Learning on the Blink: Novel physiological predictors of adaptive learning in horses.

Dr Louise Evans

University of Bristol, UK

Nottingham Trent University

The Horse Trust 135 YEARS Home of Rest for Horses

University of BRISTOL

Welcome

- Dr Louise Evans - Research Technician and Research Associate in Animal Welfare at the University of Bristol, UK
- Completed PhD in 2024 from Nottingham Trent University, UK on Equine Cognition, Physiology and Welfare
- Research interests: animal cognition, affective states, physiology and welfare
- Current projects:
  - Individual differences in affective processing and implications for animal welfare
  - The use of AI to monitor decision-making and affective state in animals

NTU Nottingham Trent University

University of BRISTOL

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The Team

- Dr Carrie Ijichi, University of Central Lancashire
- Dr Heather Cameron-Whytock, University of Central Lancashire
- Dr Annika Paukner, Nottingham Trent University

Whoa, No-Go!

Horses can plan ahead and think strategically, scientists find

Donna Ferguson

The proverb "you can lead a horse to water but you can't make it drink" has been used since the 16th century to describe the difficulty of getting someone to act in their own best interests. Now research by equine scientists suggests this phrase has been inadvertently maligning horses.

Horses have the ability to think and plan ahead and are far more intelligent than scientists previously thought, according to a Nottingham Trent University study. The horses cannily adapted their approach to a rewards-based game to get the most treats while making the least effort.

"Our study shows that horses have an awareness of the consequences and outcomes of their actions," said the lead researcher, Louise Evans.

The three-stage game involved 20 horses which were initially rewarded with a treat for touching a piece of

"When there was a timeo
ting something wrong, the
paying attention," said Ev
behaviour is very goal direc
horses focusing on what the
achieve and the steps neede

Evans hopes the study, t
lished in the journal Applie
Behaviour Science, will
improve welfare for horses
we think animals have better cogni-
tive abilities, their welfare improves.
We've shown you don't need to use
harsh methods to get a good perfor-
mance out of horses."

From Grand National to grandmasters? Horses think strategically

Will Humphries

They can run, jump and — as Olympics viewers know — dance. But horses are even smarter than previously thought, having shown the capacity to plan ahead during games of strategy.

Researchers found that when denied treats for not following the rules of a complex reward-based game, horses were able to adjust quickly to get more rewards.

Scientists said this shows the animals have the ability to think and plan ahead, something previously consid-ered beyond their capacity.

Knowing how horses learn can help carers to train them more humanely and improve their welfare, the team from Nottingham Trent University

said Dr Carrie Ijichi a senior lecturer

not require much attention.

Louise Evans, a PhD candidate at the univer-sity's school of animal, rural and environmental sciences, said: "We were expect-ing horses' performance to im-prove when we introduced the time-out, but were surprised by how immedi-ate and significant the improvement was.

"Animals usually need several repetitions of a task to gradually acquire new knowledge, whereas our horses immediately im-proved when we intro-duced a cost for errors. This suggests that the horses

Are horses as stupid as we

GEE-GEE NIUSES

Clever horses pass tricky intelligence game at canter

BY ADAM ASPINALL

HORSES are far more intelligent animals than previously thought, a study has revealed.

Research shows they did well when facing a complex reward-based game.

Experts found that when denied treats for not following the rules of the game, the horses were able to instantly switch strategies to get more rewards.

Twenty horses were set a three-stage task. In the first stage, the animals touched a piece of card with their nose in order to get a treat. In stage two things became more complicated when they were only allowed a snack if they touched the card while a light was off.

The horses kept blindly touching the card, regardless of whether the light was on or off, but rewarded when correct.

But, in the final stage of the game, a

said: "This shows they're more cognitively advanced than we give them credit for."

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@MirrorAsp

knowing how horses learn can help carers train them more humanely and improve their welfare.

Dr Carrie Ijichi, a senior lecturer in equine science at NTU, said: "Horses are not natural geniuses, they are thought of as mediocre. But this study shows

Gifted...horses learned

'Dad, this is Stella – we met at uni'

horse sense

NAGS: Thinkers

Horses 'clever beasts'

HORSES are much smarter than we may have suspect-ed, scientists reckon.

Clever nags did better than expected in a com-plex reward-based game.

When denied treats for not following the rules, the horses were able to instantly switch strategies to get more rewards, re-searchers found.

It shows the animals have the ability to think and plan ahead – some-thing previously consid-ered beyond them.

Dr Carrie Ijichi, senior lecturer at Nottingham Trent University, said horses are "more cogni-tively advanced than we give them credit for".

There's no flies on horses, brain study

Creatures are far smarter than we give them credit for and even use strategic thinking to plan ahead

By Michael Searles
HEALTH CORRESPONDENT

HORSES are actually strategic thinkers able to think and plan ahead – a trait hitherto thought beyond their capacity, according to research.

They can excel in a complex reward-based game, quickly changing tack to fit new rules and maximise the outcome, an experiment by scientists from Not-tingham Trent University (NTU) have concluded.

Dr Carrie Ijichi, a senior lecturer in equine science at NTU, said: "Horses are not natural geniuses – they are thought of as mediocre – but this study shows they're not average and are, in fact, more cognitively advanced than we give them credit for."

The experiment involved giving 20 horses a task with three stages, the first of which was to touch a piece of card with their nose in order to get a treat.

This was then made more difficult with the introduction of a light, with the

tion in order to win.

It was not that they did not under-stand the rules during the second stage, but they continued to be rewarded without giving the game too much of their attention, the scientists hypothe-sised. Louise Evans, a PhD candidate based in NTU's school of animal, rural and environmental sciences, said: "We were expecting horses' performance to improve when we introduced the time-out, but were surprised by how imme-diate and significant the improvement was.

"Animals usually need several repeti-tions of a task to gradually acquire new knowledge, whereas our horses imme-diately improved when we introduced a cost for errors. This suggests that the horses knew all along what the rules of the game were."

The study found that horses have the ability to form an internal model of the world around them to make decisions and predictions, a skill known as mod-el-based learning.

'It suggests that the horses knew all along what the rules of the game were'

'We should not make assumptions about animal intelligence based on whether they are built like us'

ANIMALS

Straight from the horse's they can think and plan a

By Nilima Marshall

Horses are much smarter than pre-viously thought, scientists have said.

the rules – only making a move at the right time in order to receive their treat.

Applied Animal Behaviour Science 277 (2024) 106339

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

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

Whoa, No-Go: Evidence consistent with model-based strategy use in horses during an inhibitory task

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ARTICLE INFO

Keywords:
Model-based learning
Strategy
Cognition
Stop-signal
Equine
Behavioural inhibition

ABSTRACT

It is thought horses lack the prospection and brain architecture required for goal-directed, reflective model-based learning which considers future states. We investigate whether horses can use model-based strategy in an inhibitory task. Twenty subjects were trained for three sessions of a Stop-Signal paradigm using positive rein-forcement (+R) for correct responding. All twenty failed to reach learning criterion. Subjects continued to touch in "Stop" contingencies indicating horses either: cannot complete Stop-Signal tasks; need further consolidation; or are utilising model-based cost-benefit analysis. Subjects underwent a further three sessions with the addition of negative punishment (+R/-P) as a cost for errors of emission (EE). If horses lack the ability to complete Stop-Signal tasks, EE would remain high across both treatments. If horses found Stop-Signal difficult but the intro-duction of cost aided their learning, EE would gradually decrease throughout the +R/-P condition. If horses built a cognitive model of the task but developed a strategy of indiscriminate responding in the +R condition, EE would suddenly decrease with the introduction of cost. A significant, immediate reduction in EE was observed when cost was introduced (p=0.02) that remained stable throughout the +R/-P condition providing evidence consistent with model-based cost-benefit analysis in horses.

1. Introduction

Instrumental learning can be acquired through both model-free and model-based learning. Model-free learning is a relatively simple computation based on accrued trial-and-error learning that forms habits. As such, changes in contingencies and environmental conditions can only be responded to slowly, as a new "cache" of trials must be built (Dayan and Berridge, 2014a). The accruing cache adjusts the reward prediction error which signals the value achieved by a given action to maximise future expected rewards (Sutton and Barto, 2018). This is achieved by comparing differences between rewards actually received and those expected, based on previous experience (Schultz, 2016). Simple tasks can be reliably learnt, given sufficient opportunities, by building associations between stimuli and their outcomes. For example, an animal may reflexively touch a target because they have been conditioned through repeated exposure to associate it with a positive outcome such as food. The target elicits an urge to make contact with it, and no more complex processing of what the target signifies. Therefore, there is no need for higher order executive function. By contrast, a model-based strategy involves prospective cognition (Dayan and Ber-ridge, 2014a) which refers to the ability to think about possible future states and understand the likely outcomes of various responses so that optimal responses can be selected. It therefore allows an individual to select the response most suitable to the current situation out of all po-tential options. The model refers to this cognitive "map" of possible outcomes and is built using the state prediction error (SPE) (Gläscher et al., 2010). SPE registers violated expectancies by comparing dis-crepancies between the current cognitive model (cognitive map) and the current observed state (reality) (Gläscher et al., 2010). Whilst model-based is goal-directed and reflective, model-free cognition is habitual and reflexive. The former is considered more computationally demanding than the latter which is counterbalanced by its value in promoting flexible adaptive responses in dynamic situations (Huang et al., 2020a).Inhibitory control is the ability to actively ignore

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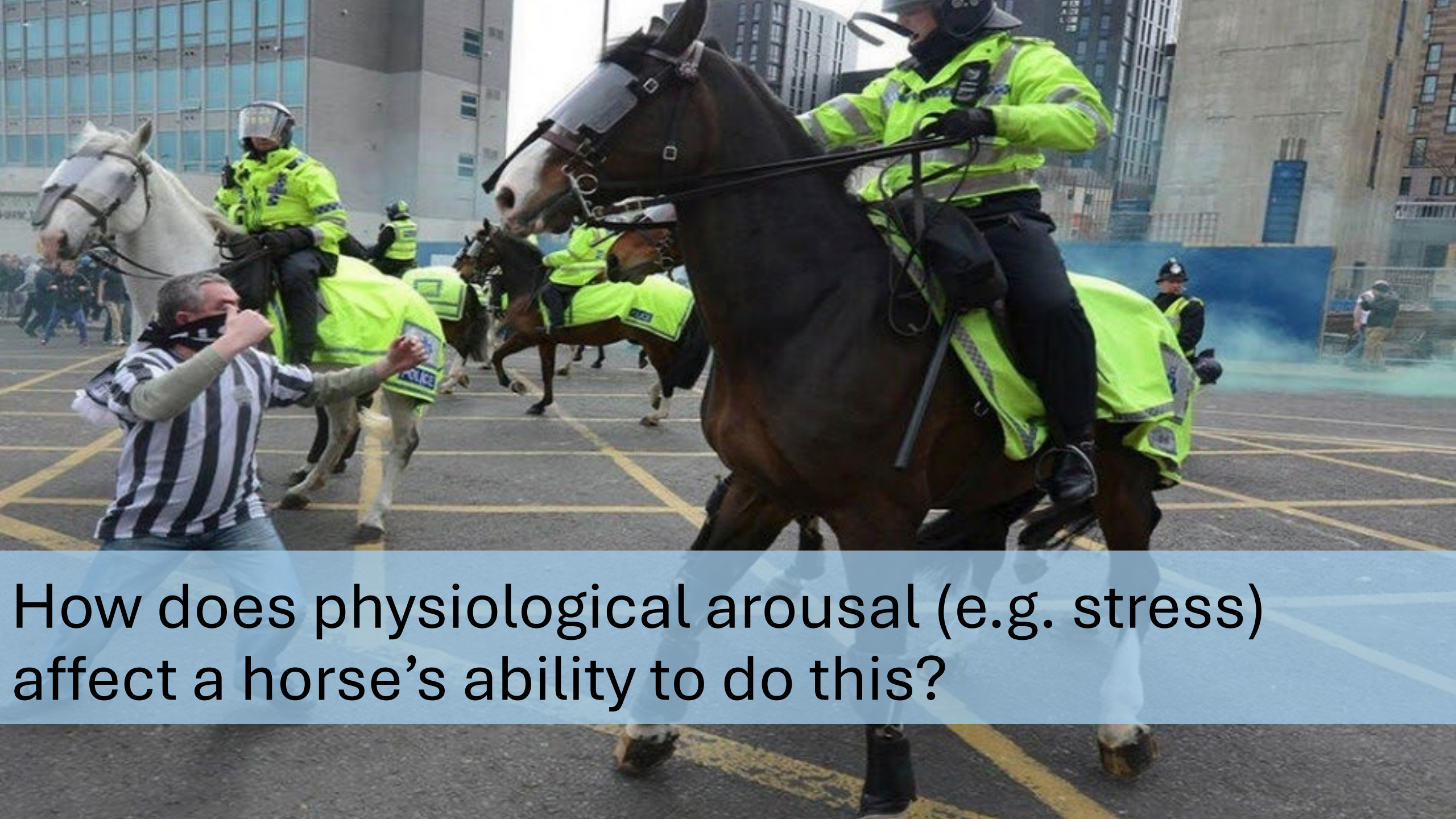
https://doi.org/10.1016/j.applanim.2024.106339

Inhibitory control

- Inhibitory Control = a core executive function - controlling automatic behavioural urges.
- In humans, it is thought of as our ability to think before we react- pausing, and using attention and reasoning to respond appropriately
- A relatively difficult task, but we rely on the horse's ability to do this

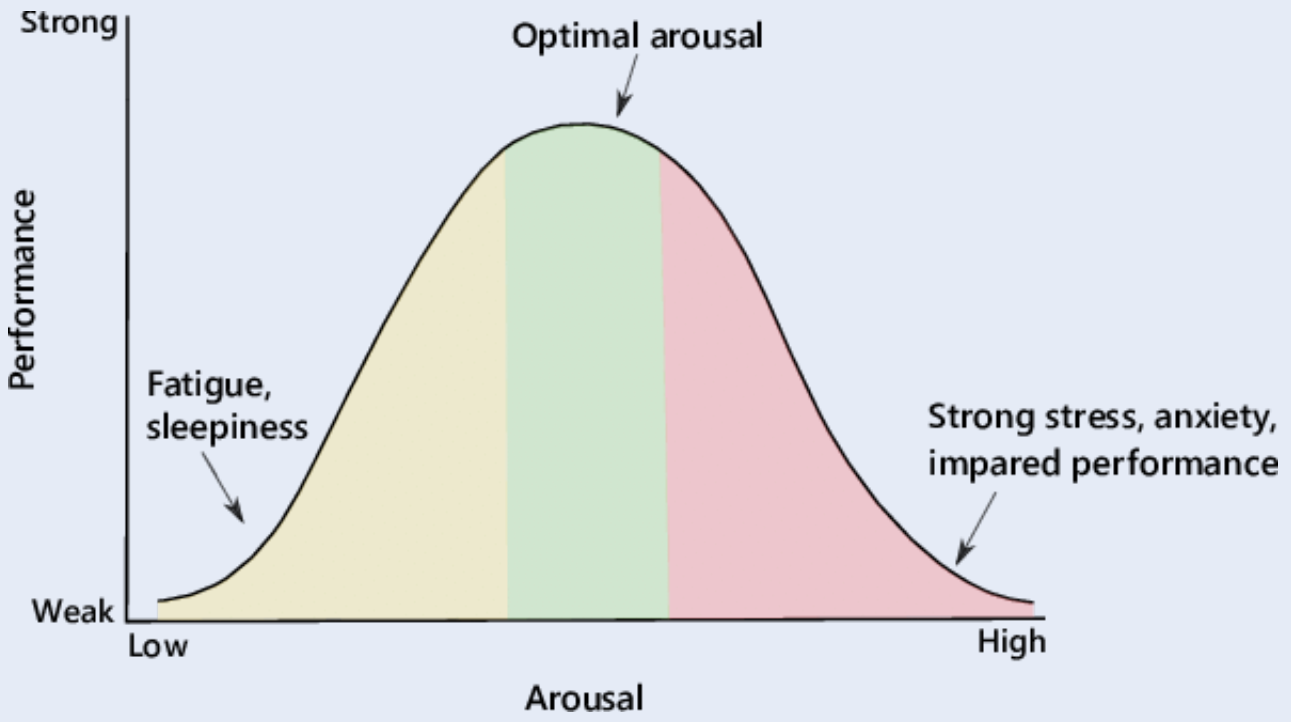
Consistent, reliable responses, even in challenging situations



How does physiological arousal (e.g. stress) affect a horse's ability to do this?

