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# What is reinforced? The timing of the release of rein tension and the horse's response latency for trot to walk transitions

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ABSTRACT

Rein tension signals are commonly used to communicate with a horse during riding. In accordance with the principles of negative reinforcement, tension on the reins acts as signals and motivates a horse to change behavior, while release of rein tension reinforces the correct behavior. The aim of this study was to investigate if the features of rider rein tension signals and timing of the release have effects on the magnitude of rein tension, horse response latency, as well as horse behavior and head posture, during downward transitions. Nine riders rode the same eight horses in a crossover design, making eight transitions from trot to walk with each horse. Rein tension was measured and from video recordings the timing of the riders' application of the decelerating rein signal and of the release were registered along with gait, behavior and head posture. Analyzing data using linear mixed models, it was found that median and minimum rein tension ($p = 0.001$) increased during the rein tension signal, compared to in trot before the transition. During the release median ($p < =0.001$) and maximum rein tension ($p < 0.0001$) decreased compared to during the rein tension signal. Interestingly, the timing of the release in relation to the downward transition varied among riders. The release was, in most cases, given 'during' the downward transition (70 %). However, in 19 % of the trials, the release was given 'before' the transition had begun, during the trot, and in 11 % the release was given 'after' the transition had ended, during the walk. Releasing rein tension 'before' the transition had begun was associated with longer response latency ($p < 0.05$). Maximum rein tension was lower at the fifth and eighth trial compared to the first ($p = 0.02$). Horse head movements were generally associated with lower magnitudes of rein tension when present compared to absent, while open mouth was associated with higher maximum rein tension. Since rein tension acts on the sensitive structures of the horse's mouth and/or head/nose, further research on ways of reducing rein tension magnitude would benefit equine welfare. There is also room for further research on the implementation of cues, in isolation and together, to investigate riders' communication via the reins as well as how to effectively implement learning theory into practice for riders on all levels.

## 1. Introduction

Rein tension signals are a central part of horse-rider-interaction, a rider may use rein tension signals to influence the speed, direction, and head posture of the horse (McGreevy and McLean, 2010). When the rider has contact (baseline tension) on the reins, rein tension in ridden horses varies in magnitude along with the horse's stride cycle in a gait-specific pattern (Egenvall et al., 2015, 2016; Piccolo and Kienapfel, 2019). When communicating a change of speed, for example a transition from trot to walk, riders generally apply a resisting rein signal, with or without a (preceding) resisting seat signal, i.e. the rider braces against the horse's movement with the hands/arms and seat (Miesner et al., 2016). This resisting rein signal (and seat signal) should then be released (and relaxed) immediately when the horse performs the correct behavior, in this case, a transition to walk (McLean and Christensen, 2017).

While the pressure from the bit via the reins (or other aids) acts as a signal and motivates the horse to decelerate, the release is what reinforces the response, e.g., 'transition to walk' (Egenvall et al., 2012). This principle for communicating with a horse is, in scientific terms,

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called negative reinforcement (Ahrendt et al., 2015), a form of associative learning (Baragli et al., 2015). Since the release is what is reinforcing a behavior, the exact timing of the release is crucial (McGreevy and McLean, 2007). Egenvall et al. (2012) indeed found that releasing rein tension at a horse's first attempt led to lower rein tension and fewer conflict behaviors during trot-walk transitions. It is less clear exactly how close in time the release needs to happen for a horse to make the intended association. However, releasing rein tension for a backing up response within one second from when the horse lifts its first front hoof to step back resulted in around 50 % reduction in the required rein tension magnitude over eight repetitions in unridden horses, suggesting that release within this time window is effective (Eisersiö et al., 2021a).

Since rein tension signals can be used to communicate several different aspects, it is important that the meaning of each rein tension signal is clear to the horse (McGreevy and McLean, 2007). Both timing and consistency in signaling is of outmost importance for animal learning in general (Pearce, 2008; Domjan, 2013). Previous research suggests that knowledge of learning theory is low among riders (Telatin et al., 2016, Brown and Connor, 2017), while the high prevalence of bit-related oral injuries in competing riding horses (Björnsdóttir et al., 2014; Uldahl and Clayton, 2019; Tuomola et al., 2021) suggests that it is common for riders to use the reins in non-optimal ways. The characteristics and magnitude of rein tension signals used by riders have rarely been investigated. Warren-Smith et al. (2007) found that a mean left/-right rein tension of 15/12 N was used for signaling to horses to halt. Egenvall et al. (2012) found that rein tension during trot-walk transitions with young horses (3–4 years) was above 30 N per rein during 19 % of the transitions if rein tension was released at the horses' first attempt, compared to 38 % if rein tension was released at the completed correct response. This suggests that timing of the release is important for reducing rein tension magnitude during rein signals. Proper learning of each rein signal used for communication between horse and rider leads to more predictable behavioral responses that remain reliable also in stressful situations. Improved horse-rider communication may also reduce the frequency of bit-related oral injuries.

The overall objective of this study was to investigate riders' use of rein tension signals and timing of the release during a series of repeated downward transitions from trot to walk. The aims were to investigate the features of rein tension signals and timing of the release, and to explore associations between the magnitude and timing of rein tension signals and horses' latency to respond, as well as horse behavior and head posture in conjunction with the transitions.

