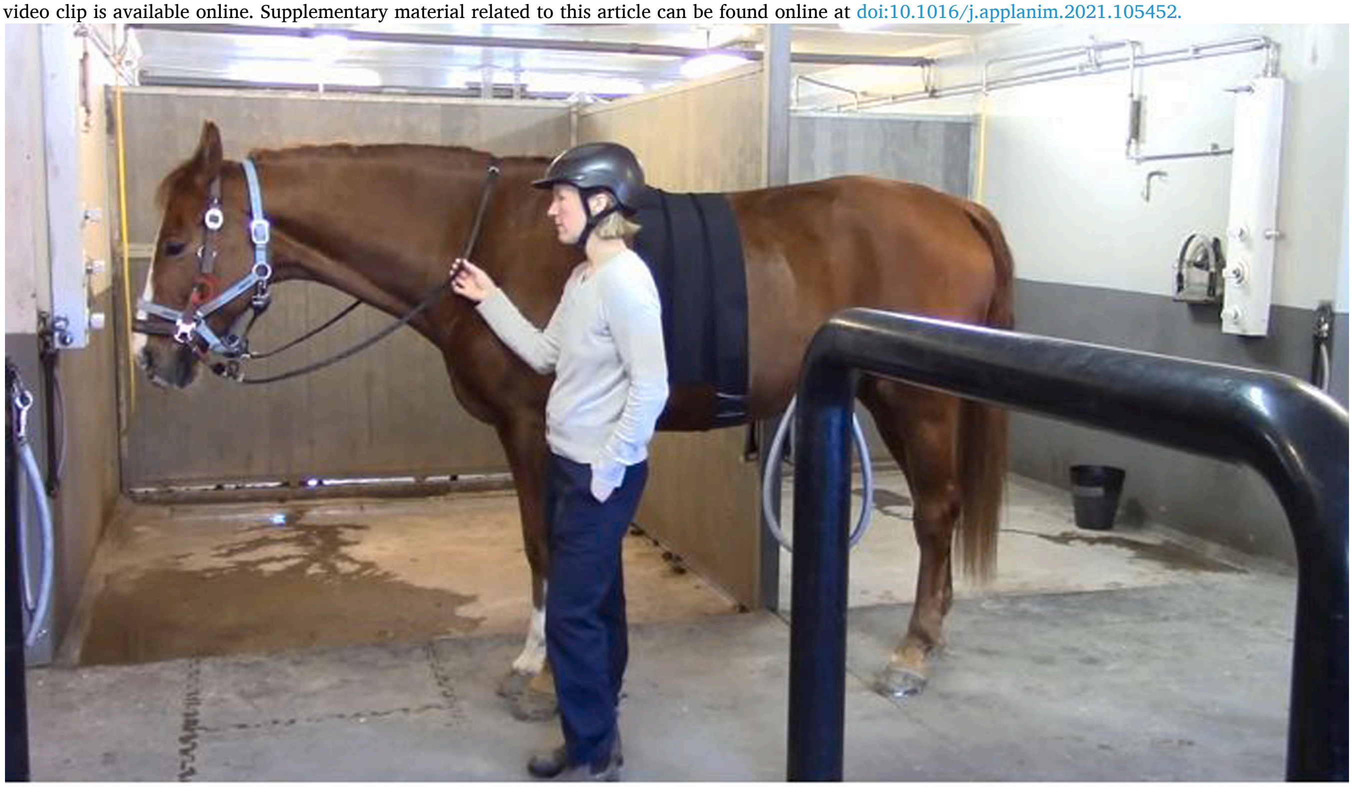


Video S2. The seventh trial of the first treatment (bridle). Rein tension applied for two steps back. Head forward and open mouth are present.
A video clip is available online. Supplementary material related to this article can be found online at doi:10.1016/j.applanim.2021.105452.

To describe the horses' learning process, descriptive statistics (median, IQR) were calculated for response latency, signaling rein tension, response rein tension, and number of behaviors other than backing that the horses showed during the application of the rein tension signal, by headstall, trial number, and order of treatment. The horses' behaviors were divided into two categories: head/neck/mouth behavior and inattentive behavior (Table 1). Additionally, the number of trials and horses with successful responses were summarized.

Linear mixed models were used for the statistical analysis of rein tension and response latency (RStudio, packages lmerTest, lme4). The three outcome variables, response latency, signaling rein tension, and response rein tension were not normally distributed and therefore transformed along the ladder of powers; i.e. response latency and signaling rein tension (sum of left and right rein) were log-transformed, and response rein tension was sqrt-transformed (sum of left and right rein).