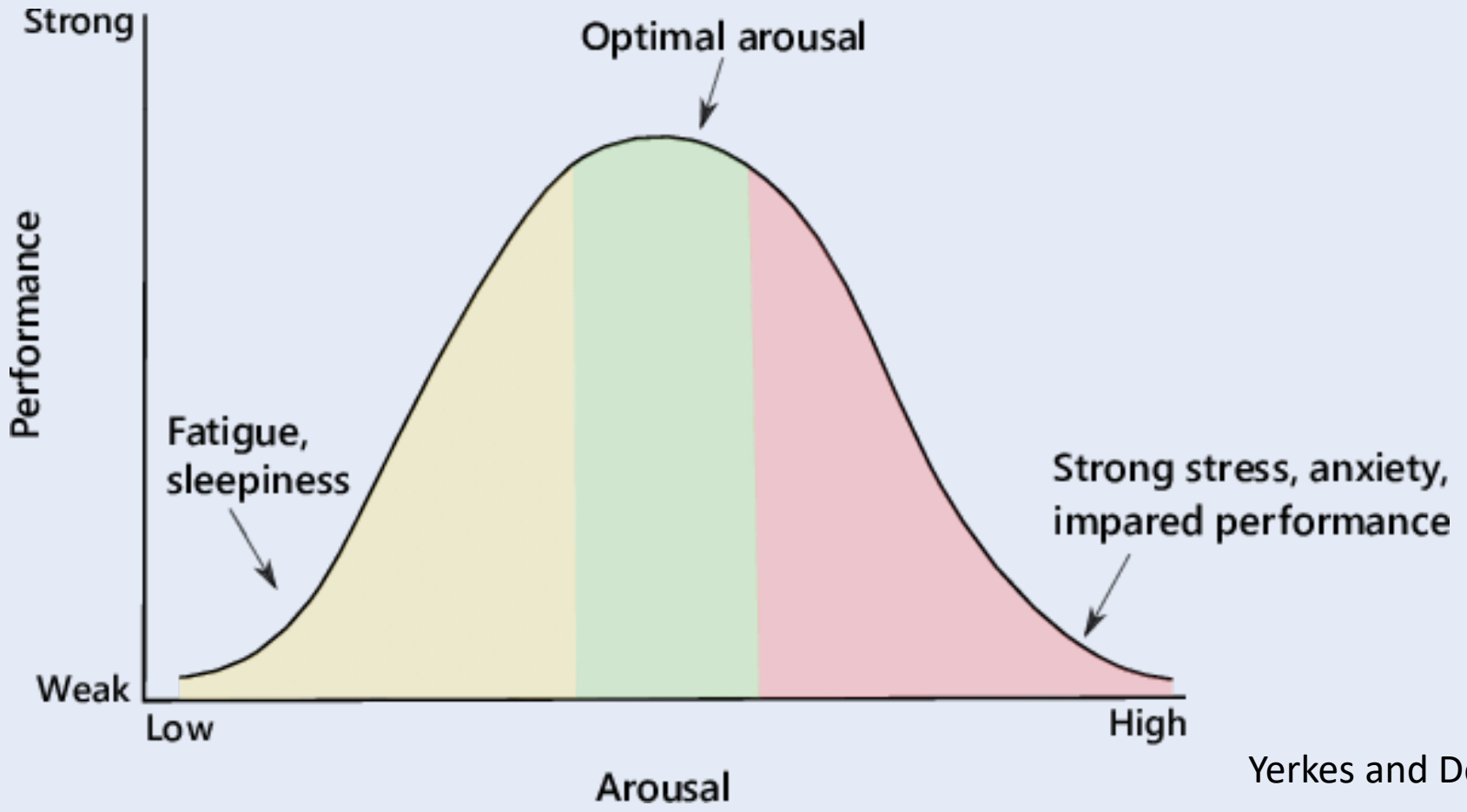
Arousal and learning

- Arousal can have a positive or negative effect on learning.
- Too much arousal = too excited/stressed/frightened/frustrated to learn
- Too little arousal = too relaxed/bored/drowsy/unmotivated to learn



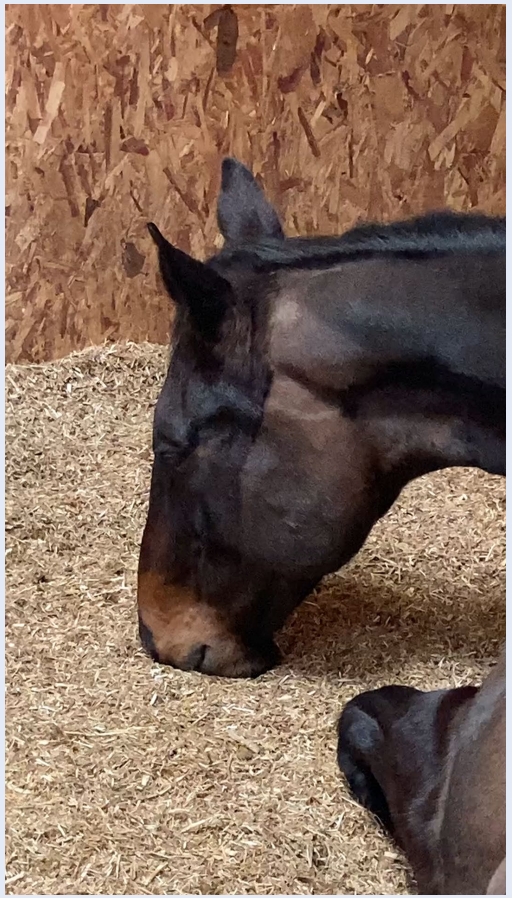
Yerkes and Dodson (1908)

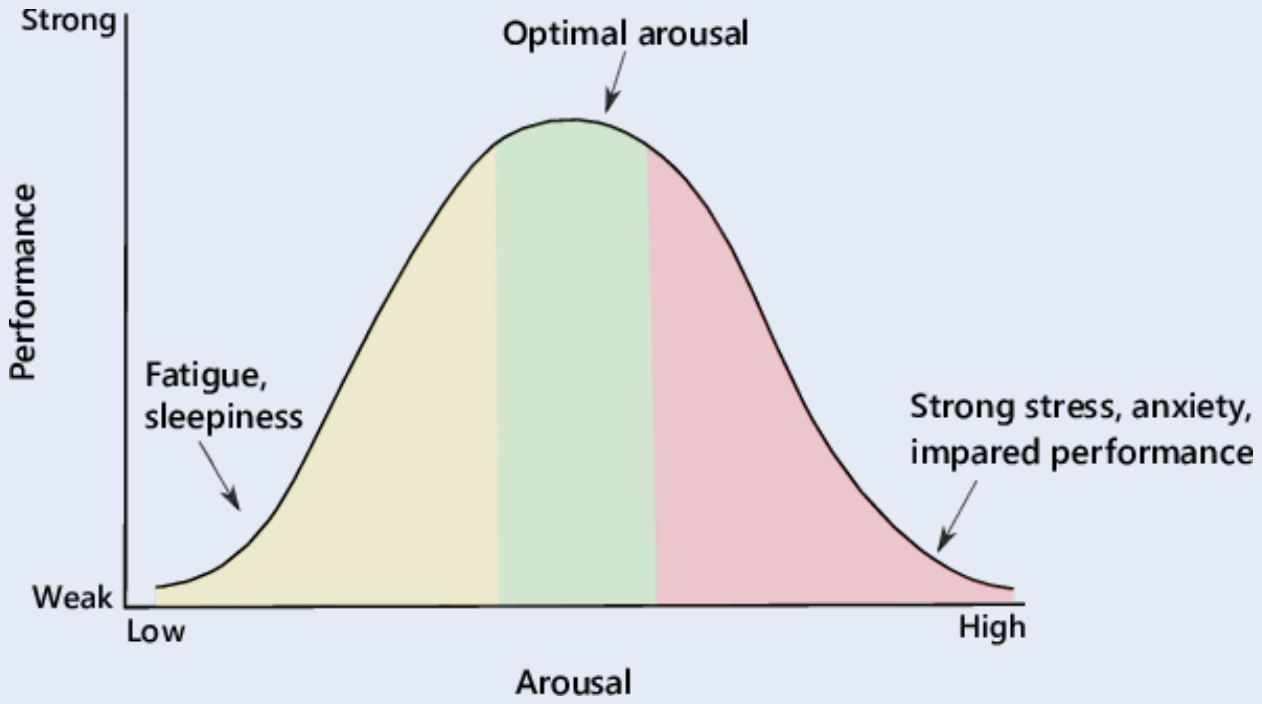
Arousal and learning



Yerkes and Dodson (1908)

Arousal and learning





Stop-Signal Task

- Stop-Signal cognitive task to test inhibitory control
- A conditioned response is rewarded unless a specified ‘Stop’ signal is given
- Can the animal inhibit (stop performing) the conditioned action when the Stop Signal is given?

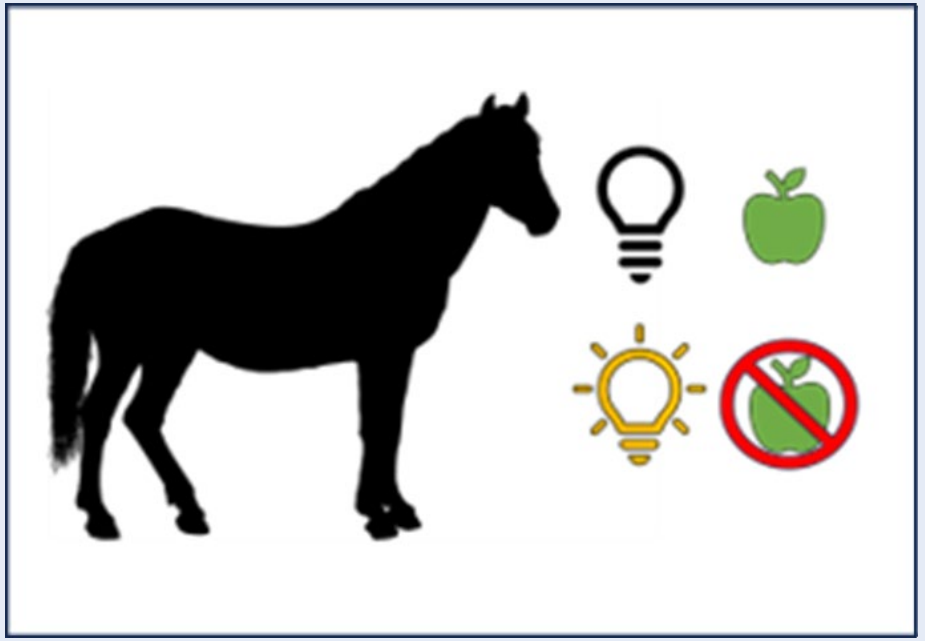
Stop-Signal Task for Horses

- 20 Horses from Nottingham Trent University
- Mixed breeds, sex (13 male, 7 female), age (11–22 years, mean=16 ± 3) and backgrounds
- Horses were managed in social housing, as per their usual routines. Horses were turned out to pasture overnight and stabled during the day
- Horses had ad libitum access to forage and water. Concentrate feed was given according to age and workload.

Stop-Signal Task for Horses

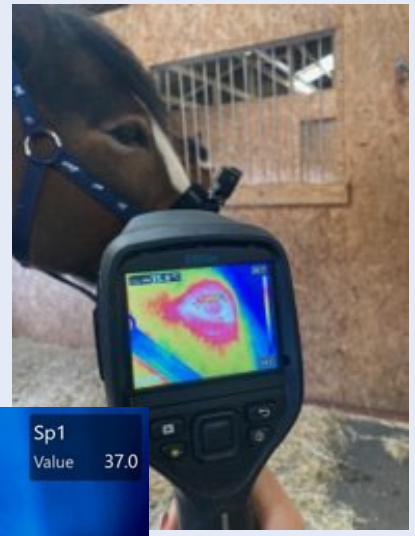
Light OFF = Go
Light ON = Stop

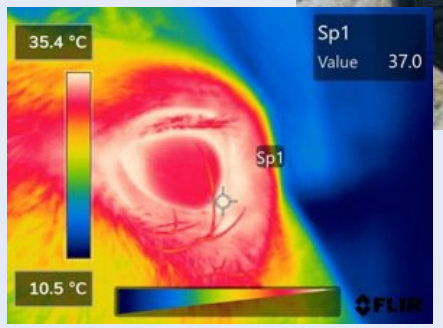
1. Horses were conditioned to touch a target (A3 laminated black or white target, pseudo-randomised and counterbalanced across sample) for a food reward
2. A **Stop** signal was introduced (a cyclists' headlight). Light OFF = Go. Light ON = Stop.
3. A trial started when the target was presented.
4. 28 Go trials (Light OFF) and 12 Stop trials (Light ON) per session, in randomised order.



Physiological arousal

- How does physiological arousal (e.g. stress) affect a horse's inhibitory control performance?
- Physiological measures:
  - Heart rate variability (arousal, 'stress')
  - Infrared thermography of eye temperature (arousal, valence)
  - Spontaneous eye blink rate (attention, striatal dopamine activity)
  - Blink rate variability (pattern of blinking associated with learning?)

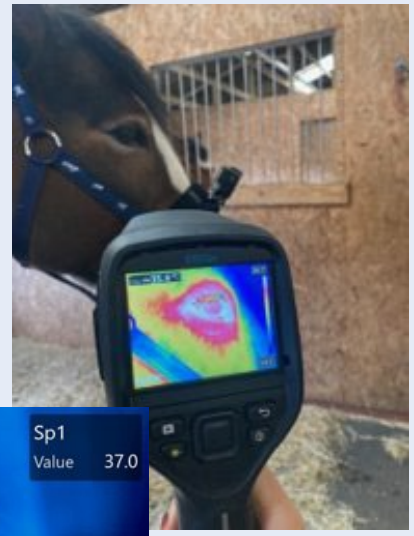


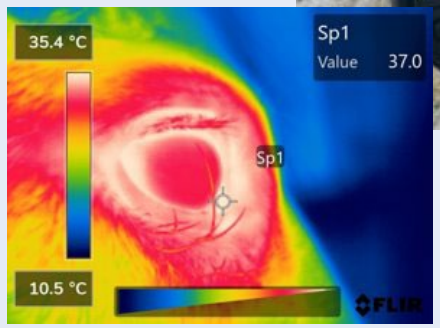


Predictors of performance

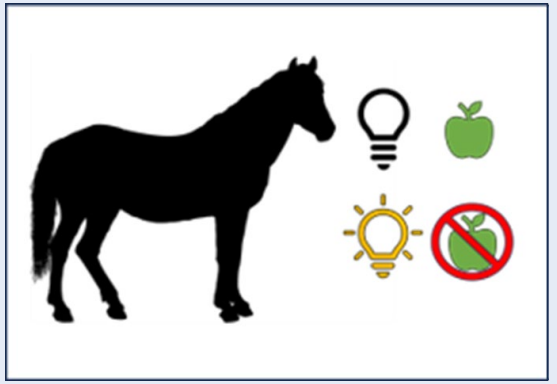
Is arousal/stress associated with inhibitory control ability in horses?

i.e. are there certain physiological predictors of performance?