## 2. Material and methods

This study was conducted during three consecutive days in October 2019 at the Swedish National Equestrian Center, Strömsholm. Ethical approval had been given by the Animal Ethics board in Uppsala, Sweden, (Dnr 5.8.18–02567/2019), and the Swedish Ethical Review Authority (Dnr: 2019–01211). Eight horses and nine riders from the Equestrian Center participated in the study. Both horses and riders were at medium level (equivalent to US Third Level, UK Medium, German M-level) in jumping and/or dressage. The riders were all female and enrolled as students at the Equine studies program at the Swedish University of Agricultural Sciences, studying to become riding teachers and horse trainers. Eight of the riders assessed themselves as right-handed and one rider as left-handed. The horses were school horses at the Equestrian Center. The horses underwent an oral examination by the Equestrian Center veterinarian approx. 6 months before the trials with no or minimal findings. The horses were deemed sound by a veterinarian who watched the horses during warm-up, additionally the horses were regularly monitored by the Equestrian Center veterinarian.

The horses wore their usual saddle and bridle. Three horses had single joint snaffles, and five horses had double joint snaffles, all with loose rings. Two horses had dropped a noseband, one horse had an English noseband, and five horses had flash a noseband. The noseband was fitted so that an ISES taupe gauge (International Society for Equitation Science, UK) could be fitted between the noseband and the nasal plane (equivalent to two adult fingers or 1.5 cm). The riders wore regular riding clothes and a riding helmet, as well as spurs and a whip at their own preference.

### 2.1. Measurement equipment

Horses and riders were fitted with the measuring equipment when first entering the riding arena. The horses were fitted with an inertial measurement unit (IMU) system for measuring movement (Equi-Pro [previously EquiMoves], Inertia Technology B.V., Enschede, The Netherlands) that consisted of brushing boots with sensors on, as well as a sensor fastened on the horse's tubera sacrale and poll, respectively, using tape. These IMU data were not included in the present study.

Rein tension data were collected using a custom-made rein tension meter consisting of load cells (FSSM-500N, Forsentek, China) with a measuring range of 0–500 N, that were wire-connected to an amplifier box bundled with an IMU (x-io technologies, UK). The IMU contained a battery and a micro-SD card for data storage, as well as a three-axial gyro and a three-axial accelerometer. Rein tension data were logged to the IMU at 100 Hz. The load cells of the rein tension meter were attached on intact reins (for safety reasons). The amplifier-IMU package and the wires were taped onto a bridle consisting of a neck piece with side pieces. This bridle was then placed on top of the horse's usual bridle. The side pieces and the reins with the rein tension meter were attached to the horse's bit with clips. The rein tension meters were calibrated with known weights ranging from 0.2 – 10 kg both before and after the trials.

### 2.2. Location and video cameras

The study took place in an indoor riding arena, which measured 69x25 m, and that was divided in half after reserving a 5 m wide area along one long side for equipment and video cameras. Thus, two smaller riding areas were created measuring 34.5x20 m. One area was used for warm-up and the other for the trot-walk transitions. Two video cameras were used to record the riding sessions. One video camera (Canon Legria HF R806, 25 Hz) was placed at the warm-up area, recording the warm-up of the horses (data not included in the current study). The other video camera (Sony FDR-AX53, 25 Hz) was placed at the transitions area, recording the entire session of transitions from trot to walk.

### 2.3. Data collection

Each rider rode all eight horses (crossover design). The riders participated on two days and rode four horses both days. Each horse participated on all three days, at approximately the same time of day, and was ridden by three different riders each day. Two horses and three riders were present in the riding arena at the same time.

All horses were hand-walked for 10 min before the first rider mounted. Each horse-rider combination was given a 10-minute warm-up period. The riders were instructed to ride like they would usually do throughout the warm-up and trial and to focus on developing a good feeling and good communication with the horse. The rein tension meter was synchronized with the respective video camera before and after the warm-up and trial for each horse-rider combination. This was done by pulling on the right rein tension meter (not the horse's mouth), five times repeated twice, while counting out loud, performed by a person standing on the ground.

When entering the trial area, the riders first rode a few straight lines and corners in both directions and then began with the transitions. The riders were asked to make eight transitions from sitting trot to walk on straight lines, making sure the video camera captured a side view of the horse. It was emphasized that they should prepare the horse appropriately for each transition and that the transitions should be carried out at different locations each time and in both directions. The entire transition session took approximately 7–8 min.

### 2.4. Data analysis

#### 2.4.1. Video recordings

The video recordings from each trial were scrutinized in the video editing program Adobe Premiere Elements (Adobe, CA, USA). This was done by an ethologist (ME, first author), who was blinded to the rein tension data. The goal of this analysis was to identify horse and rider actions throughout the transitions, including behaviors and changes in posture. Each video was first viewed at normal speed to get an overview of the complete trial. Each trot-walk transition was then viewed frame by frame. Based on visual observation, five distinct phases were identified, as detailed below. The video timestamps for when each of these phases began and ended were recorded in a protocol for each transition (if present, in a few cases no release phase was observed). The video sequence was played back and forth as needed to identify each phase.