Video S3. The first trial of the second treatment (in this case halter). Rein tension applied for one step back. The behavior head upward is present.
A video clip is available online. Supplementary material related to this article can be found online at doi:10.1016/j.applanim.2021.105452.



Video S4. The seventh trial of the second treatment (halter). Rein tension applied for three steps back. No other behaviors present.
A video clip is available online. Supplementary material related to this article can be found online at doi:10.1016/j.applanim.2021.105452.

The explanatory variables were headstall (bridle/halter), age group (young/mature), order of treatment (first treatment/second treatment) and trial (1–8). All explanatory variables were analyzed as categorical variables. Horse was included as a random variable. Plotting of Pearsons residuals was used for normality check of the models. Interactions between the four explanatory variables, headstall, age group, order of treatment, and trial number, were tested. Non-significant interactions were sequentially removed based on the type III p-value of < 0.05. Non-significant explanatory variable main effects were forced into the models.

Logistic regression models were used for statistical analysis of behaviors with head/neck/mouth behavior and inattentive behavior (present/absent) as outcome and headstall, order of treatment and trial number as explanatory variables. Horse was included as a random variable. The model with inattentive behavior as outcome did not converge with all the explanatory variables included and trial number was therefore omitted. Model fit was evaluated using ROC and AUC (RStudio, package pROC).

4. Results

All horses completed the experiment and met the criterion for a backing response to the rein tension signal in each trial. Twenty horses backing up eight times with the bridle and eight times with the halter resulted in a total of 320 observations, 20 observations for each trial number (1−8) and order of treatment (first, second). For the outcome variable signaling rein tension, there were no data to be recorded for 56 rein tension signals since in those trials the horse started backing before the rein tension signal was applied (18% of the observations, distributed among 17 horses). To avoid missing values for these observations, signaling rein tension was substituted by response rein tension for the same trial, in both analytical and descriptive statistics. This was deemed adequate since the response rein tension was recorded during the initiation of the backing response, and thus equivalent to signaling rein tension in these cases.

Descriptively, the median response latency was reduced from 6 s for bridle and 5 s for halter in the 1st trial in the first treatment (IQR 5–6 s bridle, 3–7 s halter) to 2.6 s for bridle and 2.3 s for halter in the 8th trial of the first treatment (IQR 0.25–5 s bridle, −0.05 to 3 s halter). In the 8th trial of the second treatment median response latency was 1.6 s for bridle and 1.6 s for halter (IQR 0.3–3.5 s bridle, 0.1–4 s halter) (Fig. 2).

The median maximum rein tension (sum of left and right rein) during application of the rein tension signal (signaling rein tension) was 35 N for bridle and 25 N for halter in the 1st trial of the first treatment (IQR 28–46 N for bridle, 19–36 N for halter). In the 8th trial of the first treatment, it was 17 N for bridle and 15 N for halter (IQR 4–25 N bridle, 12–19 N halter) and then further decreased to 10 N for bridle and 10 N for halter in the 8th trial of the second treatment (IQR 3–16 N bridle, 3–27 N halter) (Fig. 3). See supplementary materials for more details on signaling rein tension magnitude.

In the 1st trial of the first treatment median response rein tension (sum of left and right rein) was 24 N for bridle and 23 N for halter (IQR 21–27 N bridle, 13–25 N halter). In the 8th trial of the first treatment response rein tension was 12 N for bridle and 13 N for halter (IQR 4–20 N bridle, 12–17 N halter) and in the 8th trial of the second treatment response rein tension had decreased to 10 N for bridle and 7 N for halter (IQR 3–12 N bridle, 3–22 N halter).

Of all the backing responses (total 320), 36% (115) were successful (Table 2). In 95% of the responses labeled as successful, rein tension was below 20 N (sum of left and right rein). A higher percentage of the trials generated a successful response in the second treatment, 43%, (46% bridle, 40% halter) compared to the first treatment, 29% (both treatments). Overall, each horse responded within one second from the onset of the rein tension signal in at least two trials (mean 5 ± 3). When the criterion was raised to two or three steps, other behaviors than backing, were present in 41% of these trials (52/126 trials), i.e. the horses showed head/neck/mouth behavior in a total of 38 trials and inattentive behavior in 25 trials when taking two or three steps back (Table 2).