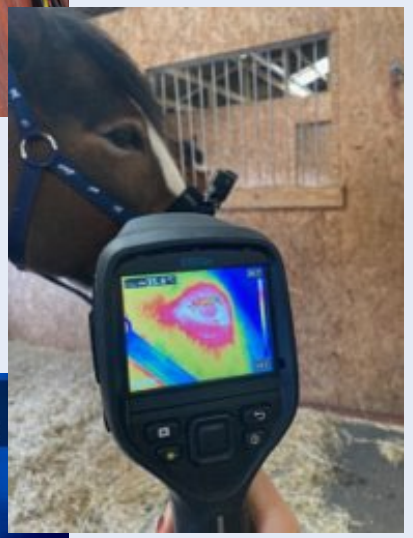


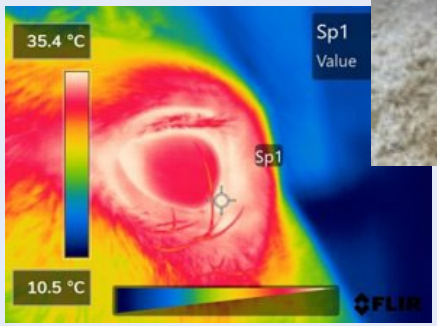


The Experiment

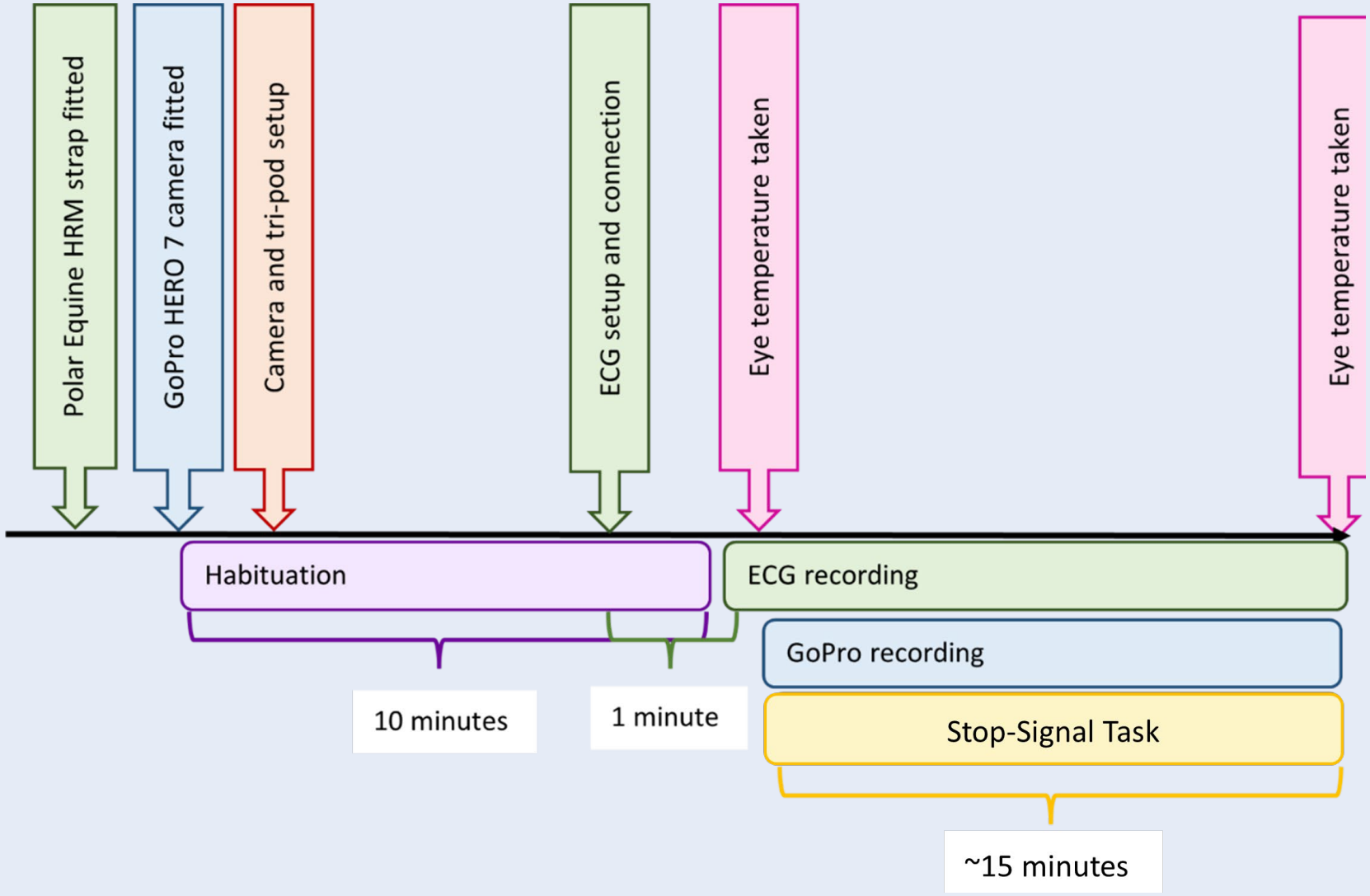


- 20 horses
- Baseline session (undisturbed in stable for 30 mins)
- 3 sessions of Stop-Signal task
- ECG continuously collecting heart rate data
- Eye temperature taken immediately before and after each session
- Blink rate measured continuously



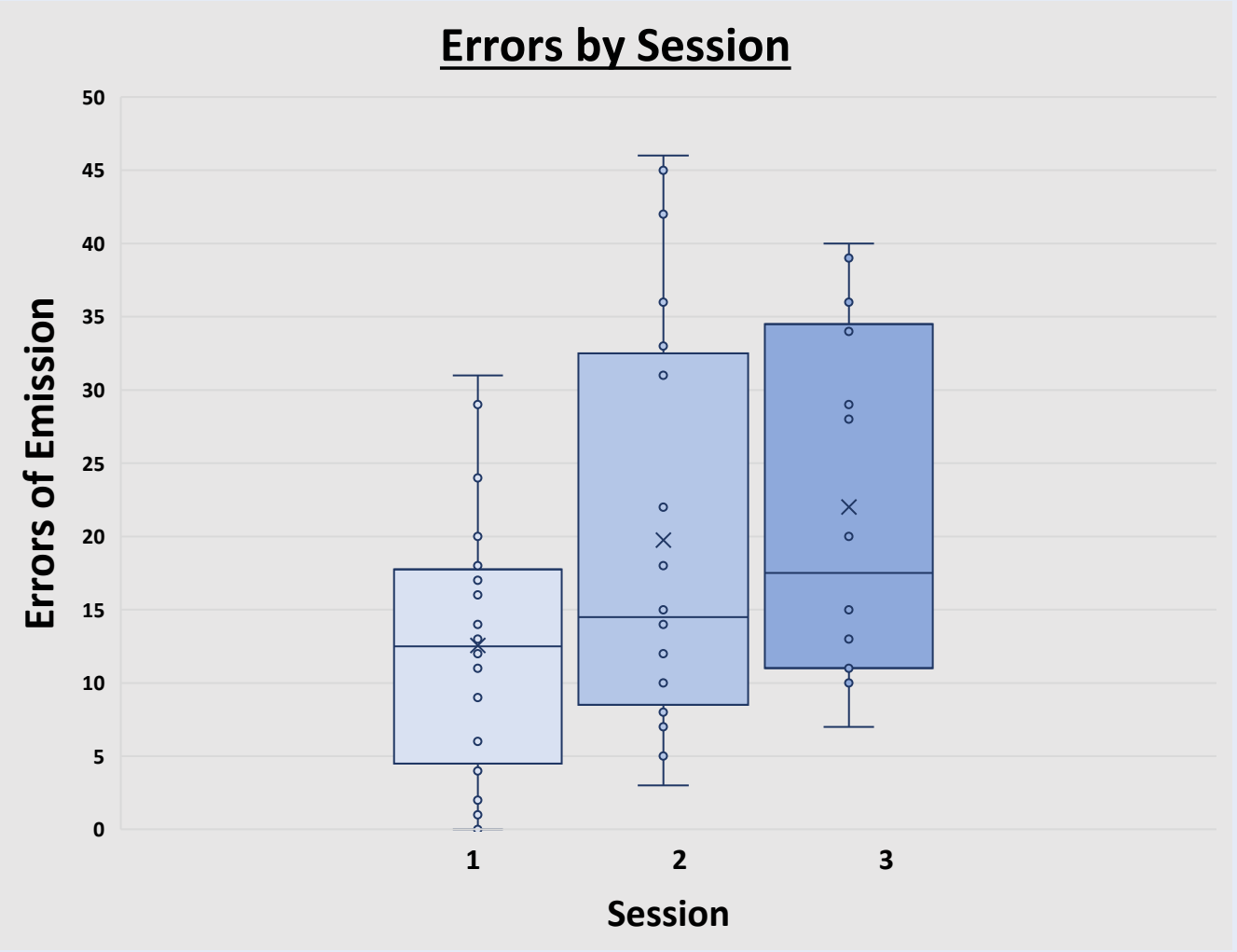


Data collection timeline



Unfortunately, things didn’t go to plan…

- Errors of emission = touching target when the light was on (Stop trials)
- Horses were not waiting for the light to switch off before touching the target
- This seemed to be getting worse each session
- **Why?**

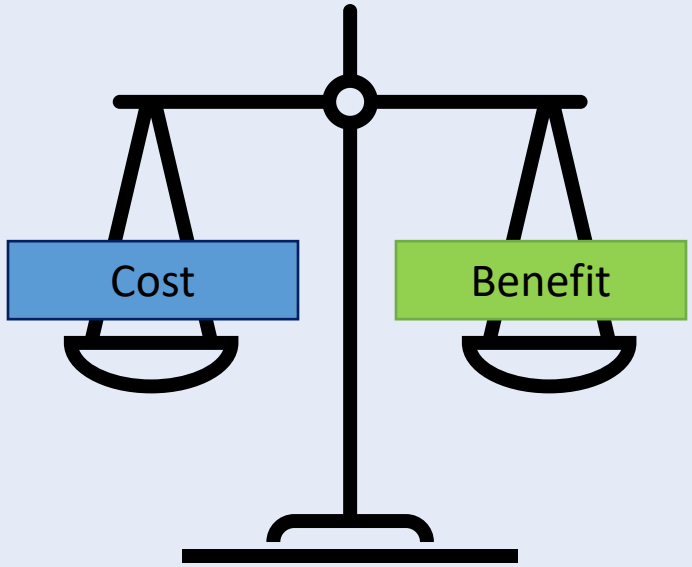


Possible explanations

1. The task is too difficult for horses
2. Horses can do this task, but they need additional help/ more sessions to learn
3. Horses can do this task, but they are not motivated to do so because there is **no cost for making errors**

An opportunistic study

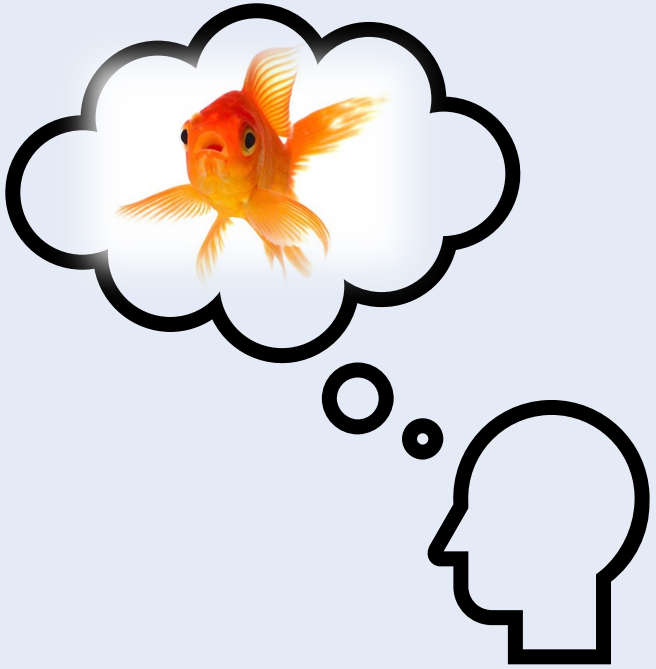
- Three more sessions, with the addition of **cost for making errors**
- Error of emission (touching target during Stop trials) = 10 seconds time-out
- In time-out, the target was removed and the game paused
- Cost for making errors is loss of opportunity for reward (Negative punishment)



Predicted responses

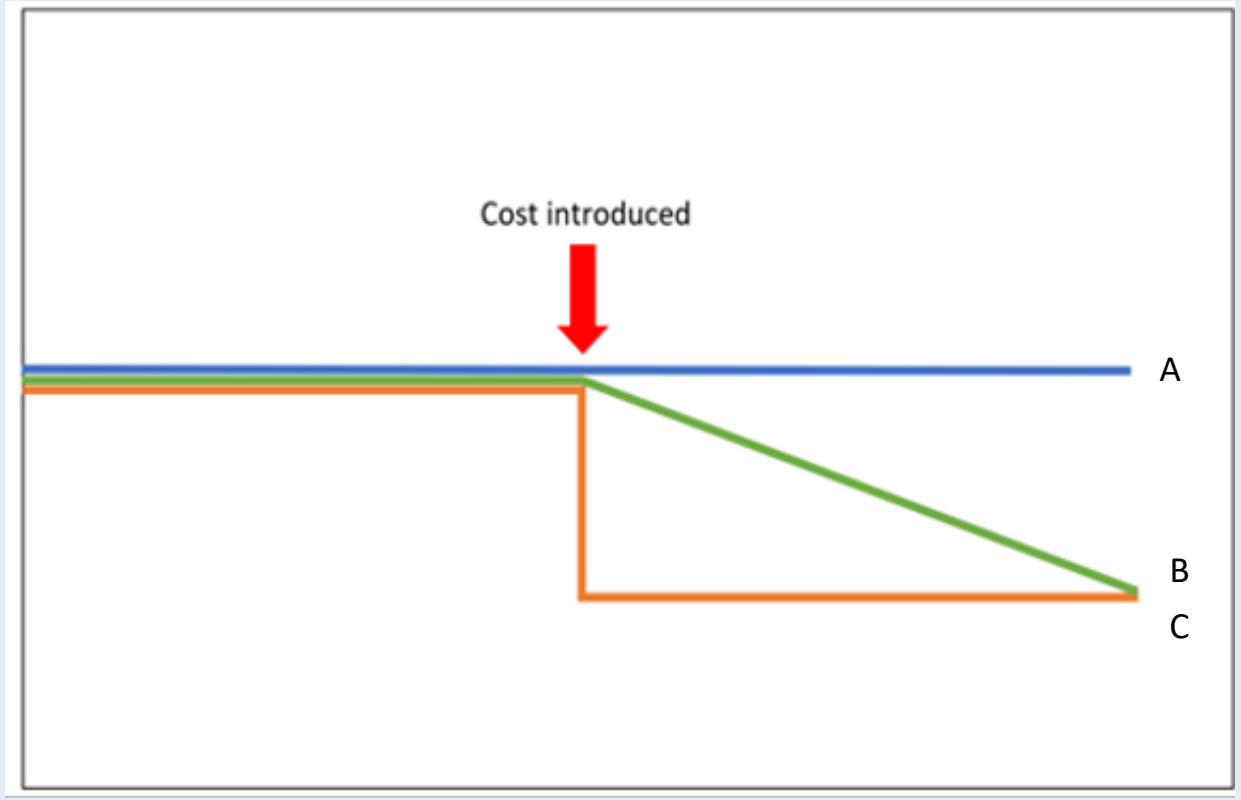
What would we expect to see, if:

1. The task is too difficult for horses
2. Horses can do this task, but they need additional help/ more sessions to learn
3. Horses can do this task, but they are not motivated to do so because there is **no cost for making errors**

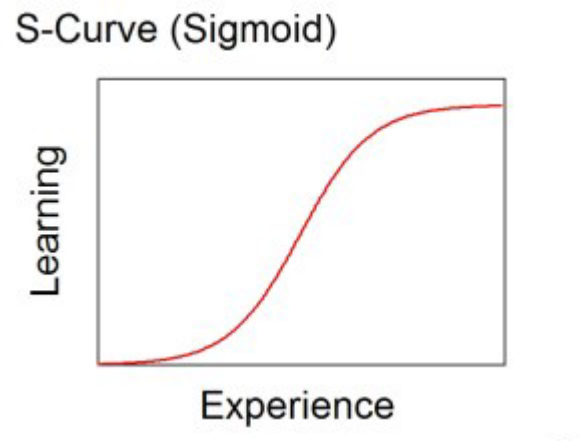


Prediction A (blue line)