The five phases identified were:

- Preparation phase – from when the horse and rider enter a straight line (e.g. exits a corner) until the horse begins to transition or the rider begins the rein tension signal, whichever occurs first.
- Rein tension signal phase – from when the rider begins to apply the rein tension signal until two frames before the release begins (to avoid overlap between the rein tension signal and the release). Visually this phase was identified as the reins becoming tauter while the rider appeared stiffer/more rigid, resisting the movements of the trot with their seat while keeping their shoulders back or even leaning back slightly.
- Release phase – from when, following the rein tension signal phase, the rider reduces the rein tension, and until the rein contact increases again. Visually the release was identified from that the reins became less taut or had a little slack (formed a slight bow) while the rider moved their hands in the direction of the horse's mouth (forward-downward, usually only a slight movement).
- Downward transition – from the last trot diagonal (limb pair moving synchronously) until the first hind limb of the walk touches the ground (i.e. that is followed by a regular four-beat gait).
- Walk – starts the next frame following the end of the downward transition and as many strides as the horse walked in a straight line while still on a contact and not yet preparing for trot.

Depending on the order of events, 'Downward transition' and 'Walk' could overlap with 'Rein tension signal' and 'Release', but not with 'Preparation'.

After identifying the phases, the video recordings were examined a second time. In this second analysis, horse head posture and behavior were annotated. The ethogram used for head posture and behavior can be found in Table 1. The predominant head posture during each phase was determined by first viewing the video at normal speed and then frame by frame. Head posture approximately 0.5 s before the release (during the rein tension signal) and 0.5 s after the onset of the release (during the release) were also recorded, to determine what head posture was reinforced by the release of rein tension (according to the principles of negative reinforcement). Head, neck and mouth behavior were annotated as present/absent during each of the five phases.

#### 2.4.2. Rein tension

Rein tension data were analyzed in Matlab (version R2020a, MathWorks Inc., USA) using custom written code. The protocols from the video registrations were imported, and protocol data were synchronized with the rein tension data. Then left and right rein tension mean, median, standard deviation (s.d.), minimum, maximum, and quartiles were calculated for each of the five transition phases. Response latency was calculated as the time from the onset of the rein tension signal to the onset of the downward transition, using frame times from the video registrations. The timing of the release was calculated as the time between the onset of the release and the onset of the downward transition. Consequently, if the release came before the downward transition, this time variable was negative and if the release came after the downward transition, this time variable was positive. The duration between onset of walk and onset of the release was also calculated. If the release came after the downward transition had ended, this variable was positive, otherwise negative. The timing of the release was then categorized into three categories: release 'before' the transition, 'during' the transition, and 'after' the transition.

**Table 1**
The ethogram used in the video registration along with the number of rein tension signal and release phases in which each behavior was present, as well as the head posture near the release (0.5 s before the onset of release for the rein signal and 0.5 s after for the release) for all transitions (n = 568).

| Category | Behavior | Description | Rein signal | Release |
|---|---|---|---|---|
| Head/neck movement | Upward | The horse's head/neck is raised upward | 162 | 20 |
| | Forward | The horse's nose is pushed forwards | 39 | 14 |
| | Backward | The horse's nose is drawn in towards the chest | 16 | 2 |
| | Downward | The horse's head/neck is lowered downward | 4 | 1 |
| Mouth behavior | Open mouth | Visible gap between upper and lower jaw | 88 | 25 |
| Head posture | At vertical | The horse's nasal plane is vertical to the ground, or up to ten degrees in front of the vertical or five degrees behind the vertical | 300 | 314 |
| | In front of vertical | The horse's nasal plane is more than ten degrees in front of the vertical | 114 | 95 |
| | Behind vertical | The horse's nasal plane is more than five degrees behind the vertical | 154 | 159 |

Adapted from Egenvall et al. (2012).

### 2.5. Statistical analysis

The final dataset included discrete rein tension variables with values for each rein and phase, and the behavioral registrations, as well as duration and onset and end times for each of the phases, events and behaviors. This dataset was further managed and analyzed statistically in R (version 4.0.1, The R Foundation, https://www.r-project.org) using RStudio (Posit Software, MA, USA). The R packages used for the analysis were tidyverse, ggplot2, dplyr, gapminder, lmerTest, lme4, and emmeans. Descriptive statistics were calculated by phase for response latency and for rein tension. Rein tension in the left and the right rein was analyzed separately for descriptive statistics and summed for the statistical models.

Linear mixed models were used for statistical analysis. Five different models were made. Median rein tension (left + right rein) was used as the outcome variable in model 1, minimum rein tension in model 2, and maximum rein tension in model 3. Response latency was the outcome variable in models 4 and 5. Models 1–3 included the data from all five phases, while models 4 and 5 only included the data from the rein tension signal phase.

In all models, the explanatory variables were head posture (at/in front of/behind the vertical), timing of the release (before/during/after), trial number (1–8) and behavior (open mouth, head upward, head backward; present/absent), all included as categorical variables. For models 1–3, phase and its interaction with the other explanatory variables were also included. Phase was omitted in models 4 and 5, since these models only included data from the rein tension signal phase. Models 4 and 5 were identical except that, in order to investigate if there was a relationship between response latency and rein tension during the rein tension signal, minimum rein tension was added as an explanatory variable in model 4, and maximum rein tension in model 5. In both models the respective rein tension variable was added both as a linear effect and as a square root effect, to also evaluate the presence of a nonlinear relationship. Horse, rider and the interaction between horse, rider and trial number were modelled as random variables in models 1–3, while horse, rider and the interaction between horse and rider were the random variables in models 4 and 5.