The results from the linear models are shown in Table 3, with further details in the supplementary materials. From the 5th trial onward, the horses responded significantly faster to the rein tension signal than during the first trial. Also, the horses responded significantly faster in the second treatment compared to the first treatment, regardless of headstall (Table 3).

At the 7th and 8th trials signaling rein tension was significantly lower than during the first trial, regardless of headstall (Table 3, Signaling RT). Likewise, signaling rein tension was significantly lower in the second treatment compared to the first treatment.

Response rein tension was significantly lower during the second treatment (Table 3, Response RT) than the first treatment. Compared to the first trial, response rein tension tended to be lower from the 5th trial onward and from the 7th trial, response rein tension was significantly lower.

The logistic regression model of head/neck/mouth behavior demonstrated that these behaviors were significantly less common in the 7th and 8th trials compared to the first trial and during the second treatment compared to the first treatment. Head/neck/mouth behavior was also less common during the halter treatment compared to the bridle treatment (Table 4). Inattentive behavior was less common in the second treatment.

5. Discussion

Our results support our hypotheses, i.e. rein tension magnitude could be substantially reduced during a single training session, regardless of headstall used. By the 7th trial of the first treatment, both response

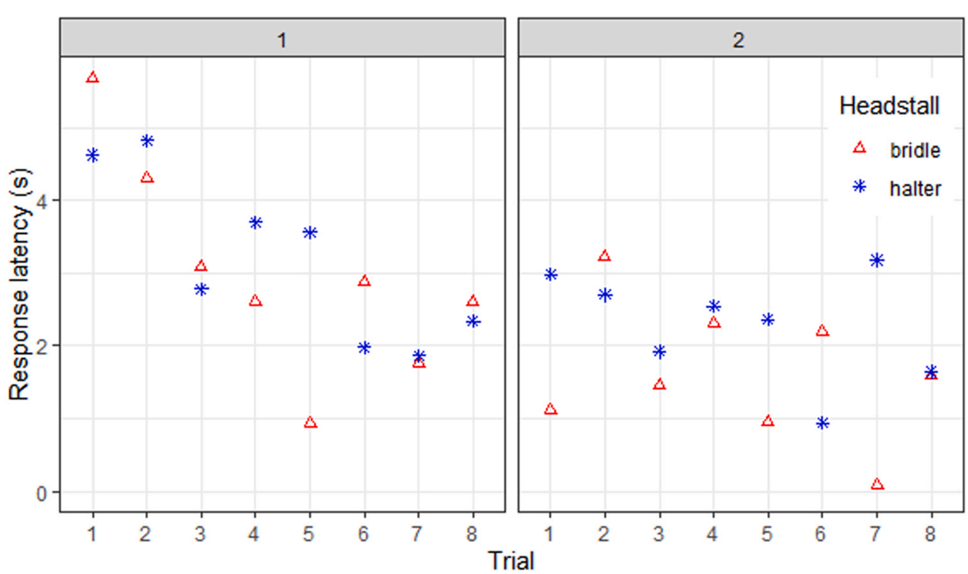


Fig. 2. Response latency across trials. Group median response latency (s) for the eight trials of the rein tension signal in the first (left) and second (right) treatment, color and shape by bridle and halter. Data are from 20 horses responding to a rein tension signal for backing up (eight times with a bridle and eight times with a halter, generating 320 rein tension signals in total).