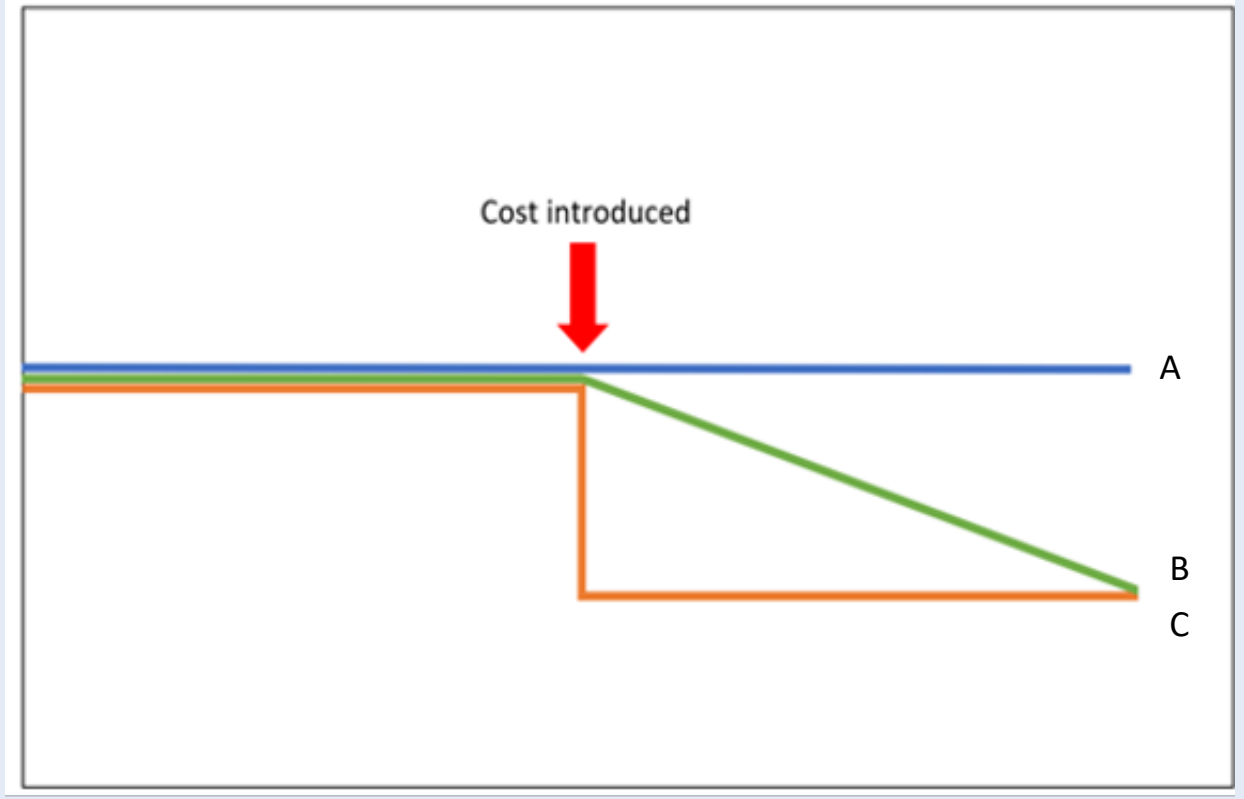
- The Stop-Signal task is too difficult for horses, because they do not have good inhibitory control, or because the task itself was not well-designed
- Errors would remain high even after the introduction of time-out cost



Prediction B (green line)

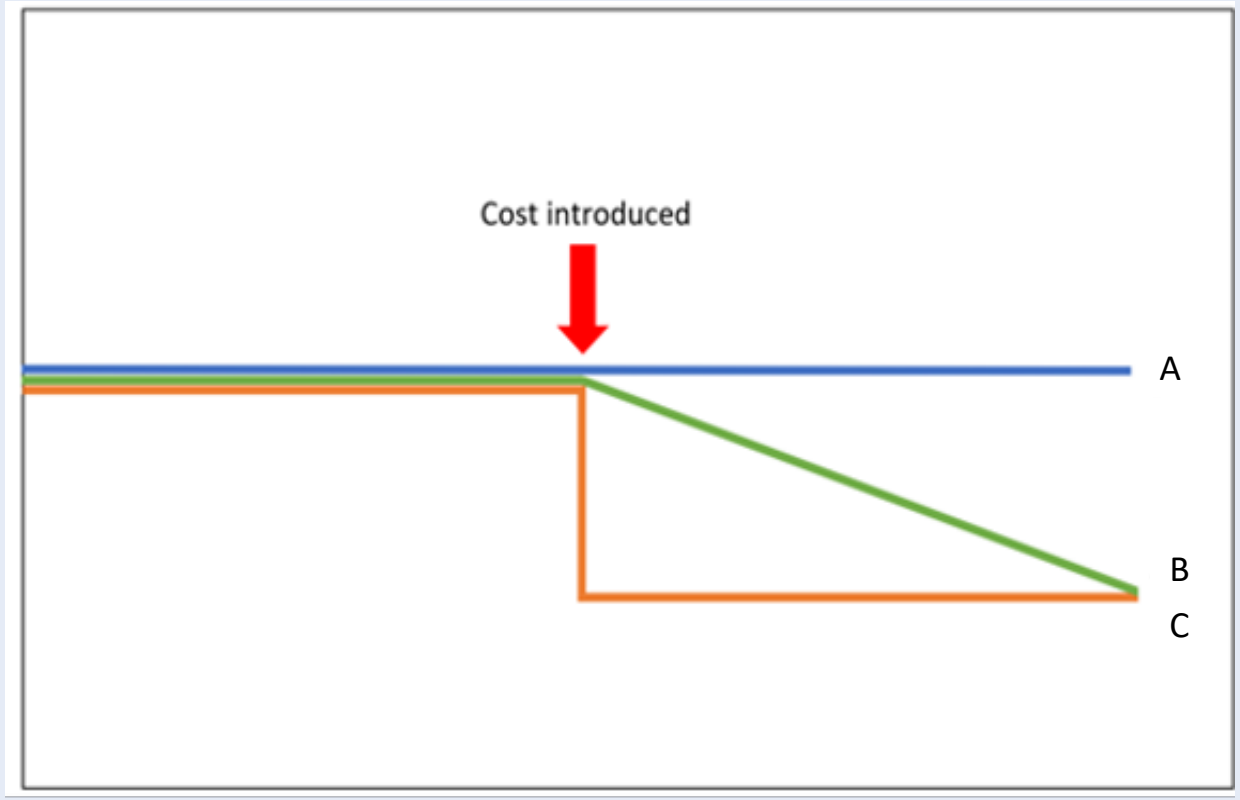


- The Stop-Signal task is challenging, but the extra sessions and/or addition of cost helps horses learn
- Errors would gradually decrease over the course of sessions 4, 5 and 6 as experiences are cached and understanding improves



Prediction C (orange line)

- Horses understand the Stop-Signal task, but (consciously or unconsciously) choose a strategy of indiscriminate responding when there is no cost for errors
- Errors decrease immediately and significantly when cost is introduced



Nottingham Trent University

https://www.youtube.com/watch?v=-02_60uHbco

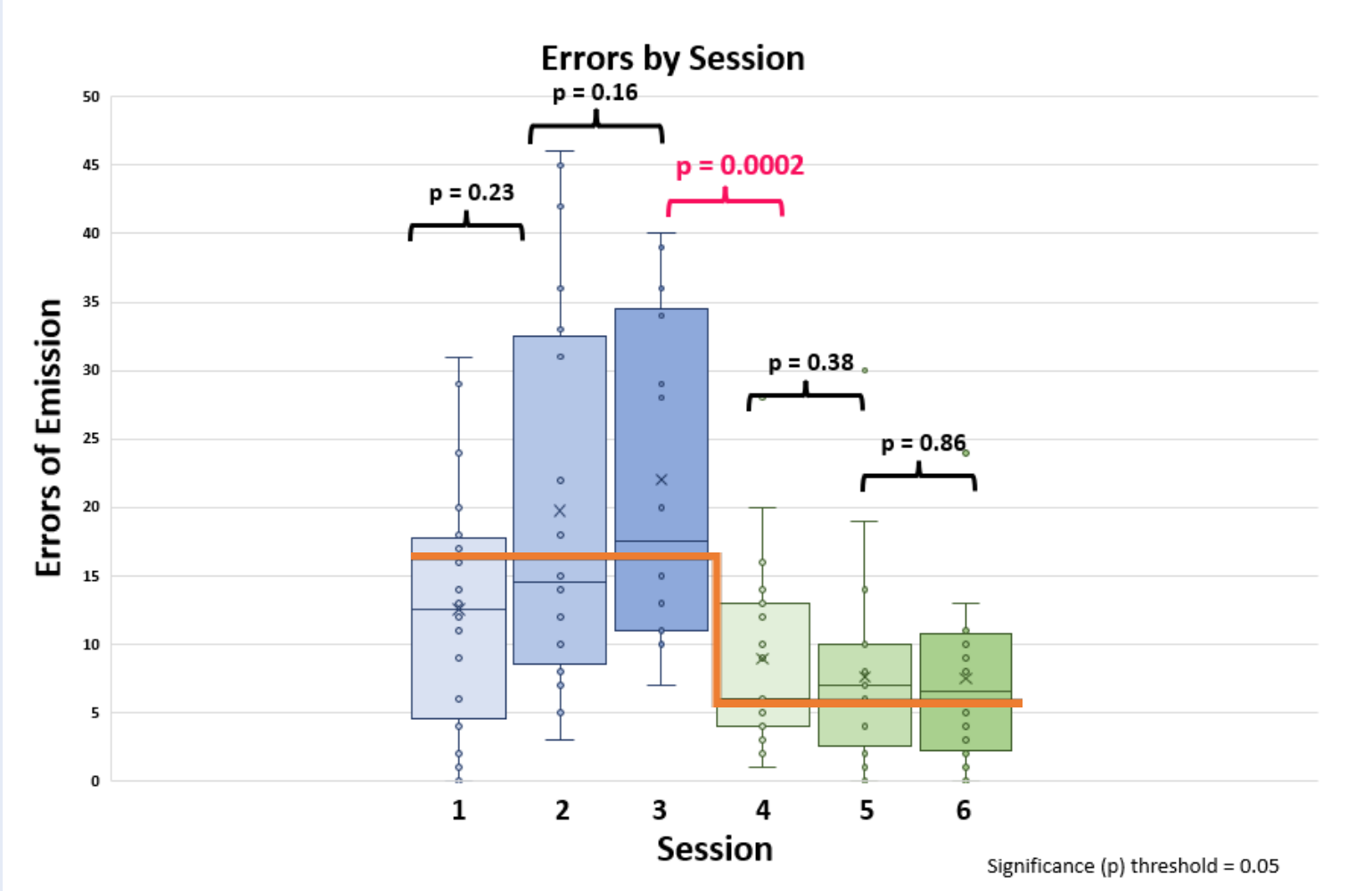
"GO" signal.
Horse is rewarded (+R) for touching target