Normality of model residuals was checked using QQ-plots and homoscedasticity (homogeneity of variance) was checked by plotting Pearson residuals versus fitted values. Rein tension was log-transformed, and response latency was square root transformed when used as outcome variable to achieve normality of residuals. Each model was backwards reduced manually, by repeatedly removing the term with the highest p-value and rerunning the model, until the final models were established. Back-transformed least square means were calculated for all categorical variables and contrast p-values were used to find significant differences between levels. Contrast p-values were adjusted for multiple comparisons within each model using the Tukey method. The p-value limit was set to $< 0.05$.

## 3. Results

### 3.1. Descriptive results

Nine riders and eight horses performed eight transitions from trot to walk for each horse-rider combination, which yielded a total of 576 downward transitions. Unfortunately, the rein tension meter stopped logging data during one trial, thus rein tension data are missing for one horse-rider combination, i.e. eight transitions, leaving 568 transitions in the dataset.

Over all transitions, median rein tension for the left/right rein during the different phases were: preparation phase 22/23 N, rein tension signal 30/31 N, downward transition 21/22 N, release 18/18 N and walk 13/12 N (Fig. 1). The downward transition phase had a median duration of 0.5 s (range 0.4 s – 1.5 s). For most transitions (70 %, n = 399), rein tension was released during the downward transition from trot to walk. For 108 transitions (19 %) the release began before the onset of the downward transition, i.e. while the horse was still trotting. Furthermore, in most cases the onset of the transition occurred within 0.5 s of the release (median 0.3 s, range 0.04 s – 2 s, Fig. 2a). For 61 transitions (11 %) the release began after the transition had ended and the horse had begun to walk. In these transitions, the release typically occurred within 0.5 s of the onset of walk (median 0.04 s, range 0.04 s – 0.6 s, Fig. 2b). The distribution of the three timing of release categories across riders, horses, and trials can be found in Table 2. Median response latency, i.e. the duration from the onset of the rein tension signal to the onset of the downward transition, was 1.3 s, ranging from 0 – 4.7 s with an interquartile range (IQR) of 0.9 s. The median duration of the rein tension signal phase (onset to end) was 1.4 s, ranging from 0.1 – 4.6 s with an IQR of 1.2 s.

Horse behaviors recorded in conjunction with the downward transitions were head, neck and mouth behaviors such as opening the mouth, or moving the head upward, downward, forward or backward. Open mouth and head movements were more common during the rein tension signal phase than during the release (Table 1), while most horses kept the same head posture from the end of the rein tension signal to the release (Table 1), i.e. the release did not change the head posture. The head moving downward only occurred eight times in total and was therefore not included in the statistical analysis. Head moving forward was mainly performed by one horse and was also excluded.

### 3.2. Model results

Least square means for transition phase vs. release category and vs. head posture, respectively, from model 1 are shown in Tables 3 and 4. Full model printouts for all models (1−5), including least square means with confidence intervals for results only reported in the text, can be found in Supplementary File 1.

The results from model 1 for median rein tension revealed that the effect of the timing of the release on median rein tension varied between phases (significant interaction between these variables). Timing of the release had a significant effect on median rein tension during the release and the downward transition phase. If the release was given before the transition, i.e. at the trot, median rein tension was significantly higher