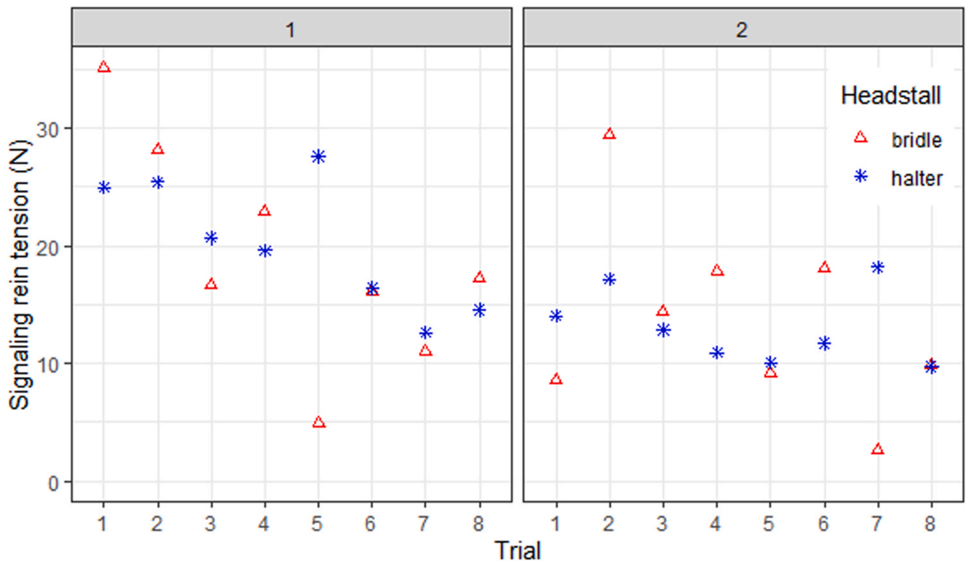


Fig. 3. Signaling rein tension across trials. Group median signaling rein tension (rein tension during the time interval from onset of the rein tension signal to onset of backing) for the eight trials of the rein tension signal in the first (left) and the second (right) treatment, color and shape by bridle and halter. Data for 20 horses responding to a rein tension signal for backing up (eight times with a bridle and eight times with a halter, generating 320 rein tension signals in total).

Table 2
Number of trials/rein tension signals (RTS) and number of horses where the handler asked for one, two or three steps back. The number of RTS followed by a successful backing response and the number of horses that responded successfully in at least one trial. The number of RTS where head/neck/mouth behavior and/or inattentive behavior was shown and the number of horses that showed those behaviors in at least one trial. The experiment included 20 horses, responding to eight RTS with a bitted bridle and eight RTS with a halter resulting with a total of 320 RTS. Group 1 (four young, six mature horses) started with the bridle and group 2 (six young, four mature horses) started with the halter.

		One step		Two steps		Three steps		Successful	
		RTS	horses	RTS	horses	RTS	horses	RTS	Horses
Group 1	Bridle	55	10	21	8	4	4	23	8
	Halter	38	10	32	9	10	5	32	10
Group 2	Halter	51	10	21	8	8	4	23	9
	Bridle	50	10	16	6	14	5	37	10
Total no of RTS		194		90		36		115	
Behavior	Head/neck/mouth	96	19	30	12	8	4	n.a.	n.a.
	Inattentive	64	16	20	10	5	3	n.a.	n.a.

latency and magnitude of the rein tension signal were reduced by half compared to at the first trial, with further reduction during the second treatment. This was consistent regardless of whether the bridle or the halter was the first treatment. In other words, the horses generalized the learning between the first and second treatment and the order of the treatments, i.e. the total number of trials, turned out to be far more important than the headstall used. Further, head/neck/mouth behaviors were significantly less common at the end of treatment than at the beginning of each treatment, and both head/neck/mouth behavior and inattentive behavior were significantly less common during the second treatment. The reduction of head/neck/mouth and inattentive behaviors was likely a key factor in reducing rein tension, as it was shown in Eisersiö et al. (2021) that horse behavior has a large influence on the magnitude of rein tension.

Rein tension was higher before the onset of backing compared to when the horse commenced the backing response. This relates to the lag between the application of pressure by the handler, the horse perceiving the pressure and deciding to step back, and the handler noting that the horse is responding and releasing the pressure. In fact, the pressure motivating the horse to step back occurs some time before the horse starts to shift their weight back. It is interesting to elaborate on if this lag can be reduced and to what extent this influences the horse's learning. Perhaps the horse can achieve a reduction in rein tension by shifting the weight back, despite that the handler had not yet initiated the release of rein tension.

The experimental design used was selected to study the learning process of rein tension signals while keeping other influential variables like gait, stride and rider influence at a minimum. Our decision to use eight trials of the rein tension signal in each treatment was based on data from two pilot studies, using four different horses who all reached the learning criterion of backing up promptly to a light rein tension signal within eight trials (unpublished data). Fenner et al. (2017) used a similar design in their study and also used eight trials of backing up using rein tension signals. Other experiments on equine learning have used between 5 and 20 trials per session (McCall et al., 1993; Ahrendt et al., 2015; Valenchon et al., 2017). It is, to our knowledge, not known how many trials a horse needs to form a conditioned response, but based on the statistical results, perhaps seven or eight trials on average is an appropriate number for teaching horses a new criterion or signal. The number of trials of an exercise will of course have to be adjusted depending on the level of physical and mental exertion the horse is subjected to. Moreover, as horses have various backgrounds, different temperamental traits and emotionality, as well as a diverse level of motivation to respond to negative reinforcement, learning performance will differ considerably between individuals (Lansade and Simon, 2010; Valenchon et al., 2017).