“Stop" signal.
Horse is punished (-P) for touching target

Results

Immediate and significant ($p<0.0005$) reduction in errors when cost was added

Consistent with prediction C



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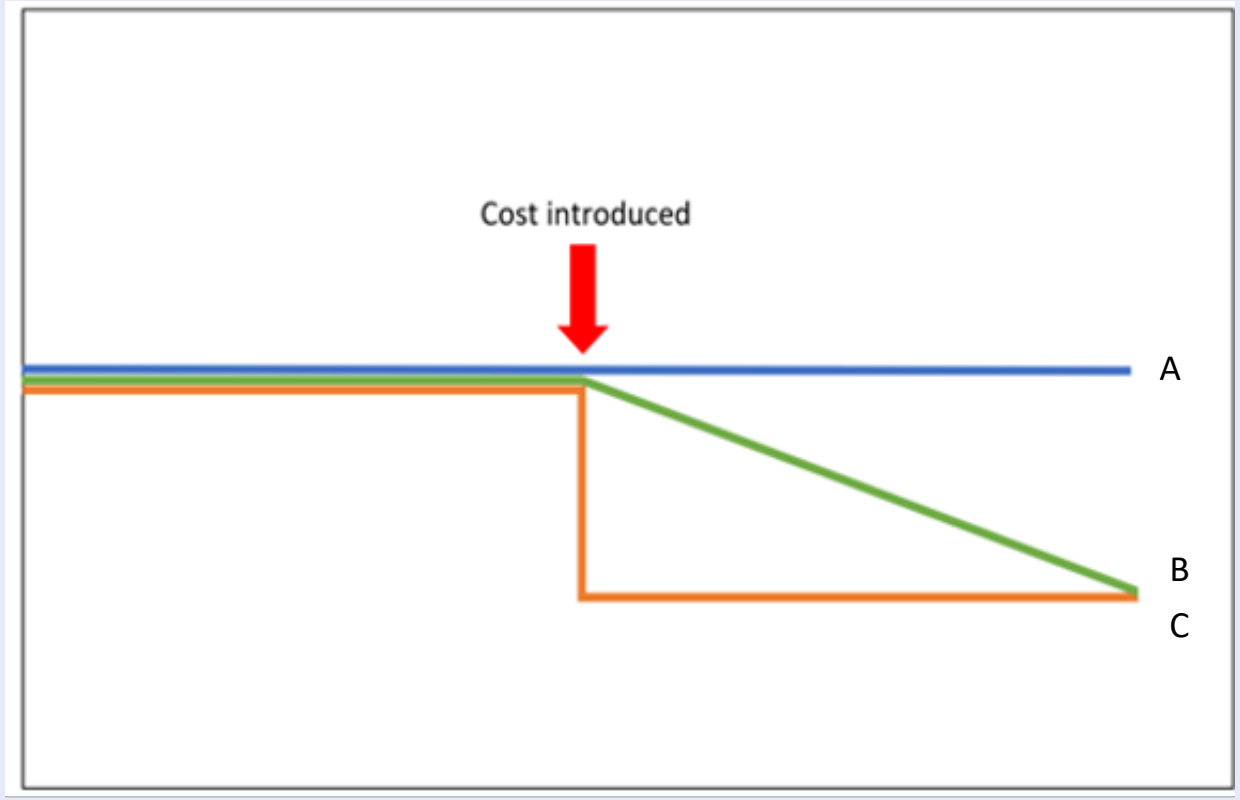
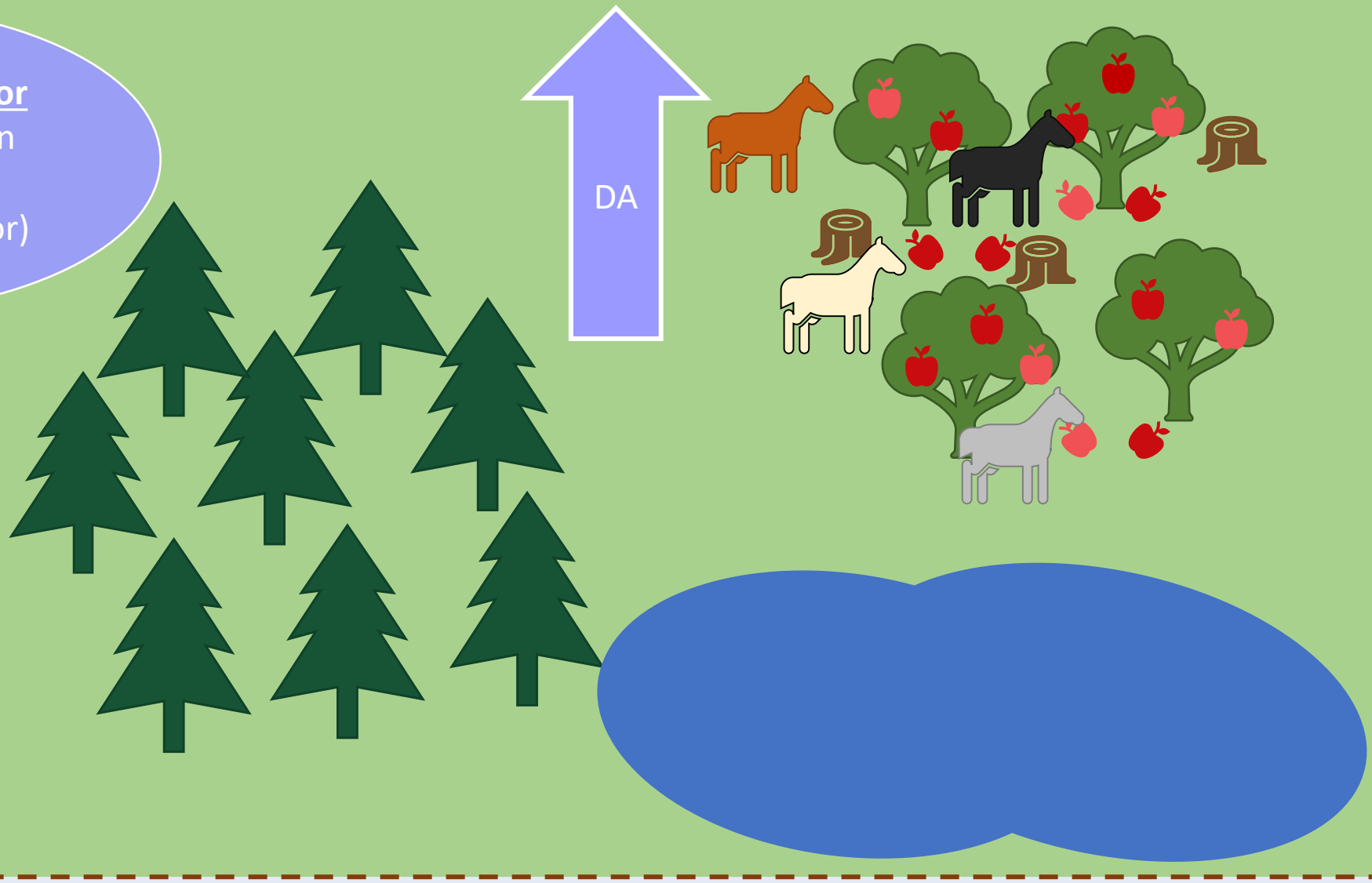
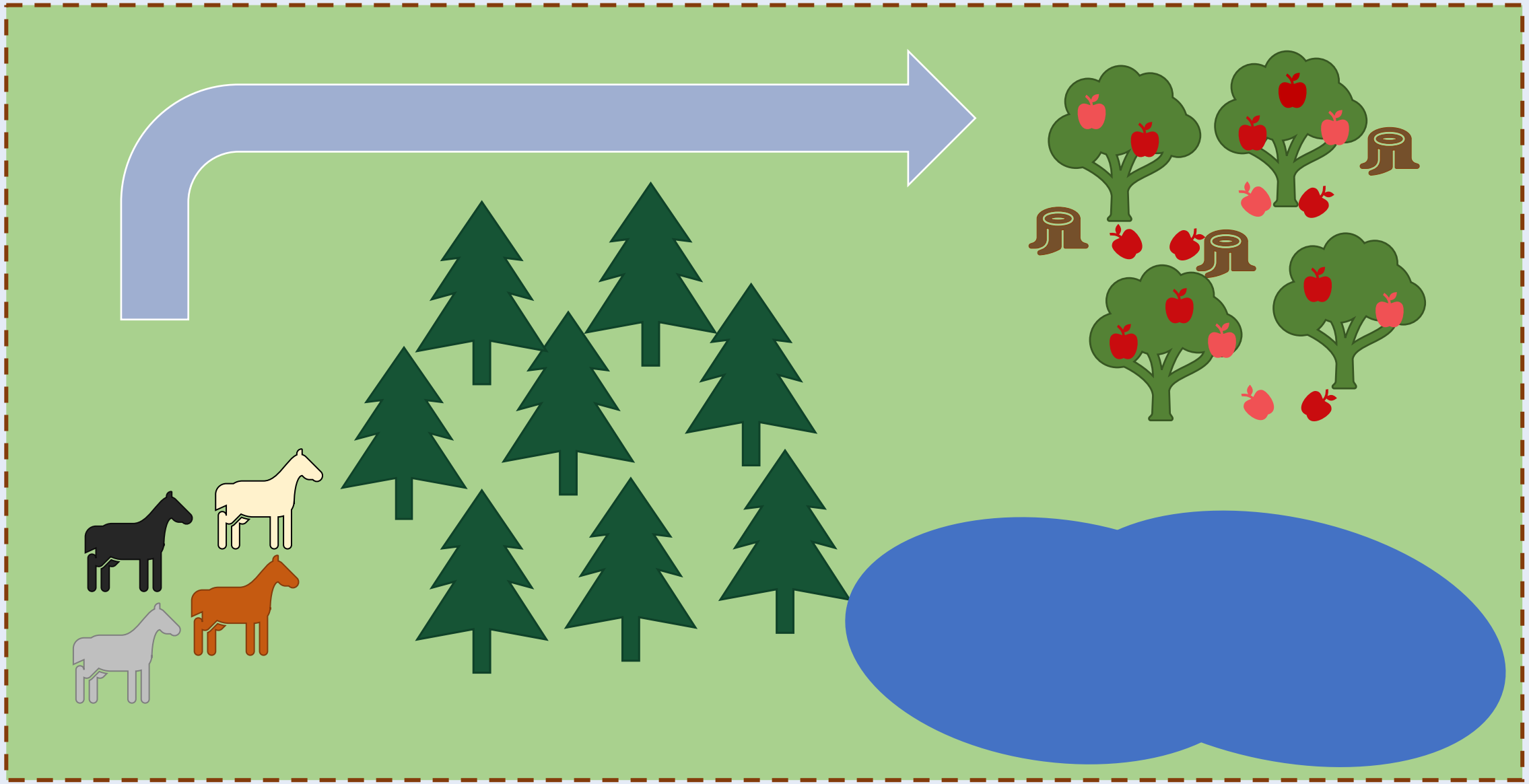
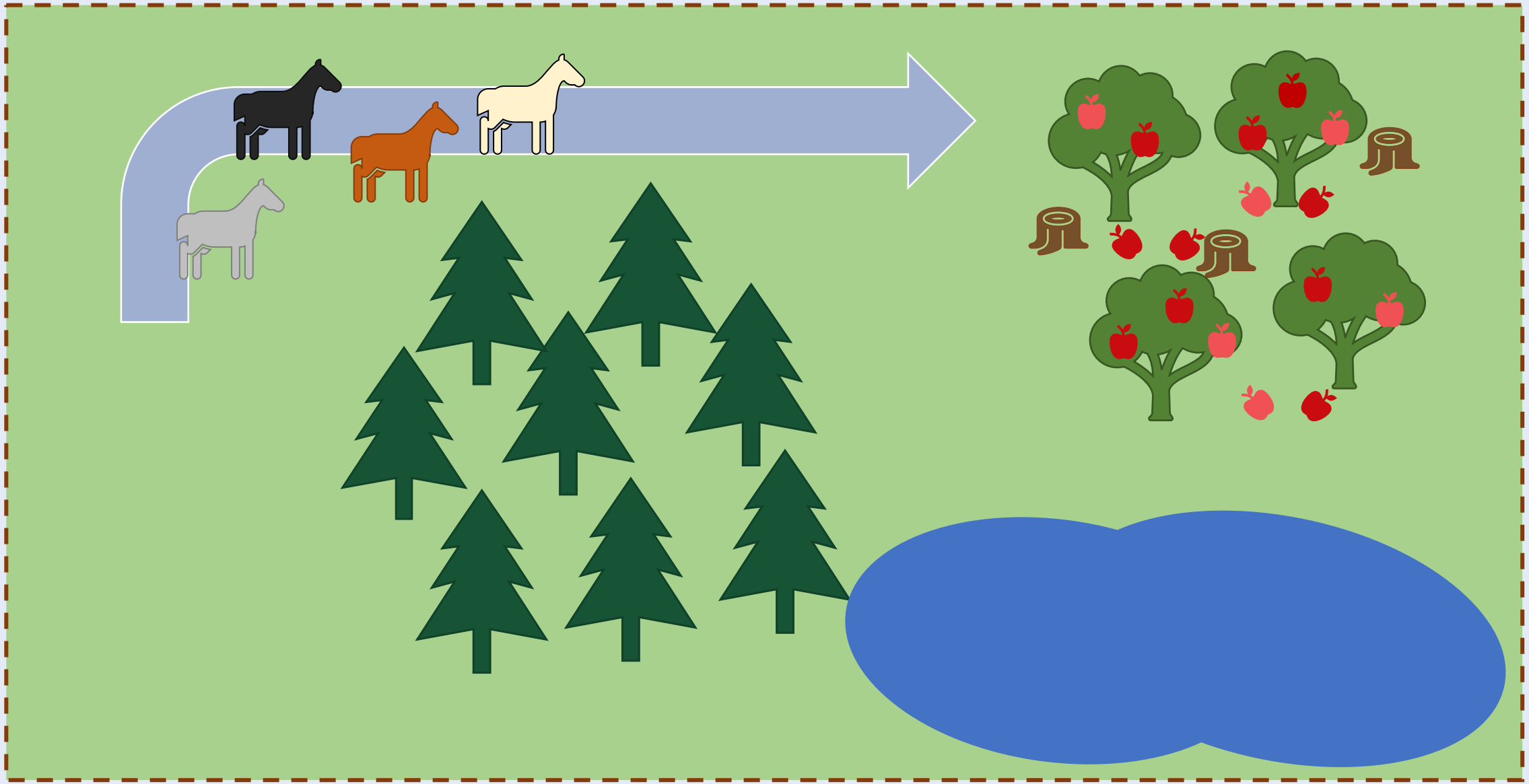


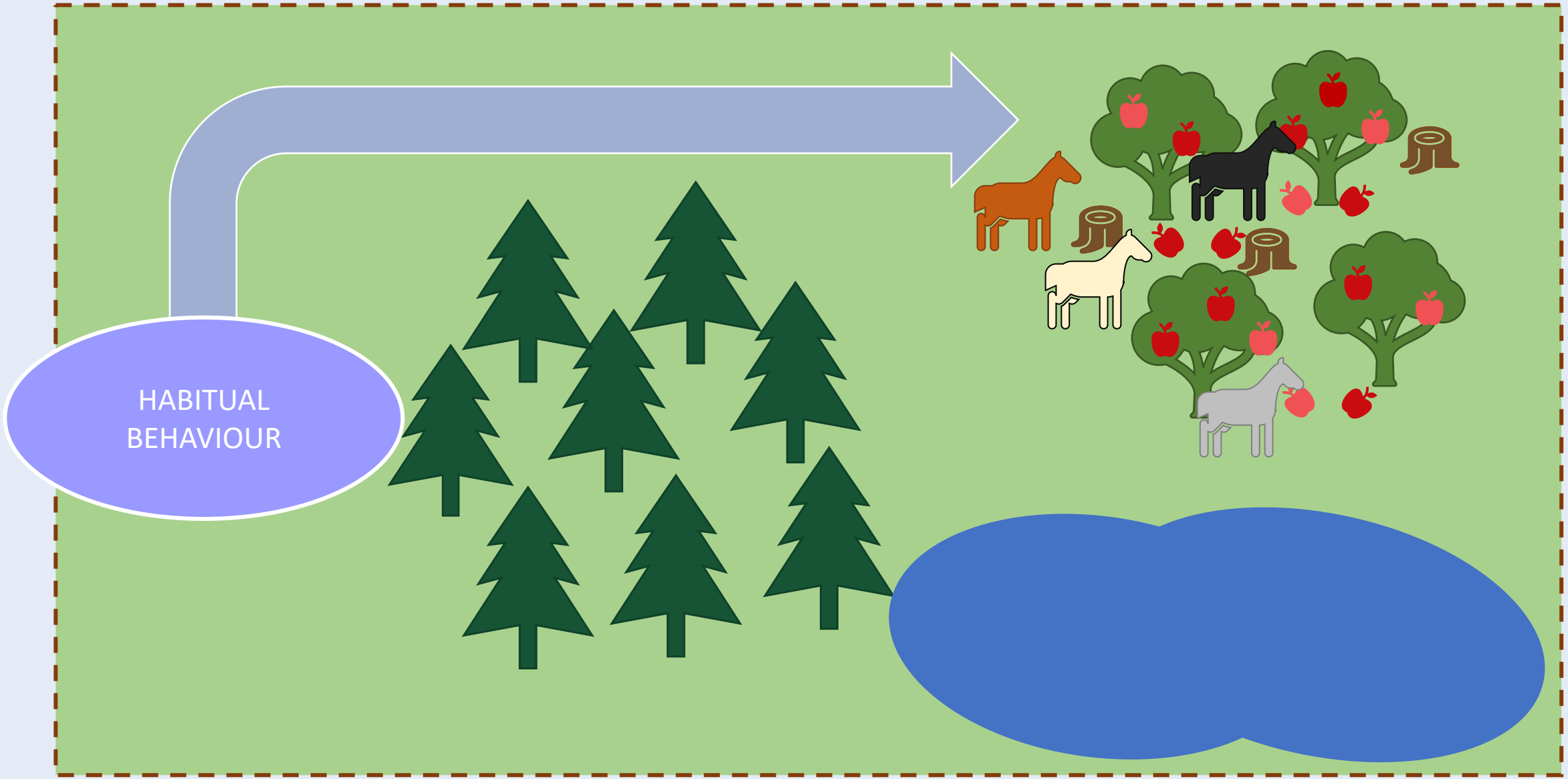
Reward Prediction Error

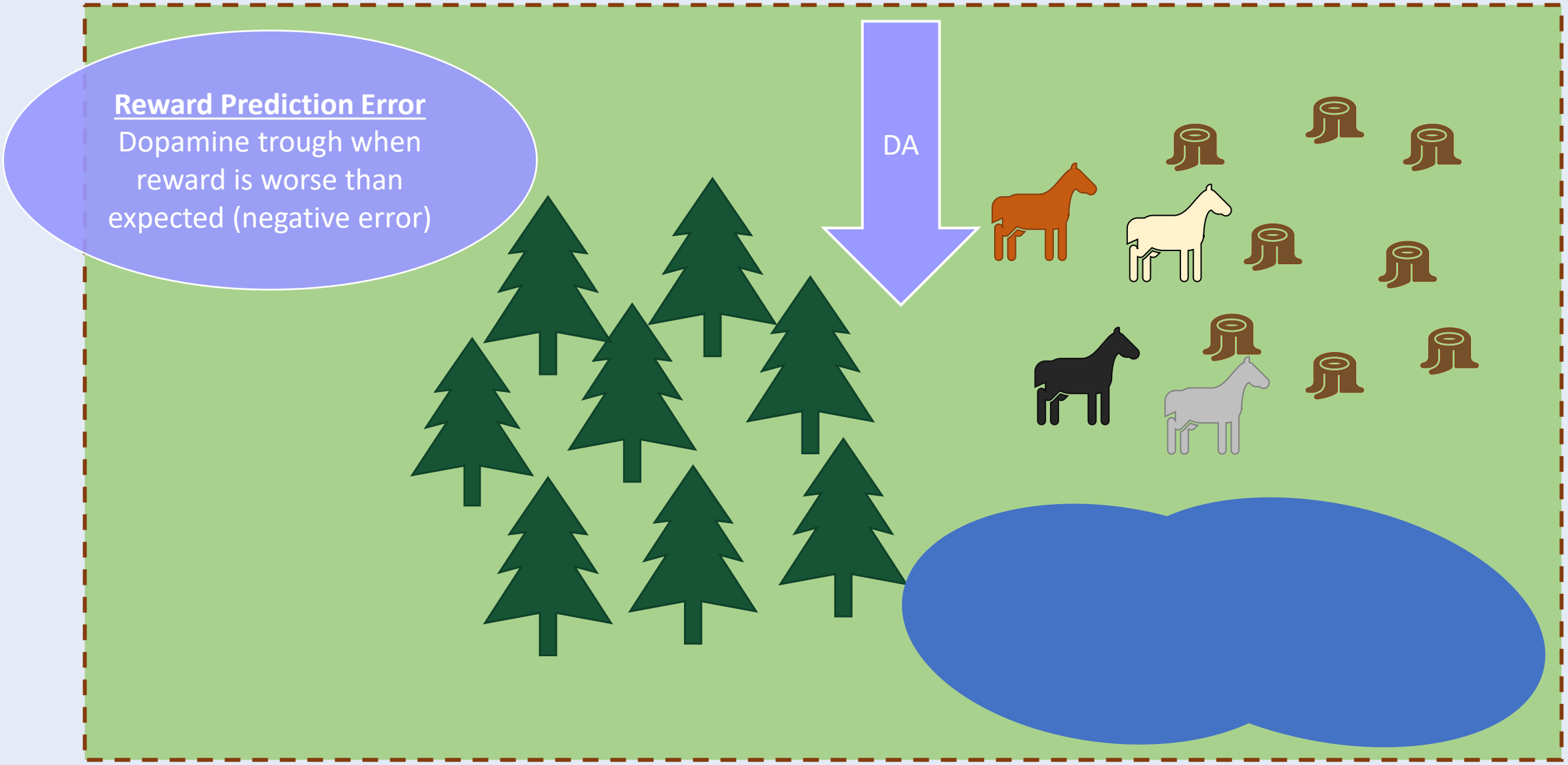
Dopamine peaks when reward is better than expected (positive error)