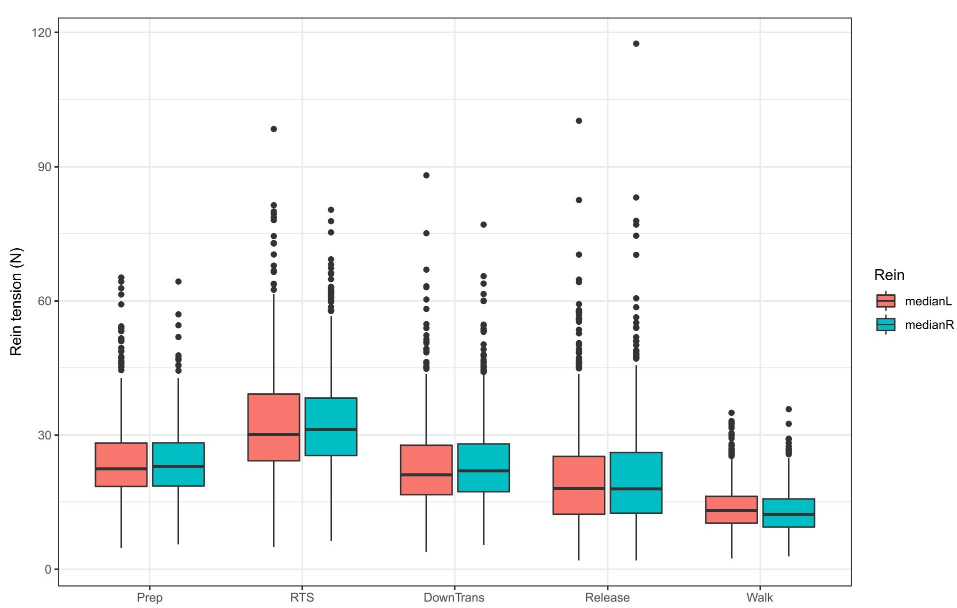


**Fig. 1.** Median rein tension for the different phases of transitions from trot to walk. Prep is the preparation phase just before the starts to decelerate, RTS is the rein tension signal, and DownTrans is the downward transition. The red box plots (to the left) are for the left rein, while the blue box plots (to the right) are for the right rein. Data from n = 568 transitions, 71 horse-rider combinations performing eight transitions each (8 horses, 9 riders but data were lost for one horse-rider combination, i.e. 8 transitions).

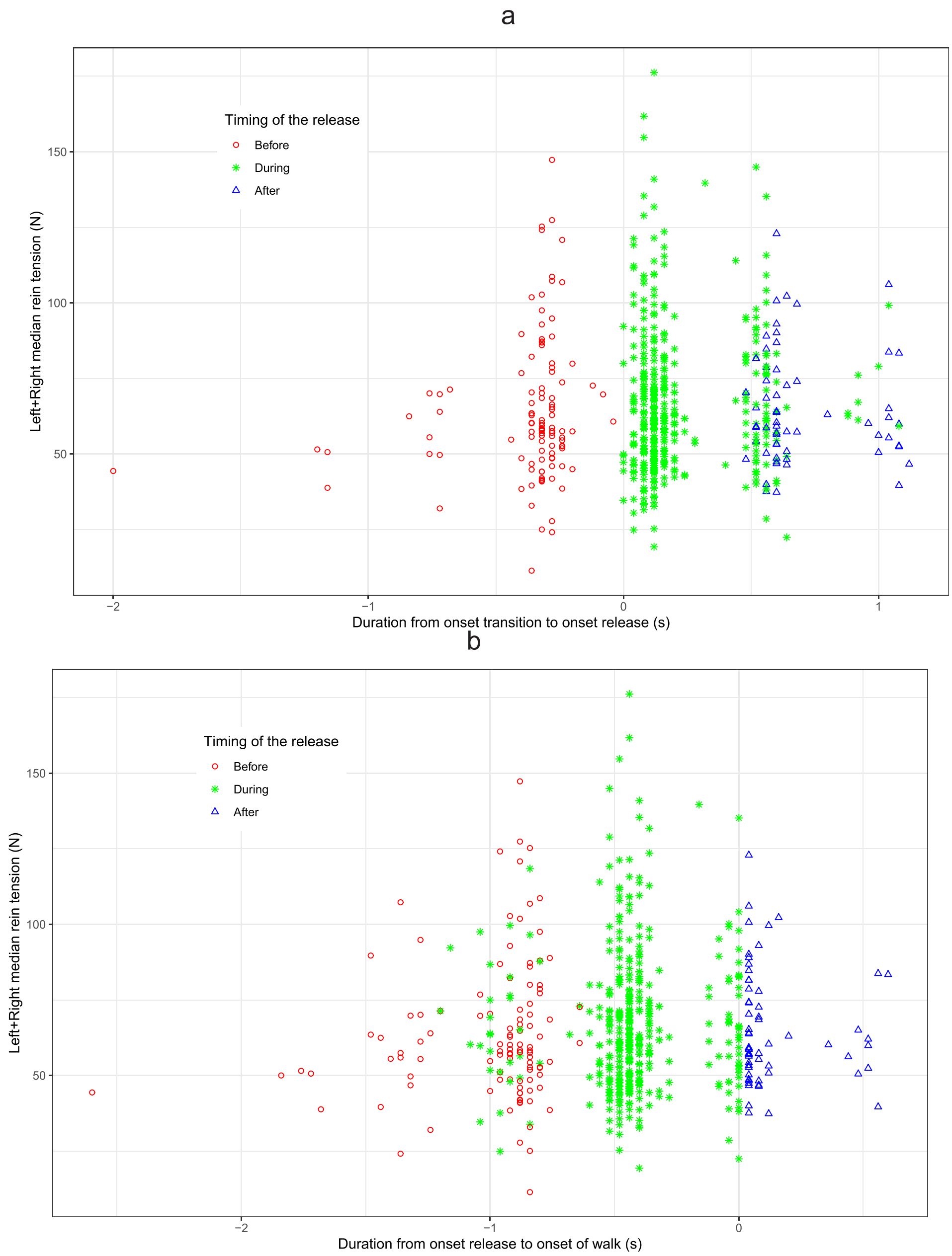


**Fig. 2.** a. Median rein tension versus duration from onset of the transition to the onset of the release for transitions from trot to walk. Zero on the x-axis represents the onset of the downward transition. The release is when the rider lowered and/or moved the hands forward so that the rein became less taut. Colors and symbols indicate if the release occurred before, during and after the downward transition. The clustering of data points results from the riders releasing rein tension in sync with the horse's stride cycle, mainly during the stance phase of the trot. Data from n = 568 transitions, 71 horse-rider combinations performing eight transitions each (8 horses, 9 riders but data were lost for one horse-rider combination, i.e. 8 transitions). b. Median rein tension versus duration from the onset of the release to the onset of the walk. Zero on the x-axis represents the onset of walk. Colors and symbols indicate if the release occurred before, during and after the downward transition. See Fig. 2a for further details.