The structures of the horse's head and mouth are sensitive (Mellor, 2020) and warrant the usage of light rein tension signals during training

Table 3
Results for mixed linear models of response latency, signaling rein tension (Signaling RT) and response rein tension (Response RT). The Estimate and SE are on the log scale for response latency and signaling RT and on the square root scale for response RT. A negative estimate indicates that this level of the explanatory variable predicted a decrease in the outcome variable value. The models each include data from 20 horses, responding to eight rein tension signals fitted with a bitted bridle and eight rein tension signals fitted with a halter (320 observations total). Bold p-values are considered significant ($p < 0.05$). Baseline categories and estimates from trial 2–4 have been omitted. Model output and R code can be found in the supplementary materials.

Dependent variable	Explanatory variable	Estimate	SE	p-value
Response latency	(Intercept)	1.74	0.14	< 0.001
	Halter	0.10	0.07	0.145
	Young horses	-0.09	0.15	0.546
	Second treatment	-0.25	0.07	**< 0.001**
	Trial 5	-0.32	0.13	**0.017**
	Trial 6	-0.29	0.13	**0.028**
	Trial 7	-0.41	0.13	**0.002**
	Trial 8	-0.37	0.13	**0.005**
Signaling RT	(Intercept)	2.99	0.29	< 0.001
	Halter	0.14	0.13	0.298
	Young horses	-0.09	0.30	0.765
	Second treatment	-0.40	0.13	**0.003**
	Trial 5	-0.41	0.27	0.128
	Trial 6	-0.30	0.27	0.265
	Trial 7	-0.66	0.27	**0.014**
	Trial 8	-0.64	0.27	**0.018**
Response RT	(Intercept)	4.31	0.42	< 0.001
	Halter	0.20	0.18	0.277
	Young horses	-0.04	0.45	0.936
	Second treatment	-0.57	0.18	**0.002**
	Trial 5	-0.65	0.36	0.075
	Trial 6	-0.71	0.36	0.052
	Trial 7	-0.87	0.36	**0.018**
	Trial 8	-0.86	0.36	**0.019**

Table 4
Odds ratios (OR) and 95% confidence intervals from the logistic regression models with head/neck/mouth behavior or inattentive behavior as outcomes. Bold p-values indicate that the explanatory variable had a significant influence ($p < 0.05$) on the outcome. The results presented are presence/absence of behavior from onset rein tension signal to onset backing (20 horses, 2 treatments, 8 trials in each treatment). Baseline categories and estimates from trial 2–4 (non-significant) have been omitted. Model output and R code can be found in the supplementary materials.

Model	Variable	OR	2.5%	97.5%	p-value
Head/neck/mouth behavior	Halter	0.52	0.30	0.87	**0.013**
	Second treatment	0.55	0.32	0.93	**0.025**
	Trial 5	0.36	0.13	0.97	**0.045**
	Trial 6	0.41	0.15	1.11	0.080
	Trial 7	0.19	0.06	0.55	**0.003**
	Trial 8	0.31	0.11	0.85	**0.024**
Inattentive behavior	Halter	1.23	0.71	2.14	0.458
	Second treatment	0.50	0.29	0.87	**0.014**

sessions. While it may be necessary to escalate rein tension in the first few trials when teaching the horse a new exercise, horse trainers should aim to quickly reduce rein tension magnitude by proper use of negative reinforcement (pressure is released with the correct timing) and classical conditioning (a light signal predictably precedes escalating pressure). This study demonstrates that rein tension can be reduced substantially over the course of eight trials in a single training session. Given that horses find pressure from the bit aversive (Christensen et al., 2011) and since horses seem to prefer lower rein tension than what riders generally apply (Piccolo and Kienapfel, 2019), this finding is important from an equine welfare perspective as it demonstrates how quickly the horse can be taught to respond to progressively lower magnitudes of pressure. The fact that the horses in our study generalized the exercise between bridle and halter emphasizes that it is the proper application of the learning principles that is crucial for successful training and not the equipment used.