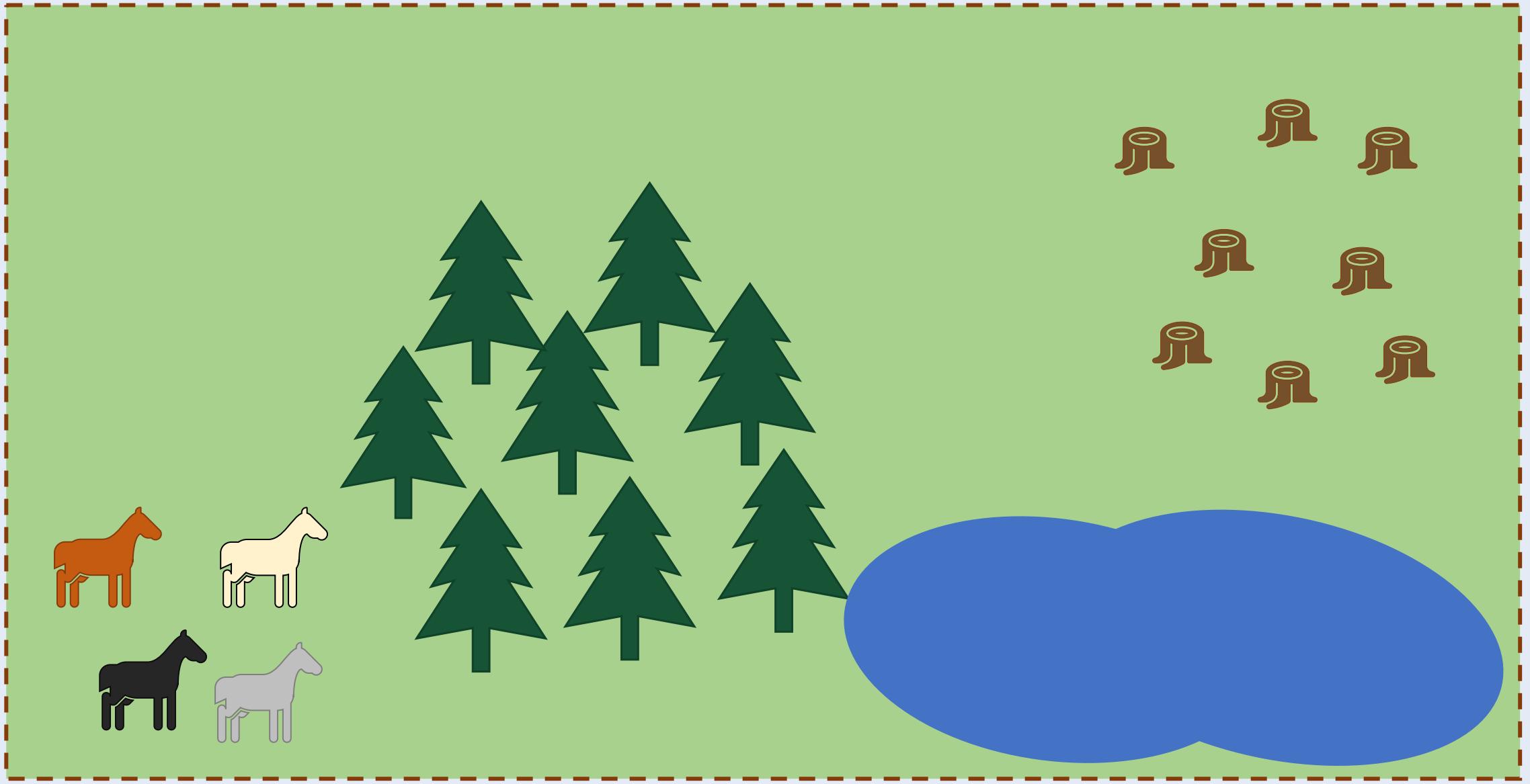





HABITUAL
BEHAVIOUR



Schultz, W., 2016. Dopamine reward prediction error coding. *Dialogues in clinical neuroscience*, *18*(1), pp.23-32.

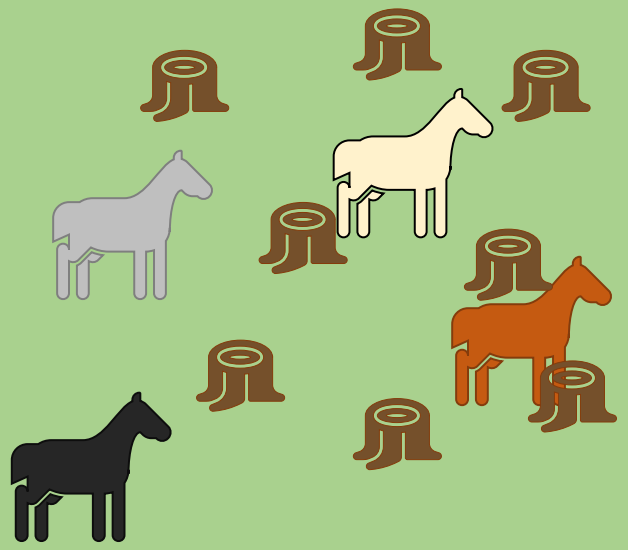


Flexible Approach

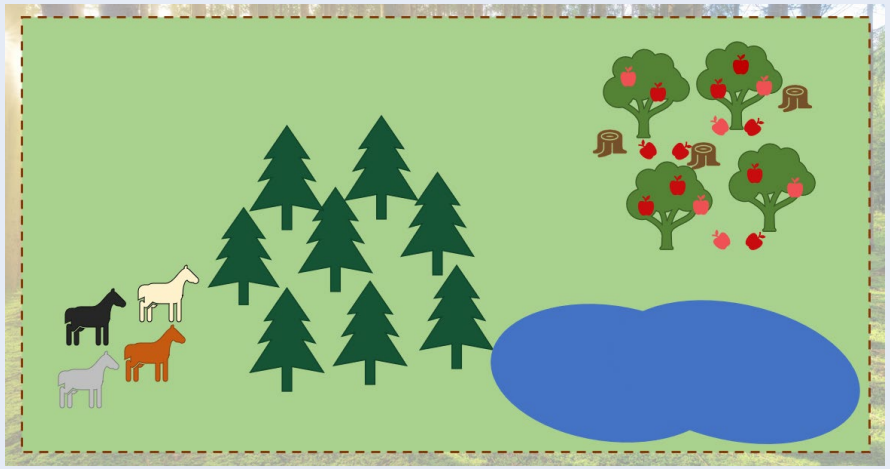
EXPLORATIVE BEHAVIOUR

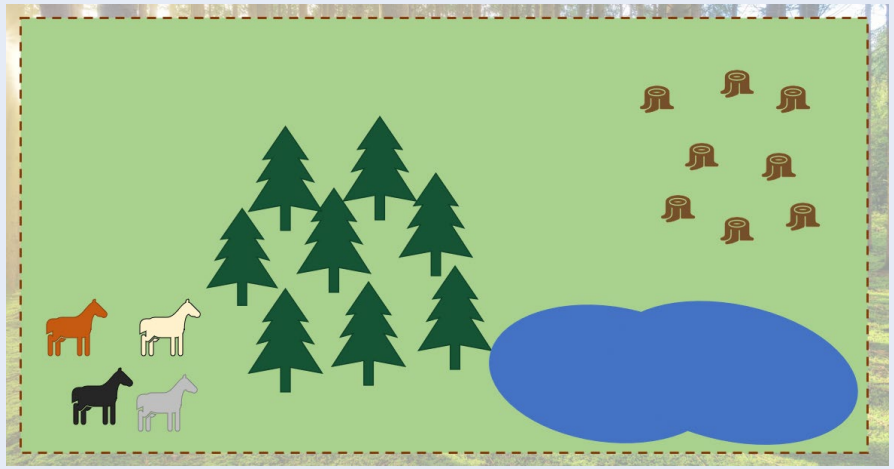
Inflexible Approach

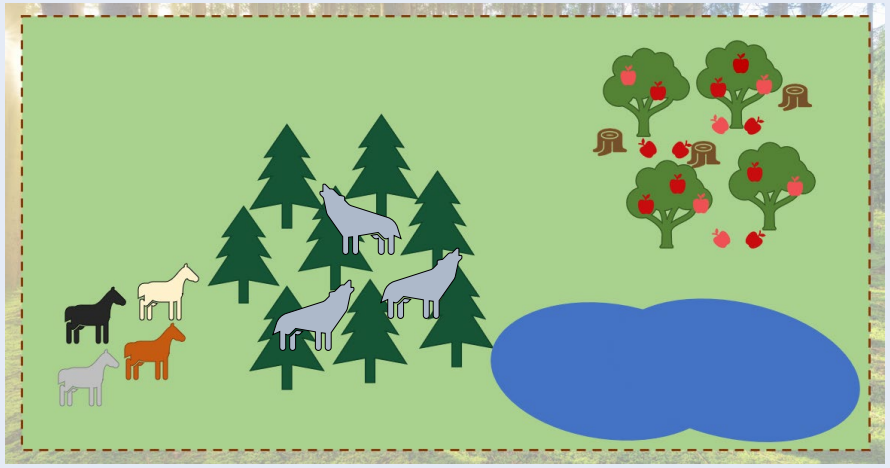
HABITUAL BEHAVIOUR

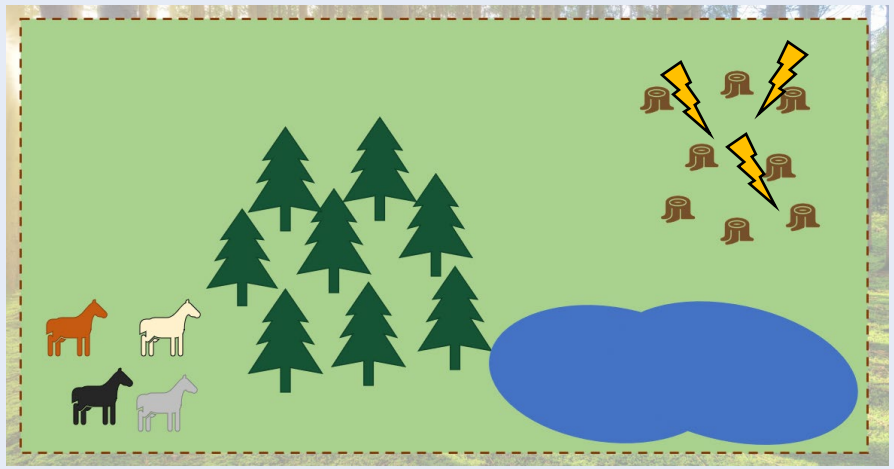


Prospection





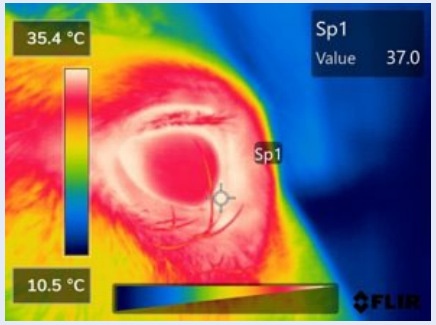


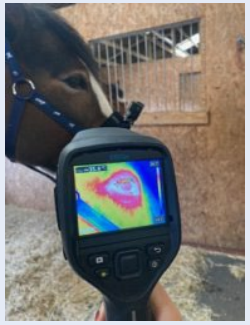


Why is this surprising?

- First evidence consistent with model-based learning in horses
- Humans use prefrontal cortex (PfC) for model-based learning, but the equine PfC is thought to be underdeveloped
- Suggests that horses may have higher level cognitive abilities than we previously thought

What about our original experiment?





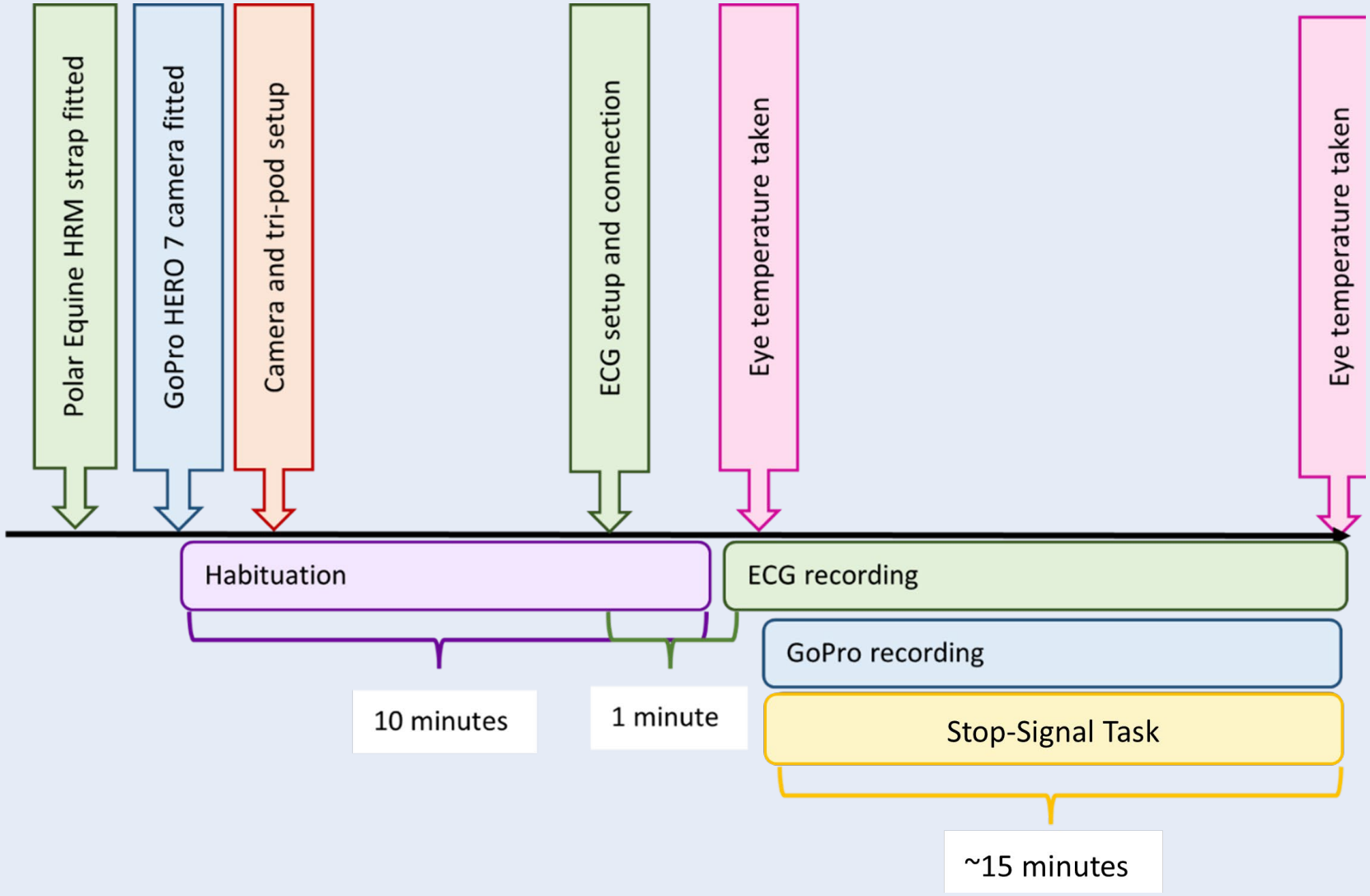
Physiological measures:

- Heart rate variability (arousal, ‘stress’)
- Infrared thermography of eye temperature (arousal, valence)
- Spontaneous eye blink rate (attention, striatal dopamine activity)
- Blink rate variability (pattern of blinking associated with learning?)