during the release phase (35 N) compared to if the release was given during or after the transition, i.e. while slowing down or at the walk (29–30 N, $p < 0.01$, Table 3). Similarly, median rein tension during the downward transition was significantly lower (37 N) when the release occurred before the transition, and significantly higher if the release occurred after the transition (54 N), compared to if the release occurred during the transition (43 N, Table 3). Comparing between phases, median rein tension during the rein tension signal phase was significantly higher than all other phases for all three release categories ($p < 0.001$), except for the downward transition phase if the release was given after the transition, i.e. the rein tension signal phase was still ongoing during the transition (Table 3).

Model 1 further showed that head posture was associated with median rein tension. If the horse's head posture was 'in front of the vertical' during the rein tension signal, transition or release phases, median rein tension was significantly higher during the same phase, compared to if the horse's head posture was 'at the vertical' or 'behind the vertical' ($p < 0.01$, Table 4).

Regardless of head posture or timing of the release, minimum rein tension increased significantly from the preparation phase to the rein tension signal phase (difference 6–12 N across release categories, $p < 0.0001$), and decreased significantly from the rein tension signal to the walk (difference 10–17 N across release categories, $p < 0.01$, model 2). However, there was no significant difference in minimum rein

**Table 2**
Timing of the release categorized into before, during or after the transition by rider (R1-R9), horse (H1-H8) and transition repetition (trial T1-T8). The release is when the rider lowered and/or moved the hands forward so that the rein became less taut; 'Before' is onset of the release before the downward transition, i.e. in trot, 'During' release during the downward transition and 'After' is release after the transition, i.e. in walk. Each horse-rider combination performed eight transitions from trot to walk, in total 576 transitions (64 transitions per rider, 72 transitions per horse). There was data loss for rider R6 on horse H5, i.e. data were missing for 8 trials.

| | Timing of the release | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Rider** | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 |
| Before | 25 | 9 | 17 | 7 | 6 | 10 | 13 | 2 | 19 |
| During | 36 | 48 | 44 | 46 | 52 | 39 | 49 | 47 | 38 |
| After | 3 | 7 | 3 | 11 | 6 | 7 | 2 | 15 | 7 |
| **Horse** | H1 | H2 | H3 | H4 | H5 | H6 | H7 | H8 | |
| Before | 21 | 17 | 17 | 11 | 7 | 11 | 12 | 12 | |
| During | 43 | 52 | 45 | 56 | 48 | 53 | 49 | 53 | |
| After | 8 | 3 | 10 | 5 | 9 | 8 | 11 | 7 | |
| **Trial** | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | |
| Before | 16 | 8 | 13 | 18 | 8 | 14 | 18 | 13 | |
| During | 41 | 58 | 50 | 48 | 49 | 52 | 49 | 52 | |
| After | 14 | 5 | 8 | 5 | 14 | 5 | 4 | 6 | |

**Table 3**
Back-transformed least square means, standard errors (SE) and confidence intervals from mixed models of the sum of median left and right rein tension (N) during the different phases of the downward transition (model 1). The release is when the rider lowered and/or moved the hands forward so that the rein became less taut. Each horse-rider combination (8 horses, 9 riders) performed eight transitions from trot to walk (64 transitions per rider, 72 transitions per horse). Data were lost for one horse-rider pair (8 transitions), hence the model included data for n = 568 transitions. Horse and rider were included as random factors in the model.

| Phase | Timing of release | Estimate | SE | lower CI | upper CI |
|---|---|---|---|---|---|
| Preparation | Before | 45 | 4 | 38 | 53 |
| | During | 45 | 3 | 38 | 52 |
| | After | 42 | 4 | 36 | 50 |
| Rein signal | Before | 64 | 5 | 54 | 75 |
| | During | 66 | 5 | 56 | 77 |
| | After | 63 | 5 | 54 | 75 |
| Transition | Before | 37 | 4 | 30 | 46 |
| | During | 43 | 4 | 36 | 53 |
| | After | 54 | 6 | 44 | 67 |
| Release | Before | 35 | 3 | 30 | 42 |
| | During | 30 | 2 | 26 | 36 |
| | After | 29 | 3 | 24 | 35 |
| Walk | Before | 29 | 4 | 23 | 37 |
| | During | 29 | 3 | 23 | 37 |
| | After | 30 | 4 | 24 | 39 |

tension between the rein tension signal and the downward transition or the release.

Maximum rein tension also increased from the preparation phase to the rein tension signal phase, but this increase was only significant for the timing of the release category 'after' (difference 21 N, $p = 0.04$) and for head posture 'at the vertical' (difference 17 N, $p = 0.03$, model 3). Maximum rein tension decreased from the rein tension signal to the downward transition (difference 25–45 N, $p < 0.01$) and to the release (difference 46–89 N, $p < 0.0001$), regardless of head posture or timing of the release. Maximum rein tension was significantly lower in the fifth and eighth trial than in the first (88 N compared to 98 N).