Training a horse successfully, using negatively reinforced pressure signals, rely on clear communication through timely and frequent release of pressure. As the release of pressure provides information to the horse about what behavior pays off, timely and consistent releases are most informative to the horse. In this experiment, the release of rein tension was given within one second from the first front hoof lifting to step back (see Eisersiö et al., 2021). However, an often forgotten variable in animal training is the criteria the trainer has set up. Low criteria, i.e. simple tasks and low requirements for precision, are more likely to be met by the horse (McCall, 1990), while increasing the demands too quickly, without a sufficient number of successful attempts at the initial level, will inevitably make it more difficult for the horse to figure out what behavior that pays off/leads to release of pressure. Releases will then be less frequent as it takes longer time for the horse to figure out the correct response. One could argue that with a too high criterion, information about the correct response is withheld from the horse, prolonging the duration from the onset of the signal to its release. This is unfortunate since lengthy application of the rein tension signal may disassociate the aimed conditioned stimuli, the initial light pressure, and the reinforcing release and thus associative learning of the light rein tension signal will fail (McGreevy and McLean, 2007).

In our study, the criterion for release of rein tension was one step back. In hindsight, the learning process would probably have benefitted from applying a lower criterion to begin with. Even in the second treatment only 43% of rein tension signals resulted in a successful response, i.e. in 57% of the trials it took longer than 2 s before the horse responded to the rein tension signal or the horse showed evasive behavior before stepping back (Table 2). Some of the horses seemed to struggle to understand how to get relief from the pressure applied. Particularly in the bridle treatment, several horses performed numerous head/neck/mouth behaviors before taking the first step back. Perhaps the learning process would have been more effective if the criterion was gradually increased from shifting the weight back to a step back, as suggested by McCall (1990). Further, it is possible that the criterion was raised too soon for some horses. To be able to sustain a continuous learning process throughout the eight trials in each of the two treatments in all horses, the handler was given the possibility to ask the horse for an additional step back, above the one step back that was asked initially. Even though the handler only applied the rein tension signal for additional steps if the horse responded with a short latency to a light signal and showed no other behaviors during signaling rein tension, the additional steps included other behaviors than backing in 41% of the trials. This finding indicates that the horses were still searching for what behavior would lead to the release, even though they were already backing or had started to step back. By staying longer on the criterion of one step back, the backing response would likely have been more firmly established and less other behaviors would probably have been shown when the criterion was raised. The head/neck/mouth behaviors did, however, decrease over trials for the horses as a group, implying that the experimental setup was effective in training the horses to respond correctly to the rein tension signal. In future research on equine learning it would be interesting to study criteria levels in relation to learning efficacy.

5.1. Practical applications

The results from this study show that the correct use of the learning principles; negative reinforcement and classical conditioning, can lead to a reduction in magnitude of a rein tension signal in a single training session. These results can likely be applied to other (ridden) exercises as well and are thus applicable for the average rider. Horse may, however, try several other behaviors before making the correct response and it seems that the bitted bridle provokes more trial and error behavior than a plain halter. During initial training of a new response it may thus be an advantage to use a soft, non-aversive headstall to avoid complicating the learning process. Reducing rein tension magnitude, in combination with a timely release, is crucial to avoid stress and discomfort due to uncomfortable sensations from the bit or bridle. A broad application of the results from this study, when training responses to rein tension signals, would largely benefit equine welfare.

5.2. Conclusion

Investigating the magnitude of a rein tension signal (with a timely release) training the horse to step back, it was found that both response latency and magnitude of rein tension could be significantly reduced during a single training session consisting of eight trials. The reduction in rein tension magnitude likely reflects the increased frequency of the horses promptly stepping back, instead of trying other behaviors, in response to the rein tension signal. There was no significant difference between the bitted bridle and the halter in terms of learning performance. However, the bitted bridle was associated with significantly more head/neck/mouth behaviors regardless if the bridle was the first or the second treatment. Both response latency and maximum rein tension were reduced by half over the first eight trials and then further reduced during the second treatment. The findings demonstrate how quickly horses can be taught to respond to progressively lighter rein tension signals through the correct application of negative reinforcement. These results are important from a horse welfare point of view as pressures applied on the horse's mouth and/or nose can cause discomfort or even pain.

Contributions to study

The idea for the study was initiated by M.E. All authors contributed in refining and improving the experimental design. M.E., J.Y. P.B. and A. E. conducted the data collection. The rein tension analysis was performed by A.E. and the behavioral recordings were done by M.E. The statistical analysis was performed by M.E., A.E. and A.B. The manuscript was drafted by M.E. and all authors contributed to improving the content.

Declaration of Competing Interest

The authors of this manuscript declare no conflict of interest, no competing interests, and no financial interests..

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2021.105452.

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