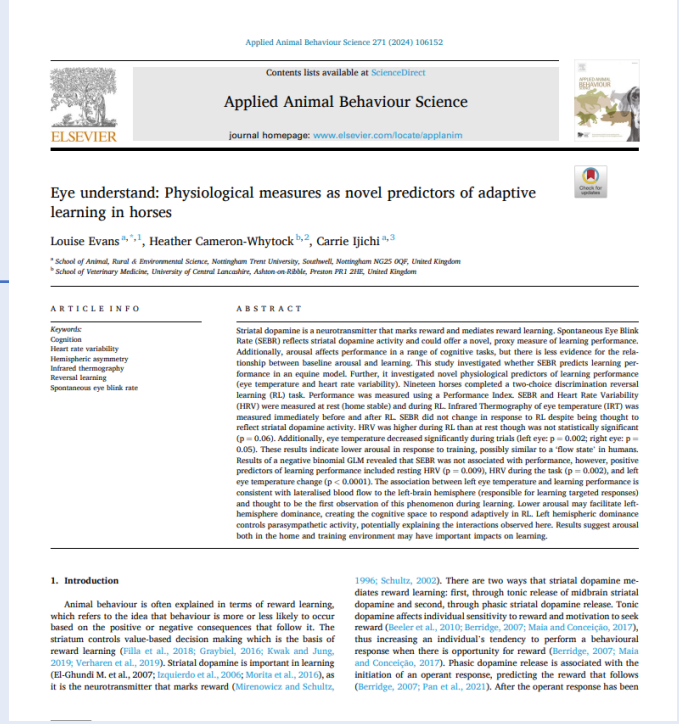
Is arousal/stress associated with inhibitory control ability in horses?

i.e. are there certain physiological predictors of performance?

Physiological measures



Heart rate variability



Applied Animal Behaviour Science 271 (2024) 106152

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

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

Eye understand: Physiological measures as novel predictors of adaptive learning in horses

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ARTICLE INFO

Keywords:
Cognition
Heart rate variability
Hemispheric asymmetry
Infrared thermography
Reversal learning
Spontaneous eye blink rate

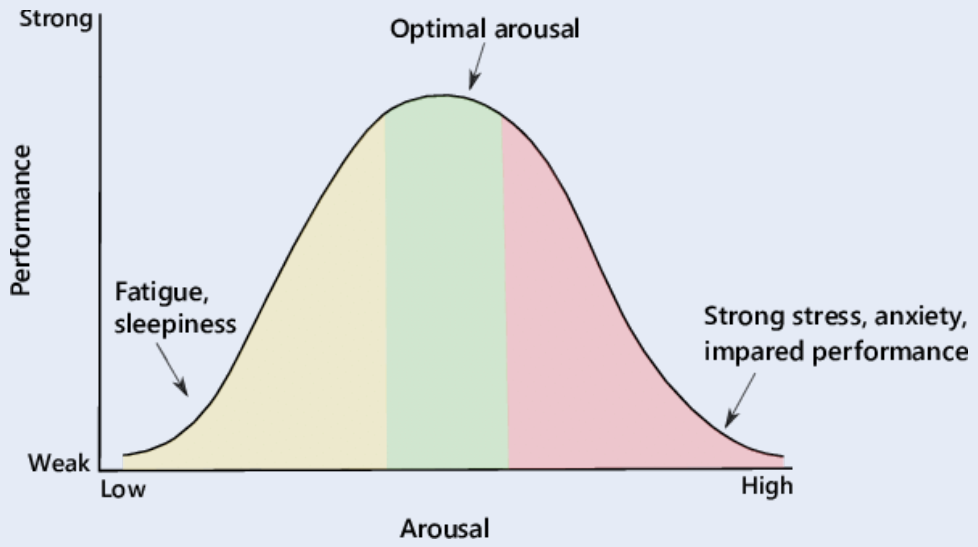
ABSTRACT

Striatal dopamine is a neurotransmitter that marks reward and mediates reward learning. Spontaneous Eye Blink Rate (SEBR) reflects striatal dopamine activity and could offer a novel, proxy measure of learning performance. Additionally, arousal affects performance in a range of cognitive tasks, but there is less evidence for the relationship between baseline arousal and learning. This study investigated whether SEBR predicts learning performance in an equine model. Further, it investigated novel physiological predictors of learning performance (eye temperature and heart rate variability). Nineteen horses completed a two-choice discrimination reversal learning (RL) task. Performance was measured using a Performance Index. SEBR and Heart Rate Variability (HRV) were measured at rest (home stable) and during RL. Infrared Thermography of eye temperature (IRT) was measured immediately before and after RL. SEBR did not change in response to RL despite being thought to reflect striatal dopamine activity. HRV was higher during RL than at rest though was not statistically significant ($p = 0.06$). Additionally, eye temperature decreased significantly during trials (left eye: $p = 0.002$; right eye: $p = 0.05$). These results indicate lower arousal in response to training, possibly similar to a 'flow state' in humans. Results of a negative binomial GLM revealed that SEBR was not associated with performance, however, positive predictors of learning performance included resting HRV ($p = 0.009$), HRV during the task ($p = 0.002$), and left eye temperature change ($p < 0.0001$). The association between left eye temperature and learning performance is consistent with lateralised blood flow to the left-brain hemisphere (responsible for learning targeted responses) and thought to be the first observation of this phenomenon during learning. Lower arousal may facilitate left-hemisphere dominance, creating the cognitive space to respond adaptively in RL. Left hemispheric dominance controls parasympathetic activity, potentially explaining the interactions observed here. Results suggest arousal both in the home and training environment may have important impacts on learning.

1. Introduction

Animal behaviour is often explained in terms of reward learning, which refers to the idea that behaviour is more or less likely to occur based on the positive or negative consequences that follow it. The striatum controls value-based decision making which is the basis of reward learning (Filla et al., 2018; Graybiel, 2016; Kwak and Jung, 2019; Verharen et al., 2019). Striatal dopamine is important in learning (El-Ghundi M. et al., 2007; Izquierdo et al., 2006; Morita et al., 2010), as it is the neurotransmitter that marks reward (Mirenowicz and Schultz, 1996; Schultz, 2002). There are two ways that striatal dopamine mediates reward learning: first, through tonic release of midbrain striatal dopamine and second, through phasic striatal dopamine release. Tonic dopamine affects individual sensitivity to reward and motivation to seek reward (Beeler et al., 2010; Berridge, 2007; Maia and Conceição, 2017), thus increasing an individual's tendency to perform a behavioural response when there is opportunity for reward (Berridge, 2007; Maia and Conceição, 2017). Phasic dopamine release is associated with the initiation of an operant response, predicting the reward that follows (Berridge, 2007; Pan et al., 2021). After the operant response has been

- Horses with higher baseline HRV (lower arousal) performed better ($p<0.0001$)
- Horses with lower HRV (higher arousal) during the Stop-Signal task performed better ($p<0.02$)
- In challenging tasks, some physiological arousal is needed, but day-to-day stress should be avoided



Spontaneous eye blink rate

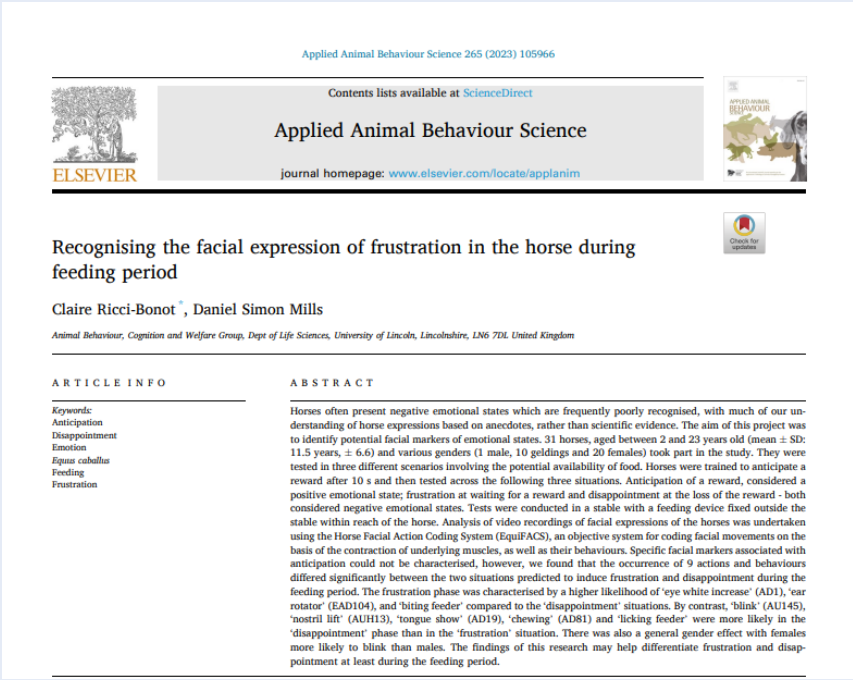
- Higher baseline blink rate predicted better performance
- Unclear whether this relates to tonic striatal dopamine
- Associated with better learners generally?

What do these results mean?

- It’s possible to use physiological measures to predict inhibitory control performance in horses
- Further evidence that maintaining low stress day-to-day is better for horse performance and welfare
- Interesting interaction between arousal and learning in horses

Cost vs No Cost for errors

- **Did the addition of cost at session 4 affect physiological responses to the task?**
- Frustration? Disappointment?



Applied Animal Behaviour Science 265 (2023) 105966

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

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

Recognising the facial expression of frustration in the horse during feeding period

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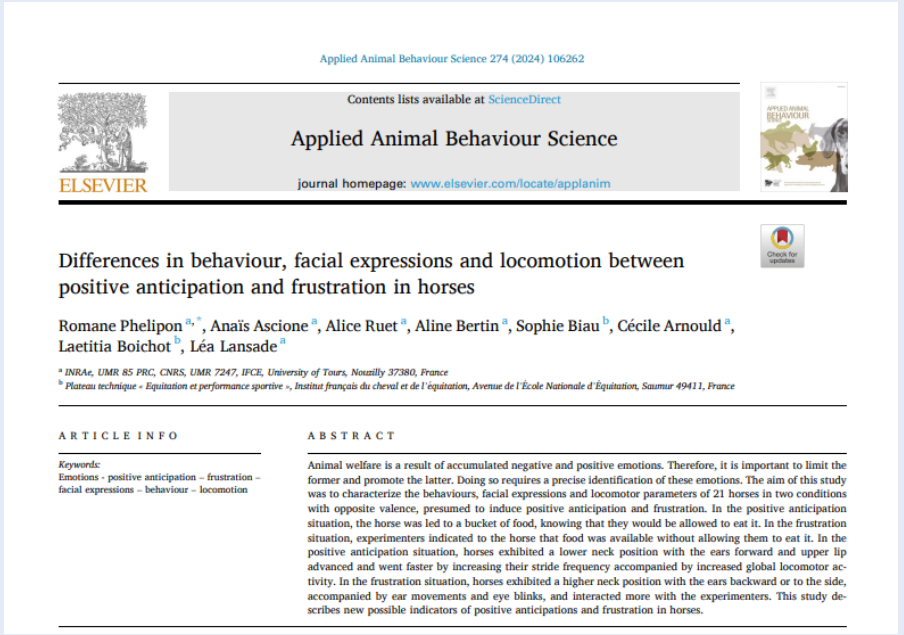
ARTICLE INFO

Keywords:
Anticipation
Disappointment
Emotion
Equus caballus
Feeding
Frustration

ABSTRACT

Horses often present negative emotional states which are frequently poorly recognised, with much of our understanding of horse expressions based on anecdotes, rather than scientific evidence. The aim of this project was to identify potential facial markers of emotional states. 31 horses, aged between 2 and 23 years old (mean ± SD: 11.5 years, ± 6.6) and various genders (1 male, 10 geldings and 20 females) took part in the study. They were tested in three different scenarios involving the potential availability of food. Horses were trained to anticipate a reward after 10 s and then tested across the following three situations. Anticipation of a reward, considered a positive emotional state; frustration at waiting for a reward and disappointment at the loss of the reward - both considered negative emotional states. Tests were conducted in a stable with a feeding device fixed outside the stable within reach of the horse. Analysis of video recordings of facial expressions of the horses was undertaken using the Horse Facial Action Coding System (EquiFACS), an objective system for coding facial movements on the basis of the contraction of underlying muscles, as well as their behaviours. Specific facial markers associated with anticipation could not be characterised, however, we found that the occurrence of 9 actions and behaviours differed significantly between the two situations predicted to induce frustration and disappointment during the feeding period. The frustration phase was characterised by a higher likelihood of 'eye white increase' (AD1), 'ear rotator' (EAD104), and 'biting feeder' compared to the 'disappointment' situations. By contrast, 'blink' (AU145), 'nostril lift' (AUH13), 'tongue show' (AD19), 'chewing' (AD81) and 'licking feeder' were more likely in the 'disappointment' phase than in the 'frustration' situation. There was also a general gender effect with females more likely to blink than males. The findings of this research may help differentiate frustration and disappointment at least during the feeding period.



Applied Animal Behaviour Science 274 (2024) 106262

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

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

Differences in behaviour, facial expressions and locomotion between positive anticipation and frustration in horses

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ARTICLE INFO

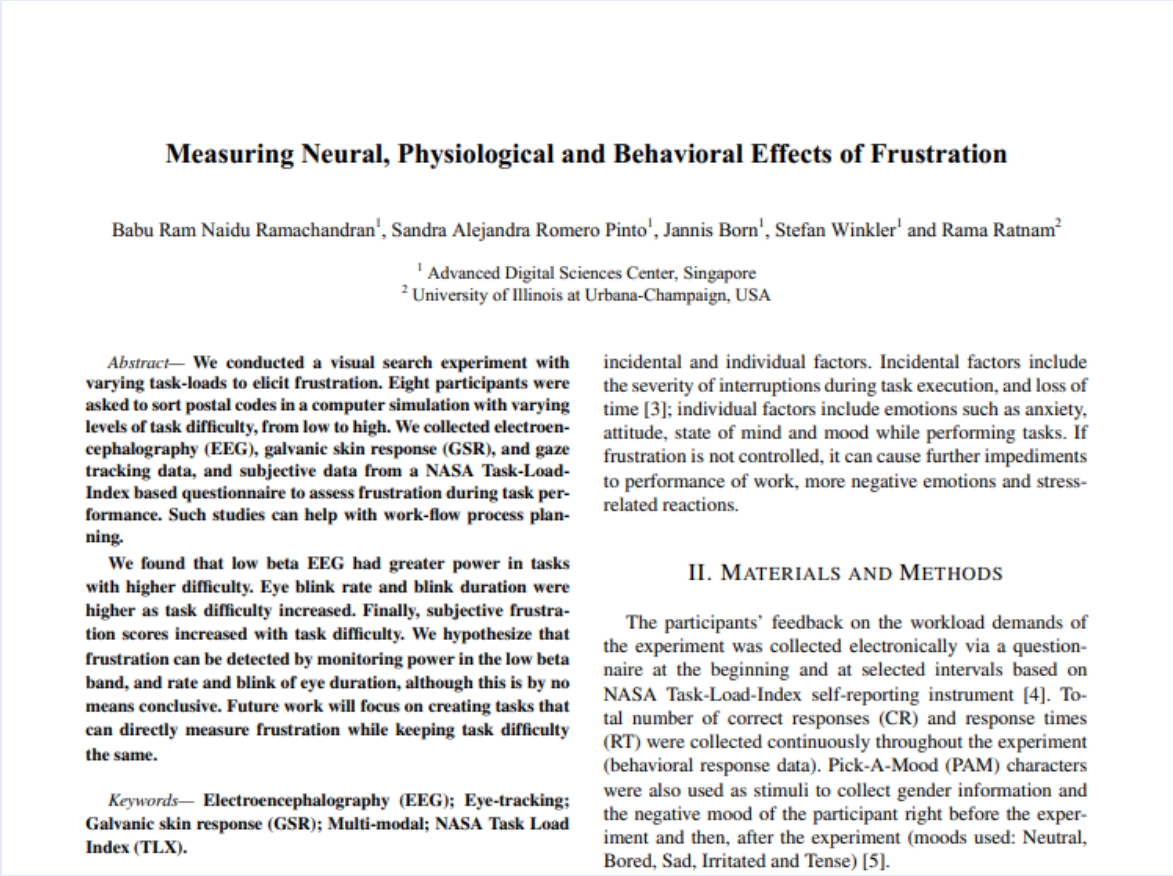
Keywords:
Emotions - positive anticipation – frustration – facial expressions – behaviour – locomotion

ABSTRACT

Animal welfare is a result of accumulated negative and positive emotions. Therefore, it is important to limit the former and promote the latter. Doing so requires a precise identification of these emotions. The aim of this study was to characterize the behaviours, facial expressions and locomotor parameters of 21 horses in two conditions with opposite valence, presumed to induce positive anticipation and frustration. In the positive anticipation situation, the horse was led to a bucket of food, knowing that they would be allowed to eat it. In the frustration situation, experimenters indicated to the horse that food was available without allowing them to eat it. In the positive anticipation situation, horses exhibited a lower neck position with the ears forward and upper lip advanced and went faster by increasing their stride frequency accompanied by increased global locomotor activity. In the frustration situation, horses exhibited a higher neck position with the ears backward or to the side, accompanied by ear movements and eye blinks, and interacted more with the experimenters. This study describes new possible indicators of positive anticipations and frustration in horses.