The horse moving the head backward during the release was associated with significantly reduced median (13 N lower, $p = 0.0001$), minimum (6 N lower, $p = 0.01$), and maximum rein tension (21 N lower, $p < 0.0001$). Minimum rein tension was also significantly reduced when the horse moved the head backward or upward during the preparation phase or the rein tension signal phase ($p < 0.02$). Likewise, maximum rein tension was significantly reduced during the release

**Table 4**
Back-transformed least square means, standard errors (SE) and confidence intervals from mixed models of the sum of the left and right median rein tension (N) presented by transition phase and head posture (model 1). The release is when the rider lowered and/or moved the hands forward so that the rein became less taut. Each horse-rider combination (8 horses, 9 riders) performed eight transitions from trot to walk (64 transitions per rider, 72 transitions per horse). Data were lost for one horse-rider pair (8 transitions), hence the model included data for n = 568 transitions. Horse and rider were included as random factors in the model.

| Phase | Head Posture | Estimate | SE | lower CI | upper CI |
|---|---|---|---|---|---|
| Preparation | At vertical | 44 | 3 | 38 | 52 |
| | In front of vertical | 44 | 4 | 37 | 52 |
| | Behind vertical | 44 | 3 | 38 | 52 |
| Rein signal | At vertical | 62 | 5 | 53 | 72 |
| | In front of vertical | 73 | 6 | 62 | 86 |
| | Behind vertical | 59 | 4 | 50 | 69 |
| Transition | At vertical | 41 | 4 | 34 | 50 |
| | In front of vertical | 51 | 5 | 41 | 63 |
| | Behind vertical | 42 | 4 | 34 | 52 |
| Release | At vertical | 30 | 2 | 25 | 35 |
| | In front of vertical | 36 | 3 | 30 | 43 |
| | Behind vertical | 29 | 2 | 24 | 34 |
| Walk | At vertical | 27 | 2 | 22 | 32 |
| | In front of vertical | 29 | 3 | 23 | 36 |
| | Behind vertical | 33 | 8 | 21 | 53 |

when the horse moved its head upward (10 N lower, $p = 0.006$). Overall, open mouth was associated with significantly lower minimum rein tension, but significantly higher maximum rein tension (6 N higher, $p = 0.01$).

Models 4 and 5 indicate that several variables affected response latency. If the release was given before the transition, response latency increased (~0.28 s longer, $p < 0.05$) compared to when the release was given during or after the transition. Likewise, response latency was longer when minimum rein tension was lower ($p < 0.0001$, model 4) or maximum rein tension was higher ($p = 0.0002$, model 5). In both models, response latency was longer when the horse opened the mouth (0.22–0.30 s longer, $p < 0.04$) or moved the head upward (~0.18 s longer, $p < 0.04$) during the rein tension signal, than if these behaviors were not present.

## 4. Discussion

Median and minimum rein tension increased significantly when the riders applied a rein tension signal to initiate a downward transition from trot to walk compared to the preparation phase, trot just prior to the transition. For maximum rein tension the same was true only for head posture 'at the vertical' and timing of the release 'after' the transition. The increase in minimum and median rein tension indicates that the oscillating pattern, that rein tension displays accompanying different gaits, showed an elevated baseline when the riders resisted on the reins, while the maximum rein tension was less affected. Interestingly, when the riders released this resistance, there was a significant decrease in median and maximum rein tension, compared to during the rein signal, but not in minimum rein tension. Minimum rein tension has previously been associated with rider (Eisersiö et al., 2015) and may represent what riders call contact on the reins.

From a horse's perspective, one may presume that the increase and subsequent decrease in pressure on the oral structures motivated and reinforced the deceleration response. However, the riders' timing of the release of rein tension was not consistent relative to the onset of the downward transition (Fig. 2a). While no statistical evaluation was conducted, it seems that some riders were more likely to release early (rider 1, 3, 9) while other riders more often released late (rider 4, 8, Table 2). This is interesting from an equine learning perspective. Following the principles of negative reinforcement, if a rider wants to train their horse to perform downward transitions, the release of rein tension should be prompt, presumably at the onset of the transition. With young horses, riders need to be immensely consistent to reinforce basic responses, whereas when horses get older and more educated, riders may want to reinforce auxiliary performance traits like straightness, head posture and lightness in hand concurrently with the transition (McGreevy and McLean, 2010). Since the horses in this study were adult, well-educated school horses that already performed transitions from trot to walk with a rider on a daily basis, the riders may have tried to signal to the horses to, for example, move straighter or change head posture, in accordance with what is considered "equestrian correctness", in addition to performing the transition. Thus, auxiliary signaling may explain the late release in 11 % of the transitions. Moreover, perhaps the instances of late release were connected to horses' horizontal balance, the horse 'leaning on the bit' during the downward transition and the riders therefore withheld the release until the horse lifted the head again, thereby releasing rein tension after the transition. It is also possible that the riders were unaware of the importance of the timing of the release for reinforcing the horse's responses and therefore paid more attention to their signals than to the timing of the release.

There was no significant reduction in median rein tension over trials. Maximum rein tension, on the other hand, was significantly lower at the fifth and eighth trial compared to the first. These results are in line with the findings in Fenner et al. (2017) and Eisersiö et al. (2021b) who both reported a significant reduction in maximum tension, but not mean/-median tension, over trials for rein tension signals.