Cost vs No Cost for errors

- We didn't measure facial expression, but we do have data on **HRV, eye temperature and blink rate**
- **HRV decreases** during periods of frustration, due to increased psychological 'stress'
- **Blink rate increases** during frustration in humans (Ramachandran *et al*., 2017)
- **Right eye temperature may increase** due to negative valence- frustration is a negative emotion



Measuring Neural, Physiological and Behavioral Effects of Frustration

Babu Ram Naidu Ramachandran[1], Sandra Alejandra Romero Pinto[1], Jannis Born[1], Stefan Winkler[1] and Rama Ratnam[2]

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[2] University of Illinois at Urbana-Champaign, USA

Abstract— **We conducted a visual search experiment with varying task-loads to elicit frustration. Eight participants were asked to sort postal codes in a computer simulation with varying levels of task difficulty, from low to high. We collected electroencephalography (EEG), galvanic skin response (GSR), and gaze tracking data, and subjective data from a NASA Task-Load-Index based questionnaire to assess frustration during task performance. Such studies can help with work-flow process planning.**

We found that low beta EEG had greater power in tasks with higher difficulty. Eye blink rate and blink duration were higher as task difficulty increased. Finally, subjective frustration scores increased with task difficulty. We hypothesize that frustration can be detected by monitoring power in the low beta band, and rate and blink of eye duration, although this is by no means conclusive. Future work will focus on creating tasks that can directly measure frustration while keeping task difficulty the same.

Keywords— **Electroencephalography (EEG); Eye-tracking; Galvanic skin response (GSR); Multi-modal; NASA Task Load Index (TLX).**

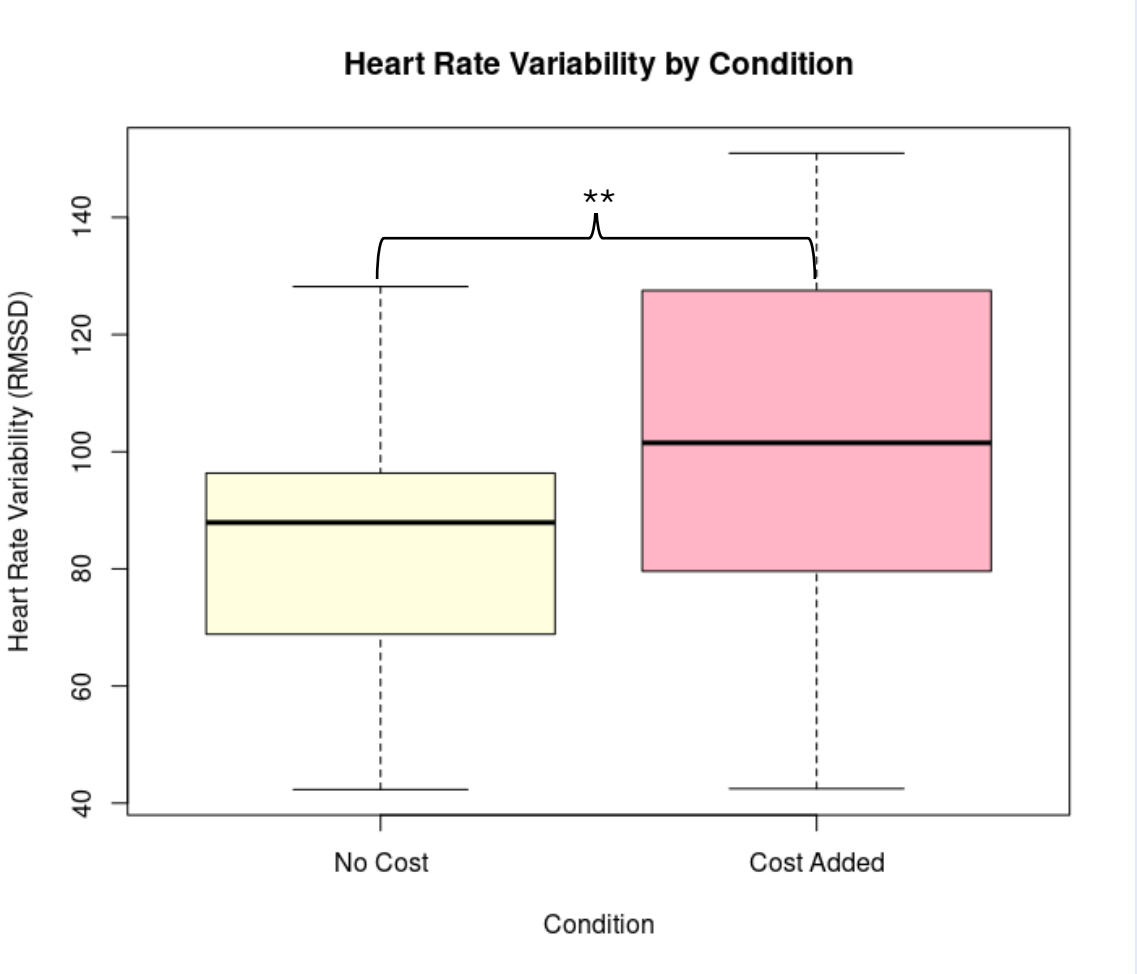
incidental and individual factors. Incidental factors include the severity of interruptions during task execution, and loss of time [3]; individual factors include emotions such as anxiety, attitude, state of mind and mood while performing tasks. If frustration is not controlled, it can cause further impediments to performance of work, more negative emotions and stress-related reactions.

II. Materials and Methods

The participants' feedback on the workload demands of the experiment was collected electronically via a questionnaire at the beginning and at selected intervals based on NASA Task-Load-Index self-reporting instrument [4]. Total number of correct responses (CR) and response times (RT) were collected continuously throughout the experiment (behavioral response data). Pick-A-Mood (PAM) characters were also used as stimuli to collect gender information and the negative mood of the participant right before the experiment and then, after the experiment (moods used: Neutral, Bored, Sad, Irritated and Tense) [5].

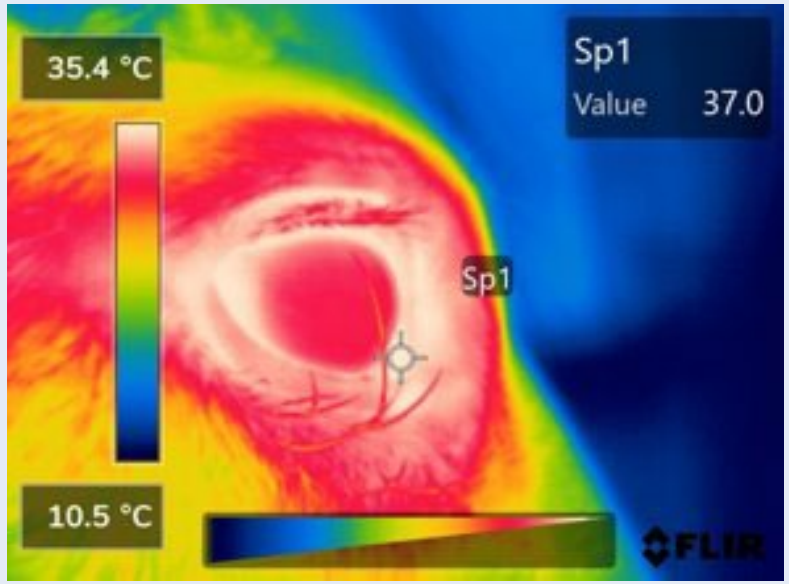
Heart rate variability

- HRV was significantly higher ($p<0.005$) when cost was added (sessions 4-6) than when there was no cost (sessions 1-3)
- Higher HRV indicates lower arousal/stress
- Horses were more ‘relaxed’ when there was a punishment for making errors



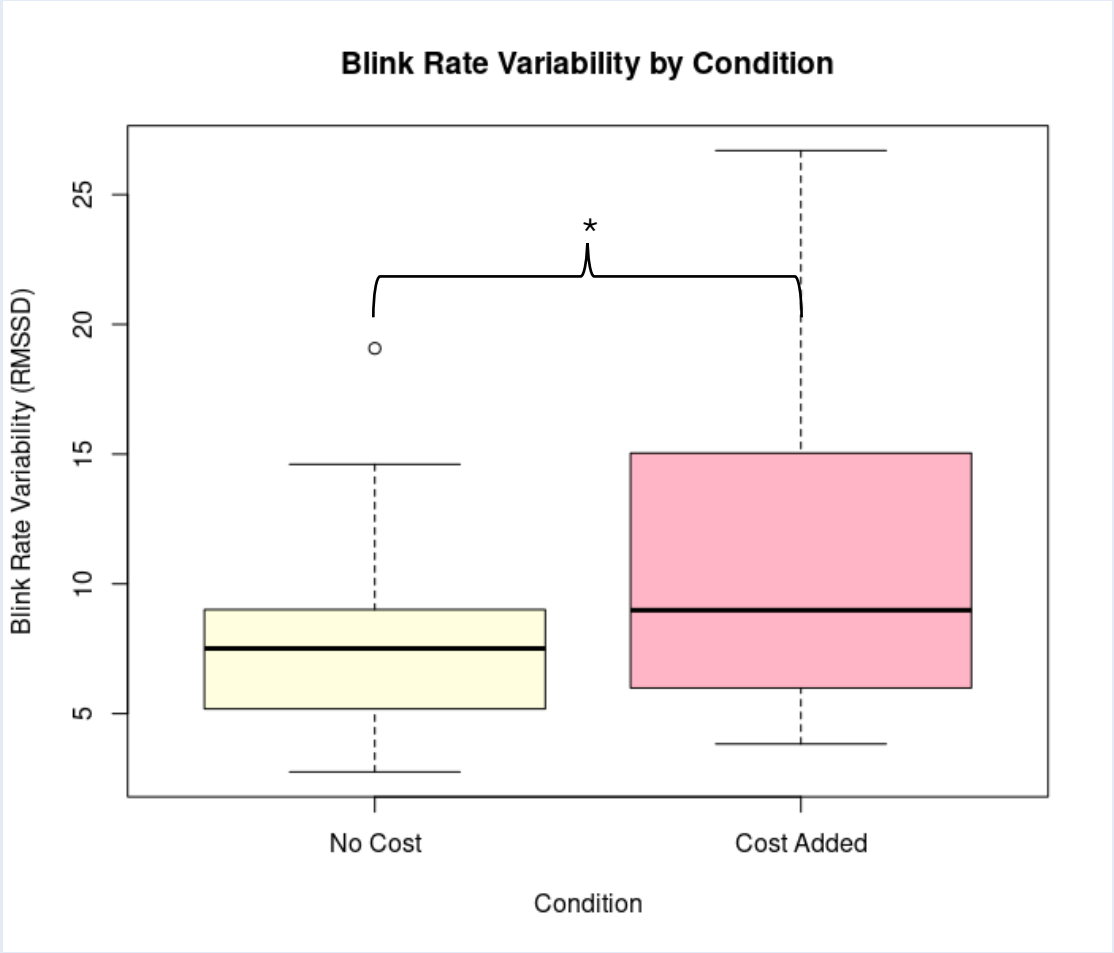
Eye temperature

- No significant difference in eye temperature changes between sessions with cost and sessions with no cost for errors (p=0.26)
- This was the same for left and right eye
- No apparent effect of punisher on stress or valence (positive or negative affect)



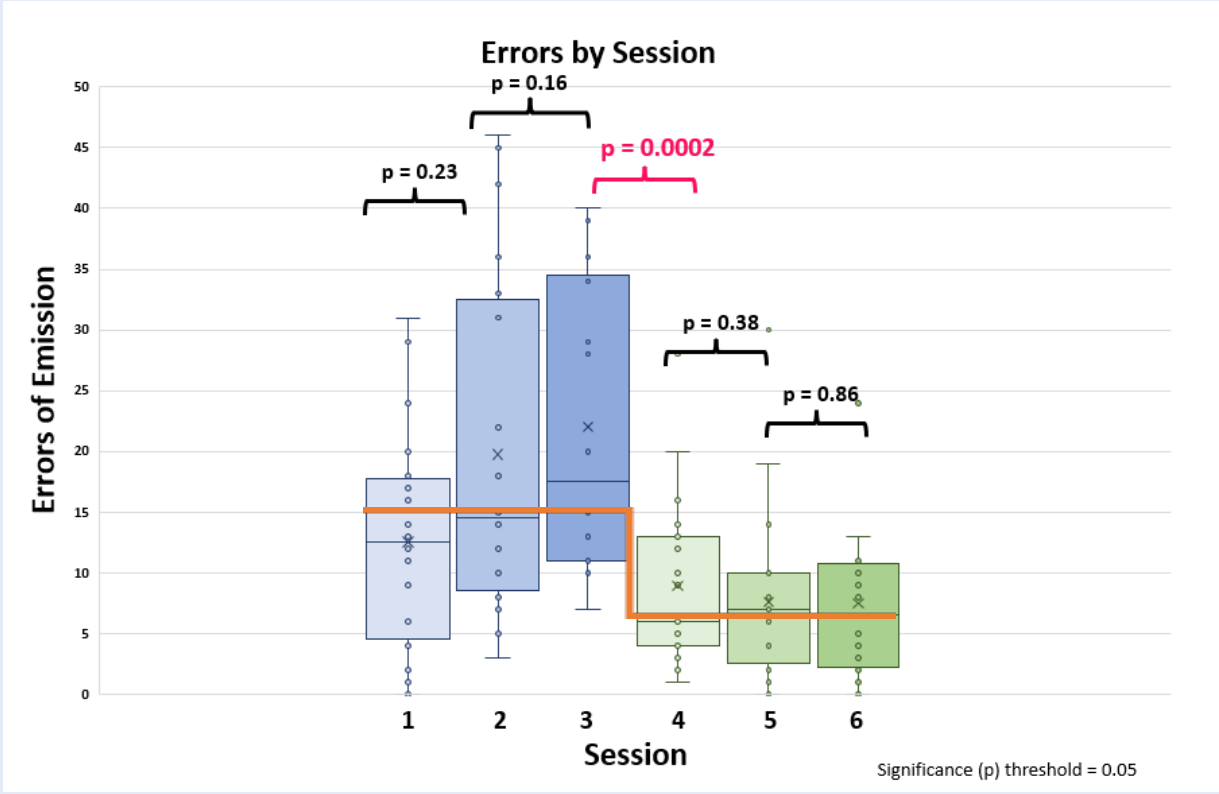
Blink rate

- Blink rate was not significantly different in sessions where cost was added, compared to sessions with no cost (p=0.22)
- However, blink rate **variability** was significantly higher during sessions where cost was added (p<0.05)



What do these results mean?

- No evidence of frustration due to the addition of negative punishment (time-out) as a cost for making errors of emission
- Switch to discriminate responding strategy not linked to frustration
- Further support for model-based learning?



Conclusions

- We (eventually) were able to design a Sto-Signal task for horses to test inhibitory control
- Combination of positive reinforcement and negative punishment can be used effectively and without negatively impacting welfare
- No evidence of frustration
- Results are consistent with model-based learning in horses

This research would not have been possible without:

Dr Carrie Ijichi, Dr Heather Cameron-Whytock and Dr Annika Paukner

This research would not have been possible without:

Anna Gregory and the NTU Equine Unit team

The equine participants!

This research would not have been possible without:

Nottingham Trent University

The Horse Trust

Home of Rest for Horses

University of BRISTOL

NTU Nottingham Trent University

The Horse Trust 135 YEARS
Home of Rest for Horses

Thank you for listening