The three timing of release categories (before, during and after) were associated with divergent magnitudes of rein tension. If the rider released rein tension 'before' the downward transition, the magnitude was significantly higher during the release (since the horse was still trotting), but significantly lower during the downward transition (reins were more slack/loose), than if the release occurred 'during' and 'after'. When rein tension was released 'after' the transition, the magnitude of rein tension during the downward transition was instead significantly higher, than if the release came 'before' or 'during' the transition. Both this and previous studies (Kuhnke et al., 2010; Egenvall et al., 2019) have demonstrated that there is generally less rein tension in walk than trot, which should be kept in mind when interpreting these results. One may ponder if horses perceive transitioning to walk as reinforcing, due to the lower baseline tension, regardless of the riders' actions or intentions, and/or due to the reduced physical effort, presenting an opportunity for rest and relaxation.

It should be kept in mind that if the release is given before the transition has commenced, the rider is, in essence, reinforcing something else than the actual downward transition. It is possible that the riders wanted to reinforce a horse's intention to make the transition when they felt that the horse was slowing down or was shortening the strides. An early release, reinforcing intention, is likely better than being late and failing to reinforce the correct response. Releasing rein tension early may also be a good strategy for reducing the overall magnitude of rein tension needed to decelerate from trot to walk, in accordance with the conclusion from a previous study in young horses (Egenvall et al., 2012). However, an early release may have made the horses less motivated to complete the transition quickly, or unsure if the rider wanted a transition or just a slower trot, making the transition become less swift, explaining the longer response latency.

Horse behavior was significantly associated with both magnitude of rein tension and response latency. Interestingly, when open mouth was present minimum rein tension was significantly lower, but maximum rein tension was significantly higher. Pondering on cause and effect, horses may open the mouth at higher magnitudes of rein tension (maximum rein tension), and this behavior may, in turn, lead to a reduction in rein tension, which has been found in unridden horses (Eisersiö et al., 2023).

Horse head posture had major influence on the magnitude of rein tension. Potential reasons for this include that head posture may relate to whether a horse was resisting the rein tension signal, and that a rider may resist more insistently on the reins if a horse is 'in front of the vertical', to make the horse drop the nose and return to the head posture 'at the vertical'. Having the nasal plane at the vertical is generally desired by most riders, for equestrian correctness (e.g., Rhodin et al., 2005). Horse head movements, head upward and head backward, were generally associated with lower magnitudes of rein tension when present compared to when absent and may represent the horse yielding to the rein pressure applied by changing head posture. Head backward mainly affected rein tension magnitude during the release phase, which may represent a combination of the horse yielding to the bit pressure and the rider releasing the reins. Previous research has found that both open mouth and moving the head upward can lead to reduced rein tension (Eisersiö et al., 2023). In other words, these behaviors led to less pressure on the oral structures and were likely performed to alleviate the oral structures from bit pressure. That these behaviors were associated with lowered rein tension, may explain the longer response latency when these behaviors were performed versus not.

### 4.1. Limitations

In this study, we asked the riders to focus on developing a good feeling and a good communication with the horses. If we had, for example, asked the riders to mainly focus on reducing the magnitude of rein tension needed to decelerate from trot to walk, our results in terms of timing of the release and/or magnitude of rein tension may have differed. For comparison, a recent study found that overall lesson design may influence rein tension magnitude during transitions between walk and trot performed during riding lessons (Byström et al., 2025).

The study included a homogenous group of horses and riders, respectively, with similar training and level of experience. Different results may have been obtained if a different category of riders had been included. It has previously been found that rein tension varies both between horses and between riders (Eisersiö et al., 2015). However, the complete crossover study design is a benefit in this regard, allowing us to account for both horse- and rider-related effects. The data could additionally have been examined for left-right rein tension asymmetry, related to horse or rider, however, this was outside the scope of the current analysis.

## 5. Conclusion

Riders applying a decelerating rein tension signal involved an increase in median rein tension of approximately 8 N in each rein, while the release entailed a decrease in median rein tension of approximately 12 N in each rein while transitioning from trot to the walk. The timing of the release relative to the downward transition varied among riders without an apparent cause. In 19 % of the trials, the release was given 'before' the transition had begun, during the trot, and in 11 % the release was given 'after' the transition had ended, during the walk. An early release, 'before', was associated with significantly longer response latency. A horse opening the mouth was also associated with longer response latency, and with lower minimum but higher maximum rein tension. Median rein tension did not decrease significantly over the eight trials, but maximum rein tension was significantly lower at the fifth and eighth trial compared to the first. Since rein tension acts on the sensitive structures of the horse's mouth and/or head/nose, further research on ways of reducing rein tension magnitude would benefit equine welfare. There is also room for further research on implementation of aids, in isolation and together, to investigate riders' communication via the reins as well as how to effectively implement learning theory into practice for riders on all levels.

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## CRediT authorship contribution statement

**Marie Eisersiö:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Agneta Egenvall:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Jenny Yngvesson:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Elin Hernlund:** Writing – review & editing, Investigation, Conceptualization. **Anna Byström:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2025.106590.

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